

ENG. ZAFAR HUSSAIN

SCE-ACCREDITED CONSULTANT ELECTRICAL ENGINEER

GCC ENGINEERING REFERENCE SERIES

COMMERCIAL AND INDUSTRIAL SOLAR PV SYSTEMS

Complete solar PV design calculations for GCC commercial and industrial facilities.



ENGINEERING
REFERENCE SERIES

Commercial and Industrial Solar PV

SYSTEMS

A practical engineering handbook for commercial and industrial photovoltaic systems, from facility load analysis and tariffs through architecture, electrical integration, storage, commissioning, operation and lifecycle economics.

GCC C&I SOLAR PV ENGINEERING SERIES

A structured reference for facility owners, consultants, EPC contractors, energy managers, operations teams and inspectors who need transparent C&I; PV calculations.

200 PRACTICAL C&I SOLAR PV SHEETS

Loads | Tariffs | Electrical | Storage | Lifecycle

Prepared by

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ENGINEERING USE

This handbook supports commercial and industrial solar PV engineering in the GCC. Verify equation applicability, facility records, tariff data, equipment limits, utility requirements and current standards before project use.

ILLUSTRATIVE DATA

Worked values are transparent teaching examples and are not certified surveys, tariff offers, detailed designs, construction drawings, acceptance certificates or operating instructions.

PROFESSIONAL RESPONSIBILITY

C&I; PV systems require competent electrical, structural, fire, commercial and HSE review, approved facility data, certified equipment and independently checked calculations.



Preface

WHY THIS BOOK WAS PREPARED

PURPOSE

C&I; solar design succeeds when facility demand, tariffs, site constraints, electrical integration, storage, operations and lifecycle decisions use one coherent basis. This volume makes that chain explicit.

METHOD

Each sheet presents one governing relationship, defined values with units, a transparent worked substitution, a conservative design check and the decision supported by the result.

SCOPE

The 200 sheets progress from load profiles, site and tariff analysis through array, DC and AC design, storage, grid connection, monitoring, commissioning, O&M; and investment evaluation.

USE WITH JUDGMENT

Examples are starting points. Replace them with verified interval data, current tariffs, approved surveys, certified equipment curves, current codes and independently reviewed assumptions.



Acknowledgments

PEOPLE AND PRACTICE BEHIND C&I SOLAR PV

C&I PV COMMUNITY

This volume reflects methods used by facility owners, energy managers, designers, commercial teams, EPC contractors, operators, inspectors and instructors.

ENGINEERING DISCIPLINE

Reliable C&I; performance depends on verified load and tariff data, coordinated interfaces, certified limits, safe access, field verification and independent review.

STANDARDS AND INSTITUTIONS

The framework draws on IEC, IEEE, ISO, WMO, IEA PVPS, IRENA, national regulations, utility requirements and current GCC grid codes.

READERS

Corrections and verified engineering observations are welcome through the author's LinkedIn QR printed throughout the book.



About the Author

WHO WROTE THIS BOOK

ENG. ZAFAR HUSSAIN

SCE-Accredited Consultant Electrical Engineer with more than seventeen years of Gulf experience in substation commissioning and maintenance, low-voltage distribution, industrial installations and technical training.

PROFESSIONAL PRACTICE

He has served in electricity-distribution roles in the United Arab Emirates and Qatar and later moved to training and consultancy in the Kingdom of Saudi Arabia. His work includes calculation sheets, test records, training posters and field reference material.

EDUCATION AND INDUSTRY

As an instructor at the Energy and Water Academy in Dammam, he delivers technical courses supporting electricity-sector engineers and technicians. This reference series extends that practical teaching format to renewable-energy engineering.

CONTACT AND CORRECTIONS

Readers are invited to report corrections and request calculations for later editions. Scan the footer QR code to reach the author's LinkedIn profile.



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Abbreviations

COMMON COMMERCIAL AND INDUSTRIAL SOLAR PV TERMS

AC	Alternating current	LCOE	Levelized cost of energy
AEP	Annual energy production	LV	Low voltage
BESS	Battery energy storage system	MPPT	Maximum power point tracking
BMS	Building management system	MTBF	Mean time between failures
BOS	Balance of system	MTTR	Mean time to repair
C&I	Commercial and industrial	NPV	Net present value
CAPEX	Capital expenditure	O&M	Operation and maintenance
COD	Commercial operation date	PCC	Point of common coupling
CT	Current transformer	PPA	Power purchase agreement
DC	Direct current	PR	Performance ratio
DSCR	Debt-service coverage ratio	PV	Photovoltaic
EPC	Engineering, procurement and construction	SCADA	Supervisory control and data acquisition
GCC	Gulf Cooperation Council	SPD	Surge protective device
GHI	Global horizontal irradiance	THD	Total harmonic distortion
HVAC	Heating, ventilation and air conditioning	UPS	Uninterruptible power supply
IRR	Internal rate of return	Voc	Open-circuit voltage



Symbols and Units

CALCULATION NOTATION

A	Area - m2	PF	Power factor
A	Availability - % or fraction	Q	Reactive power or flow - context specific
CF	Capacity factor - % or fraction	R	Resistance or rate - context specific
D	Diameter - m	rho	Density - kg/m3
E	Energy - kWh, MWh or GWh	S	Apparent power - VA, kVA or MVA
eta	Efficiency - % or fraction	t	Time - s, min, h or year
f	Frequency - Hz	T	Temperature - C or K
H	Head, irradiation or inertia constant - context specific	V	Voltage or volume - context specific
I	Electrical current - A	v	Velocity - m/s
m	Mass - kg or t	X	Reactance - ohm
N	Number of items	Z	Impedance - ohm or per unit
P	Active power - W, kW or MW	Delta	Difference between two values

UNIT DISCIPLINE

Every worked example shows its units. Convert inputs before substitution, retain sufficient precision during calculation, and round only the final reported result. Prefixes are case-sensitive: k = kilo, M = mega, G = giga and m = milli.



Safety Notice

READ BEFORE USING ANY CALCULATION

- 01

De-energize, isolate, lock out and verify absence of voltage before electrical work.
- 02

Treat PV strings as energized whenever illuminated; open-circuit voltage remains present.
- 03

Battery systems can deliver extreme fault current and may create toxic or flammable gases.
- 04

Hydrogen is highly flammable and requires classified-area, ventilation and leak-detection design.
- 05

Wind turbines involve work at height, rotating machinery, stored energy and remote access.
- 06

CSP and solar-thermal systems contain hot fluids, pressure and thermal-storage hazards.
- 07

Use approved arc-flash, earthing, fire, lifting and confined-space procedures.
- 08

Only competent persons may approve settings, protection schemes and energization plans.

STOP-WORK RULE

Stop work whenever actual conditions differ from the approved design basis, permit, isolation or risk assessment.



How to Use This Book

A REPEATABLE WORKFLOW FOR EVERY SHEET

- 1

CHOOSE THE SHEET
Use the contents or index to find the required engineering quantity.
- 2

DEFINE THE BOUNDARY
Confirm whether values are AC or DC, gross or net, instantaneous or interval energy.
- 3

COLLECT VERIFIED INPUTS
Use approved drawings, nameplates, measurements, contracts and current standards.
- 4

CONVERT UNITS
Place every value in one consistent unit system before substitution.
- 5

FOLLOW THE THREE STEPS
Calculate the base result, apply the project factor, then check the criterion and margin.
- 6

REVIEW THE GCC NOTE
Temperature, dust, humidity, salt, water and grid strength can change the design.
- 7

RECORD ASSUMPTIONS
Keep calculation revision, data source, author, checker and approval status traceable.
- 8

VERIFY INDEPENDENTLY
Use detailed software, vendor data and competent review for final engineering.



Introduction

HOW THE COMMERCIAL AND INDUSTRIAL SOLAR PV HANDBOOK IS ORGANIZED

A C&I; solar PV system sits inside an operating business: interval demand, tariffs, production schedules, roof and site constraints, DC and AC integration, storage, utility rules, safety and maintenance must be coordinated. This volume organizes 200 worked methods around that complete facility interface.

01	FACILITY LOAD AND ENERGY BASELINE	11	TRANSFORMERS, SWITCHGEAR AND FACILITY AUXILIARIES
02	SITE DUE DILIGENCE AND CONSTRUCTABILITY	12	GRID INTERCONNECTION AND POWER QUALITY
03	SOLAR RESOURCE AND PRODUCTION BASIS	13	PROTECTION, EARTHING, LIGHTNING AND ARC SAFETY
04	TARIFFS, SELF-CONSUMPTION AND EXPORT	14	STRUCTURAL, FIRE, WATERPROOFING AND THERMAL DESIGN
05	TECHNOLOGY SELECTION AND SYSTEM ARCHITECTURE	15	STORAGE, DEMAND MANAGEMENT AND MICROGRIDS
06	PV MODULES, ARRAY LAYOUT AND SHADING	16	MONITORING, BMS, SCADA AND COMMUNICATIONS
07	STRING DESIGN AND DC CONFIGURATION	17	PROCUREMENT, CONSTRUCTION AND HSE
08	DC CABLING, ISOLATION AND PROTECTION	18	TESTING, COMMISSIONING AND PERFORMANCE
09	INVERTER DESIGN AND OPERATING MODES	19	O&M, RELIABILITY AND DIAGNOSTICS
10	AC DISTRIBUTION AND BUILDING INTEGRATION	20	FINANCIAL EVALUATION AND LIFECYCLE

Every worked value is illustrative. Live projects must use verified interval loads, current tariffs, approved surveys, certified equipment data, current fire and utility codes, and independently reviewed calculations.



1 CALCULATE C&I ANNUAL ELECTRICITY DEMAND

FORMULA

$$E_{load} = \sum(P_i \Delta t)$$

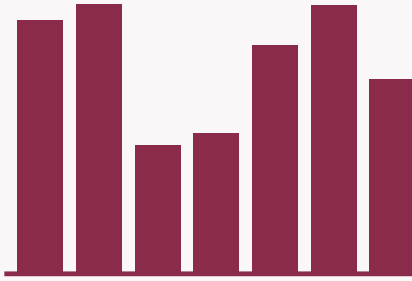
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$E_{load} = 8,760 \times 42 \text{ MW} \times 0.68 = 250.2 \text{ GWh}$$

Calculated result = 250.2 GWh/year

C&I PV FIGURE 001



C&I ANNUAL ELECTRICITY DEMAND

EXAMPLE VALUES

Peak load	42 MW
Load factor	0.68
Hours	8,760

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use interval metering for bankable demand assessment. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 250.2 \text{ GWh/year} \times 1.10 = 275.2 \text{ GWh/year}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	250.2 GWh/year
K_design	1.10
X_design	275.2 GWh/year

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 302.7 \text{ GWh/year} - 275.2 \text{ GWh/year} = 27.5 \text{ GWh/year}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

250.2 GWh/year

worked result

REQUIRED

275.2 GWh/year

factor 1.10

SELECTED

302.7 GWh/year

project criterion

RESERVE

27.5 GWh/year

available difference

GCC design note: Use interval metering for bankable demand assessment. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I AVERAGE ELECTRICAL DEMAND

FORMULA

$$P_{avg} = E_{load} / 8760$$

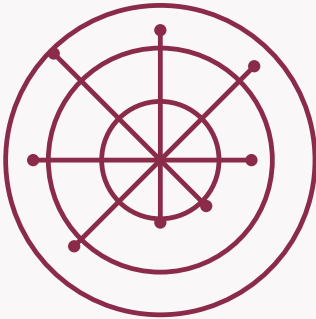
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{avg} = 250,200 \text{ MWh} / 8,760 \text{ h} = 28.56 \text{ MW}$$

Calculated result = 28.56 MW

C&I PV FIGURE 002



C&I AVERAGE ELECTRICAL DEMAND

EXAMPLE VALUES

Annual load	250,200 MWh
Hours	8,760



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Adjust for leap years and partial operating periods. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 28.6 \text{ MW} \times 1.10 = \mathbf{31.4 \text{ MW}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	28.6 MW
K_design	1.10
X_design	31.4 MW



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 34.6 \text{ MW} - 31.4 \text{ MW} = \mathbf{3.14 \text{ MW}}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

28.6 MW

worked result

REQUIRED

31.4 MW

factor 1.10

SELECTED

34.6 MW

project criterion

RESERVE

3.14 MW

available difference

GCC design note: Adjust for leap years and partial operating periods. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I DESIGN LOAD FACTOR

FORMULA

$$LF = P_{avg} / P_{peak}$$

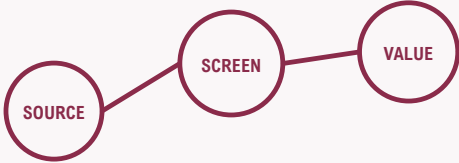
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$LF = 28.56 \text{ MW} / 42 \text{ MW} = 68.00\%$$

Calculated result = 68 %

C&I PV FIGURE 003



C&I DESIGN LOAD FACTOR

EXAMPLE VALUES

Average load	28.56 MW
Peak load	42 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Peak and average demand must use the same metering boundary. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 68 \% \times 0.95 = \mathbf{64.6 \%}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	68 %
K_design	0.95
X_design	64.6 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 64.6 \% - 58.1 \% = \mathbf{6.46 \%}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

68 %

worked result

CONSERVATIVE

64.6 %

factor 0.95

MINIMUM

58.1 %

project criterion

MARGIN

6.46 %

available difference

GCC design note: Peak and average demand must use the same metering boundary. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I PV LOAD-COINCIDENCE FACTOR

FORMULA

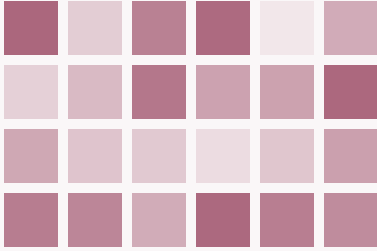
$$CF_c = P_{RE,peakload} / P_{RE,rated}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

CF_c = 24 MW / 36 MW = 66.67%
Calculated result = 66.67 %

C&I PV FIGURE 004



C&I PV LOAD-COINCIDENCE FACTOR

EXAMPLE VALUES

Renewable at load peak	24 MW
Renewable rating	36 MW

i

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use coincident timestamps rather than separate annual maxima. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 66.7 % x 0.95 = 63.3 %

GIVEN VALUES FOR EXAMPLE

X_calculated	66.7 %
K_design	0.95
X_design	63.3 %

i

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$Margin = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 63.3 % - 57 % = 6.33 %

i

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

i

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK

SUMMARY

CALCULATED

66.7 %

worked result

CONSERVATIVE

63.3 %

factor 0.95

MINIMUM

57 %

project criterion

MARGIN

6.33 %

available difference

GCC design note: Use coincident timestamps rather than separate annual maxima. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I PV SELF-CONSUMED ENERGY

FORMULA

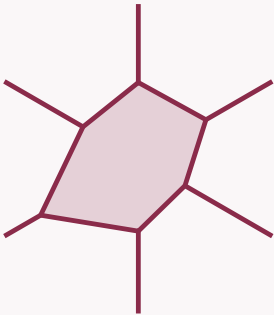
$R_{self} = E_{self} / E_{RE}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{self} = 82 \text{ GWh} / 105 \text{ GWh} = 78.10\%$
Calculated result = 78.1 %

C&I PV FIGURE 005



C&I PV SELF-CONSUMED ENERGY

EXAMPLE VALUES

Self-consumed	82 GWh
Renewable output	105 GWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Treat storage charging and export according to the commercial boundary. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{design} = X_{calculated} \times K_{conservative}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 78.1 \% \times 0.95 = 74.2 \%$

GIVEN VALUES FOR EXAMPLE

X_calculated	78.1 %
K_design	0.95
X_design	74.2 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$Margin = X_{design} - X_{min}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 74.2 \% - 66.8 \% = 7.42 \%$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

78.1 %

worked result

CONSERVATIVE

74.2 %

factor 0.95

MINIMUM

66.8 %

project criterion

MARGIN

7.42 %

available difference

GCC design note: Treat storage charging and export according to the commercial boundary. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I PV ANNUAL GRID EXPORT

FORMULA

$E_{\text{export}} = E_{\text{RE}} - E_{\text{self}}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$E_{\text{export}} = 105 \text{ GWh} - 82 \text{ GWh} = 23.0 \text{ GWh}$
Calculated result = 23 GWh/year

C&I PV FIGURE 006



C&I PV ANNUAL GRID EXPORT

EXAMPLE VALUES

Renewable output	105 GWh
Self-consumed	82 GWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply export limits and curtailment before commercial valuation. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 23 \text{ GWh/year} \times 1.10 = 25.3 \text{ GWh/year}$

GIVEN VALUES FOR EXAMPLE

X_calculated	23 GWh/year
K_design	1.10
X_design	25.3 GWh/year



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 27.8 \text{ GWh/year} - 25.3 \text{ GWh/year} = 2.53 \text{ GWh/year}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

23 GWh/year

worked result

REQUIRED

25.3 GWh/year

factor 1.10

SELECTED

27.8 GWh/year

project criterion

RESERVE

2.53 GWh/year

available difference

GCC design note: Apply export limits and curtailment before commercial valuation. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I TARGET RENEWABLE FRACTION

FORMULA

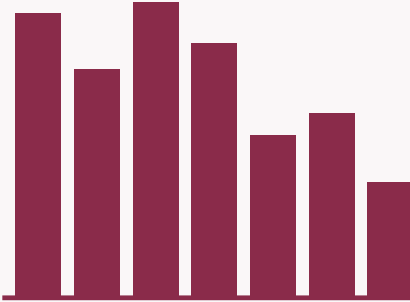
REF = E_RE,used / E_load

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

REF = 82 GWh / 250.2 GWh = 32.77%
Calculated result = 32.77 %

C&I PV FIGURE 007



C&I TARGET RENEWABLE FRACTION

EXAMPLE VALUES

Renewable used	82 GWh
Annual load	250.2 GWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Define whether renewable imports and storage losses are included. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 32.8 % x 0.95 = 31.1 %

GIVEN VALUES FOR EXAMPLE

X_calculated	32.8 %
K_design	0.95
X_design	31.1 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 31.1 % - 28 % = 3.11 %



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

32.8 %

worked result

CONSERVATIVE

31.1 %

factor 0.95

MINIMUM

28 %

project criterion

MARGIN

3.11 %

available difference

GCC design note: Define whether renewable imports and storage losses are included. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I PV PROFILE MISMATCH ENERGY

FORMULA

E_mis = E_RE - E_coincident

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

E_mis = 105 GWh - 82 GWh = 23.0 GWh
Calculated result = 23 GWh/year

C&I PV FIGURE 008



C&I PV PROFILE MISMATCH ENERGY

EXAMPLE VALUES

Renewable energy	105 GWh
Coincident use	82 GWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Hourly or subhourly simulation is required for storage sizing. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

X_design = X_calculated x K_upper

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 23 GWh/year x 1.05 = 24.2 GWh/year

GIVEN VALUES FOR EXAMPLE

X_calculated	23 GWh/year
K_design	1.05
X_design	24.2 GWh/year



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

Margin = X_limit - X_design

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 26.6 GWh/year - 24.2 GWh/year = 2.42 GWh/year



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

23 GWh/year

worked result

DESIGN

24.2 GWh/year

factor 1.05

LIMIT

26.6 GWh/year

project criterion

MARGIN

2.42 GWh/year

available difference

GCC design note: Hourly or subhourly simulation is required for storage sizing. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I LOAD-SHIFTING STORAGE NEED

FORMULA

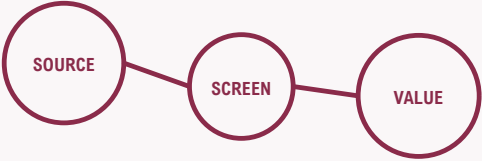
$E_{\text{BESS}} = P_{\text{shift}} t_{\text{shift}} / \eta$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$E_{\text{BESS}} = 12 \text{ MW} \times 4 \text{ h} / 0.90 = 53.33 \text{ MWh}$
Calculated result = 53.33 MWh

C&I PV FIGURE 009



C&I LOAD-SHIFTING STORAGE NEED

EXAMPLE VALUES

Shift power	12 MW
Duration	4 h
Round-trip efficiency	90%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add state-of-charge reserve and degradation allowance. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 53.3 \text{ MWh} \times 1.10 = 58.7 \text{ MWh}$

GIVEN VALUES FOR EXAMPLE

X_calculated	53.3 MWh
K_design	1.10
X_design	58.7 MWh

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 64.5 \text{ MWh} - 58.7 \text{ MWh} = 5.87 \text{ MWh}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

53.3 MWh

worked result

REQUIRED

58.7 MWh

factor 1.10

SELECTED

64.5 MWh

project criterion

RESERVE

5.87 MWh

available difference

GCC design note: Add state-of-charge reserve and degradation allowance. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I DESIGN-HORIZON DEMAND

FORMULA

$$E_5 = E_0(1+g)^5$$

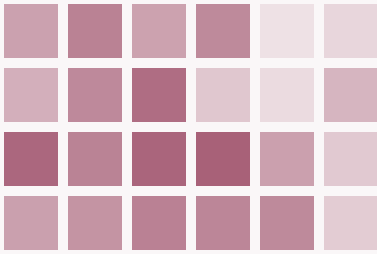
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$E_5 = 250.2 \times (1 + 0.035)^5 = 297.1 \text{ GWh}$$

Calculated result = 297.2 GWh/year

C&I PV FIGURE 010



C&I DESIGN-HORIZON DEMAND

EXAMPLE VALUES

Base demand	250.2 GWh
Growth	3.5%/year
Years	5

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Develop high, base and low scenarios for uncertain growth. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 297.2 \text{ GWh/year} \times 1.10 = 326.9 \text{ GWh/year}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	297.2 GWh/year
K_design	1.10
X_design	326.9 GWh/year

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 359.6 \text{ GWh/year} - 326.9 \text{ GWh/year} = 32.7 \text{ GWh/year}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

297.2 GWh/year

worked result

REQUIRED

326.9 GWh/year

factor 1.10

SELECTED

359.6 GWh/year

project criterion

RESERVE

32.7 GWh/year

available difference

GCC design note: Develop high, base and low scenarios for uncertain growth. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Establish interval demand, operating schedules, load coincidence, self-consumption and growth before fixing the C&I; solar capacity.



1 CALCULATE C&I GROSS ROOF AND SITE AREA

FORMULA

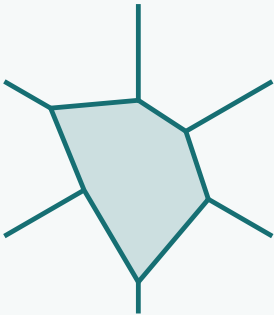
A_gross = L x W

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

A_gross = 2,400 m x 1,800 m = 4.32 km2
Calculated result = 4.32 km2

C&I PV FIGURE 011



C&I GROSS ROOF AND SITE AREA

EXAMPLE VALUES

Length	2,400 m
Width	1,800 m



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Confirm surveyed boundaries and exclude overlapping parcels. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 4.32 km2 x 1.10 = **4.75 km2**

GIVEN VALUES FOR EXAMPLE

X_calculated	4.32 km2
K_design	1.10
X_design	4.75 km2



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 5.23 km2 - 4.75 km2 = **0.475 km2**



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

4.32 km2

worked result

REQUIRED

4.75 km2

factor 1.10

SELECTED

5.23 km2

project criterion

RESERVE

0.475 km2

available difference

GCC design note: Confirm surveyed boundaries and exclude overlapping parcels. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE C&I USABLE INSTALLATION FOOTPRINT

FORMULA

$$A_{\text{net}} = A_{\text{gross}}(1 - f_{\text{excl}})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$A_{\text{net}} = 4.32 \times (1 - 0.22) = 3.370 \text{ km}^2$$

Calculated result = 3.37 km2

C&I PV FIGURE 012



C&I USABLE INSTALLATION FOOTPRINT

EXAMPLE VALUES

Gross area	4.32 km2
Excluded fraction	22%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Map environmental, geotechnical, access and setback exclusions. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 3.37 \text{ km}^2 \times 0.95 = \mathbf{3.2 \text{ km}^2}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	3.37 km2
K_design	0.95
X_design	3.2 km2



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{\text{design}} - X_{\text{min}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 3.2 \text{ km}^2 - 2.88 \text{ km}^2 = \mathbf{0.32 \text{ km}^2}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

3.37 km2

worked result

CONSERVATIVE

3.2 km2

factor 0.95

MINIMUM

2.88 km2

project criterion

MARGIN

0.32 km2

available difference

GCC design note: Map environmental, geotechnical, access and setback exclusions. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE C&I SITE EXCLUSION PERCENTAGE

FORMULA

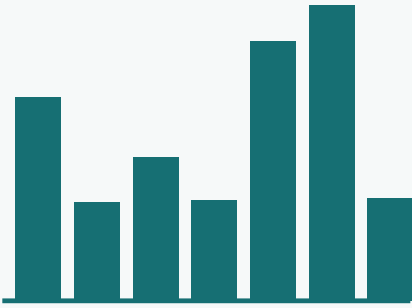
$$f_{excl} = A_{excl} / A_{gross}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$f_{excl} = 0.95 / 4.32 = 21.99\%$
Calculated result = 21.99 %

C&I PV FIGURE 013



C&I SITE EXCLUSION PERCENTAGE

EXAMPLE VALUES

Excluded area	0.95 km2
Gross area	4.32 km2



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Remove double-counted overlaps before summing exclusion areas. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 22\% \times 1.05 = 23.1\%$

GIVEN VALUES FOR EXAMPLE

X_calculated	22 %
K_design	1.05
X_design	23.1 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 25.4\% - 23.1\% = 2.31\%$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

22 %

worked result

DESIGN

23.1 %

factor 1.05

LIMIT

25.4 %

project criterion

MARGIN

2.31 %

available difference

GCC design note: Remove double-counted overlaps before summing exclusion areas. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE C&I PV CAPACITY DENSITY

FORMULA

$$D_P = P_AC / A_net$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$D_P = 180 \text{ MW} / 3.37 \text{ km}^2 = 53.41 \text{ MW/km}^2$$

Calculated result = 53.41 MW/km2

C&I PV FIGURE 014



C&I PV CAPACITY DENSITY

EXAMPLE VALUES

Plant capacity	180 MW
Net area	3.37 km2



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the same boundary for capacity and occupied land. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_required = X_calculated \times K_design$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 53.4 \text{ MW/km}^2 \times 1.10 = 58.8 \text{ MW/km}^2$$

GIVEN VALUES FOR EXAMPLE

X_calculated	53.4 MW/km2
K_design	1.10
X_design	58.8 MW/km2



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_selected - X_required$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 64.6 \text{ MW/km}^2 - 58.8 \text{ MW/km}^2 = 5.88 \text{ MW/km}^2$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

53.4 MW/km2

worked result

REQUIRED

58.8 MW/km2

factor 1.10

SELECTED

64.6 MW/km2

project criterion

RESERVE

5.88 MW/km2

available difference

GCC design note: Use the same boundary for capacity and occupied land. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE AREA-CONSTRAINED C&I PV CAPACITY

FORMULA

$$P_{\text{land}} = A_{\text{net}} D_P$$

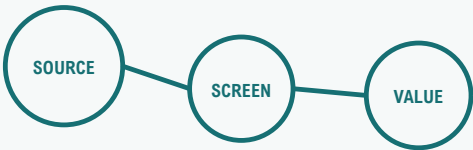
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{\text{land}} = 3.37 \text{ km}^2 \times 50 \text{ MW/km}^2 = 168.5 \text{ MW}$$

Calculated result = 168.5 MW

C&I PV FIGURE 015



AREA-CONSTRAINED C&I PV CAPACITY

EXAMPLE VALUES

Net area	3.37 km2
Design density	50 MW/km2

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Layout, terrain and technology constraints determine final density. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 168.5 \text{ MW} \times 1.10 = \mathbf{185.4 \text{ MW}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	168.5 MW
K_design	1.10
X_design	185.4 MW

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 203.9 \text{ MW} - 185.4 \text{ MW} = \mathbf{18.5 \text{ MW}}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

168.5 MW

worked result

REQUIRED

185.4 MW

factor 1.10

SELECTED

203.9 MW

project criterion

RESERVE

18.5 MW

available difference

GCC design note: Layout, terrain and technology constraints determine final density. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE ANNUAL C&I SITE OCCUPANCY COST

FORMULA

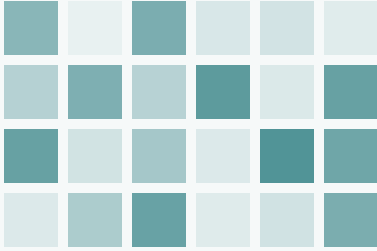
C_lease = A_lease r_A

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

C_lease = 420 ha x 4,800 SAR/ha = 2.016 MSAR/year
Calculated result = 2.016 MSAR/year

C&I PV FIGURE 016



ANNUAL C&I SITE OCCUPANCY COST

EXAMPLE VALUES

Lease area	420 ha
Lease rate	4,800 SAR/ha-year

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include escalation, access corridors and temporary construction land. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 2.02 MSAR/year x 1.10 = 2.22 MSAR/year

GIVEN VALUES FOR EXAMPLE

X_calculated	2.02 MSAR/year
K_design	1.10
X_design	2.22 MSAR/year

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 2.44 MSAR/year - 2.22 MSAR/year = 0.222 MSAR/year

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

2.02 MSAR/year

worked result

REQUIRED

2.22 MSAR/year

factor 1.10

SELECTED

2.44 MSAR/year

project criterion

RESERVE

0.222 MSAR/year

available difference

GCC design note: Include escalation, access corridors and temporary construction land. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE C&I CONSTRUCTION ACCESS DENSITY

FORMULA

$$D_{road} = L_{road} / A_{site}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$D_{road} = 28 \text{ km} / 4.32 \text{ km}^2 = 6.481 \text{ km/km}^2$$

Calculated result = 6.481 km/km2

C&I PV FIGURE 017



C&I CONSTRUCTION ACCESS DENSITY

EXAMPLE VALUES

Road length	28 km
Site area	4.32 km2



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Road density depends on technology blocks, terrain and emergency access. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 6.48 \text{ km/km}^2 \times 1.10 = 7.13 \text{ km/km}^2$$

GIVEN VALUES FOR EXAMPLE

X_calculated	6.48 km/km2
K_design	1.10
X_design	7.13 km/km2



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 7.84 \text{ km/km}^2 - 7.13 \text{ km/km}^2 = 0.713 \text{ km/km}^2$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

6.48 km/km2

worked result

REQUIRED

7.13 km/km2

factor 1.10

SELECTED

7.84 km/km2

project criterion

RESERVE

0.713 km/km2

available difference

GCC design note: Road density depends on technology blocks, terrain and emergency access. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE C&I SITE TERRAIN GRADIENT

FORMULA

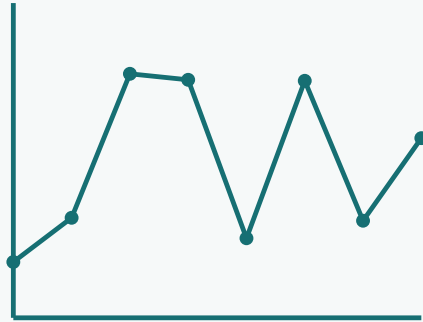
$$G = \Delta z / L_h$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

G = 18 m / 600 m = 3.00%
Calculated result = 3 %

C&I PV FIGURE 018



C&I SITE TERRAIN GRADIENT

EXAMPLE VALUES

Elevation change	18 m
Horizontal length	600 m

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use surveyed local slopes for grading and equipment limits. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{upper}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 3 % x 1.05 = 3.15 %

GIVEN VALUES FOR EXAMPLE

X_calculated	3 %
K_design	1.05
X_design	3.15 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{\text{limit}} - X_{\text{design}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 3.47 % - 3.15 % = 0.315 %

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

3 %

worked result

DESIGN

3.15 %

factor 1.05

LIMIT

3.47 %

project criterion

MARGIN

0.315 %

available difference

GCC design note: Use surveyed local slopes for grading and equipment limits. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE C&I BOUNDARY SETBACK ALLOWANCE

FORMULA

$$A_{set} = P \ L_{set}$$

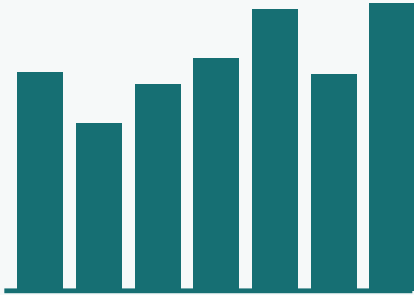
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$A_{set} = 8.4 \text{ km} \times 20 \text{ m} = 0.168 \text{ km}^2$$

Calculated result = 0.168 km2

C&I PV FIGURE 019



C&I BOUNDARY SETBACK ALLOWANCE

EXAMPLE VALUES

Affected perimeter	8.4 km
Setback width	20 m

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Corner geometry and overlapping setbacks need GIS calculation. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 0.168 \text{ km}^2 \times 1.10 = 0.185 \text{ km}^2$$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.168 km2
K_design	1.10
X_design	0.185 km2

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 0.203 \text{ km}^2 - 0.185 \text{ km}^2 = 0.018 \text{ km}^2$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

0.168 km2

worked result

REQUIRED

0.185 km2

factor 1.10

SELECTED

0.203 km2

project criterion

RESERVE

0.018 km2

available difference

GCC design note: Corner geometry and overlapping setbacks need GIS calculation. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE C&I SITE SELECTION WEIGHTED SCORE

FORMULA

$$S_{site} = \sum(w_i s_i)$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$S_{site} = 0.30 \times 88 + 0.25 \times 82 + 0.20 \times 75 + 0.15 \times 90 + 0.10 \times 70 = 83.4$$

Calculated result = 82.4 score

C&I PV FIGURE 020



C&I SITE SELECTION WEIGHTED SCORE

EXAMPLE VALUES

Resource	30% at 88
Grid	25% at 82
Land	20% at 75
Environment	15% at 90; access 10% at 70

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: A fatal flaw overrides a favorable weighted score. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 82.4 \text{ score} \times 0.95 = 78.3 \text{ score}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	82.4 score
K_design	0.95
X_design	78.3 score

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 78.3 \text{ score} - 70.5 \text{ score} = 7.83 \text{ score}$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

82.4 score

worked result

CONSERVATIVE

78.3 score

factor 0.95

MINIMUM

70.5 score

project criterion

MARGIN

7.83 score

available difference

GCC design note: A fatal flaw overrides a favorable weighted score. Carry the verified land constraint into the site-control and concept-layout records. Verify ownership, usable roof and ground areas, exclusions, access, setbacks, terrain and capacity density before concept selection.



1 CALCULATE C&I SOLAR DECLINATION ANGLE

FORMULA

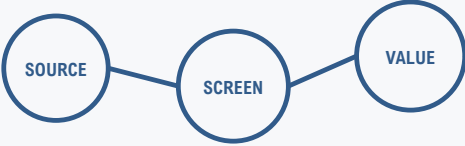
$$\text{delta} = 23.45\sin[360(284+n)/365]$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

delta = 23.45sin[360x456/365] = 23.45 deg
Calculated result = 23.45 deg

C&I PV FIGURE 021



C&I SOLAR DECLINATION ANGLE

EXAMPLE VALUES

Day number	172
Axial angle	23.45 deg

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: This common approximation is adequate for preliminary geometry. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 23.4 deg x 1.10 = 25.8 deg

GIVEN VALUES FOR EXAMPLE

X_calculated	23.4 deg
K_design	1.10
X_design	25.8 deg

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 28.4 deg - 25.8 deg = 2.58 deg

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

23.4 deg

worked result

REQUIRED

25.8 deg

factor 1.10

SELECTED

28.4 deg

project criterion

RESERVE

2.58 deg

available difference

GCC design note: This common approximation is adequate for preliminary geometry. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I SOLAR HOUR ANGLE

FORMULA

$$\omega = 15(t_{\text{solar}} - 12)$$

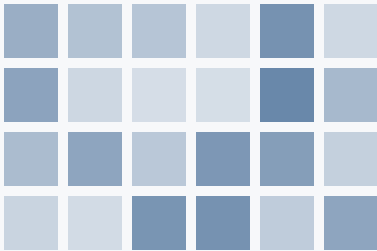
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$\omega = 15 \times (14.5 - 12) = 37.50 \text{ deg}$$

Calculated result = 37.5 deg

C&I PV FIGURE 022



C&I SOLAR HOUR ANGLE

EXAMPLE VALUES

Solar time	14.5 h
Solar noon	12 h



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Convert clock time to local solar time before use. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 37.5 \text{ deg} \times 1.10 = \mathbf{41.2 \text{ deg}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	37.5 deg
K_design	1.10
X_design	41.2 deg



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 45.4 \text{ deg} - 41.2 \text{ deg} = \mathbf{4.13 \text{ deg}}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

37.5 deg

worked result

REQUIRED

41.2 deg

factor 1.10

SELECTED

45.4 deg

project criterion

RESERVE

4.13 deg

available difference

GCC design note: Convert clock time to local solar time before use. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I SOLAR-NOON ALTITUDE

FORMULA

$$\alpha = 90 - \text{abs}(\phi - \delta)$$

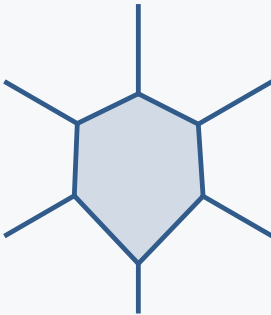
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$\alpha = 90 - \text{abs}(24.7 - 22.95) = 88.25 \text{ deg}$$

Calculated result = 88.25 deg

C&I PV FIGURE 023



C&I SOLAR-NOON ALTITUDE

EXAMPLE VALUES

Latitude	24.7 deg
Declination	22.95 deg



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: This noon relation assumes a level horizon. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 88.2 \text{ deg} \times 1.10 = \mathbf{97.1 \text{ deg}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	88.2 deg
K_design	1.10
X_design	97.1 deg



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 106.8 \text{ deg} - 97.1 \text{ deg} = \mathbf{9.71 \text{ deg}}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

88.2 deg

worked result

REQUIRED

97.1 deg

factor 1.10

SELECTED

106.8 deg

project criterion

RESERVE

9.71 deg

available difference

GCC design note: This noon relation assumes a level horizon. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I RELATIVE OPTICAL AIR MASS

FORMULA

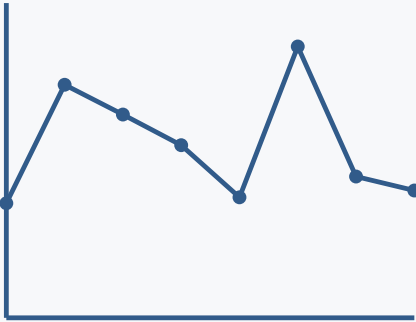
AM = 1/cos(theta_z)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

AM = 1/cos(35) = 1.221
Calculated result = 1.221 ratio

C&I PV FIGURE 024



C&I RELATIVE OPTICAL AIR MASS

EXAMPLE VALUES

Zenith angle	35 deg
Approximation	secant



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use a refined air-mass model near the horizon. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

X_design = X_calculated x K_upper

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 1.22 ratio x 1.05 = 1.28 ratio

GIVEN VALUES FOR EXAMPLE

X_calculated	1.22 ratio
K_design	1.05
X_design	1.28 ratio



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

Margin = X_limit - X_design

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 1.41 ratio - 1.28 ratio = 0.128 ratio



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

1.22 ratio

worked result

DESIGN

1.28 ratio

factor 1.05

LIMIT

1.41 ratio

project criterion

MARGIN

0.128 ratio

available difference

GCC design note: Use a refined air-mass model near the horizon. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I EXTRATERRESTRIAL DNI

FORMULA

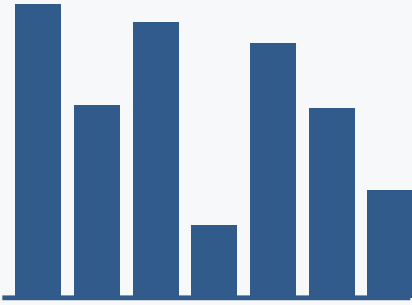
$$G_{on} = G_{sc}(1+0.033\cos(360n/365))$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$G_{on} = 1,361 \times [1 + 0.033 \cos(360 \times 20 / 365)] = 1,403 \text{ W/m}^2$
Calculated result = 1,403.3 W/m2

C&I PV FIGURE 025



C&I EXTRATERRESTRIAL DNI

EXAMPLE VALUES

Solar constant	1,361 W/m2
Day number	20



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: The equation describes Earth-Sun distance variation. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 1,403 \text{ W/m}^2 \times 1.10 = 1,544 \text{ W/m}^2$

GIVEN VALUES FOR EXAMPLE

X_calculated	1,403 W/m2
K_design	1.10
X_design	1,544 W/m2



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 1,698 \text{ W/m}^2 - 1,544 \text{ W/m}^2 = 154.4 \text{ W/m}^2$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

1,403 W/m2

worked result

REQUIRED

1,544 W/m2

factor 1.10

SELECTED

1,698 W/m2

project criterion

RESERVE

154.4 W/m2

available difference

GCC design note: The equation describes Earth-Sun distance variation. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I DAILY SOLAR CLEARNESS INDEX

FORMULA

$K_t = H/H_0$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$K_t = 6.35/8.12 = 0.7820$
Calculated result = 0.782 ratio

C&I PV FIGURE 026



C&I DAILY SOLAR CLEARNESS INDEX

EXAMPLE VALUES

Global irradiation	6.35 kWh/m2
Extraterrestrial	8.12 kWh/m2



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use matching planes and time periods. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{design} = X_{calculated} \times K_{conservative}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 0.782 \text{ ratio} \times 0.95 = 0.743 \text{ ratio}$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.782 ratio
K_design	0.95
X_design	0.743 ratio



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$Margin = X_{design} - X_{min}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 0.743 \text{ ratio} - 0.669 \text{ ratio} = 0.074 \text{ ratio}$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

0.782 ratio

worked result

CONSERVATIVE

0.743 ratio

factor 0.95

MINIMUM

0.669 ratio

project criterion

MARGIN

0.074 ratio

available difference

GCC design note: Use matching planes and time periods. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I BEAM IRRADIANCE PROJECTION

FORMULA

$G_{b,POA} = DNI \cos(\theta_i)$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$G_{b,POA} = 890 \times \cos(17) = 851.1 \text{ W/m}^2$
Calculated result = 851.1 W/m2

C&I PV FIGURE 027



C&I BEAM IRRADIANCE PROJECTION

EXAMPLE VALUES

DNI	890 W/m2
Incidence angle	17 deg

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Set the beam term to zero when the sun is behind the plane. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{required} = X_{calculated} \times K_{design}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 851.1 \text{ W/m}^2 \times 1.10 = 936.2 \text{ W/m}^2$

GIVEN VALUES FOR EXAMPLE

X_calculated	851.1 W/m2
K_design	1.10
X_design	936.2 W/m2

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$Reserve = X_{selected} - X_{required}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 1,030 \text{ W/m}^2 - 936.2 \text{ W/m}^2 = 93.6 \text{ W/m}^2$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

851.1 W/m2

worked result

REQUIRED

936.2 W/m2

factor 1.10

SELECTED

1,030 W/m2

project criterion

RESERVE

93.6 W/m2

available difference

GCC design note: Set the beam term to zero when the sun is behind the plane. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I PLANE-OF-ARRAY IRRADIATION

FORMULA

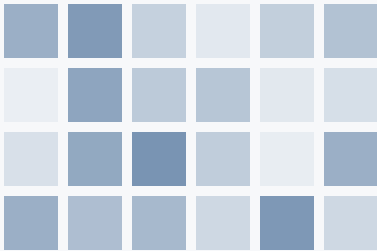
$H_{POA} = H_{GHI} \times K_{tilt}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$H_{POA} = 6.0 \times 1.08 = 6.48 \text{ kWh/m}^2/\text{day}$
Calculated result = 6.48 kWh/m2/day

C&I PV FIGURE 028



C&I PLANE-OF-ARRAY IRRADIATION

EXAMPLE VALUES

H_GHI	6.0 kWh/m2/day
K_tilt	1.08



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use a validated transposition model for monthly and hourly production studies. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{design} = X_{calculated} \times K_{conservative}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 6.48 \text{ kWh/m}^2/\text{day} \times 0.95 = 6.16 \text{ kWh/m}^2/\text{day}$

GIVEN VALUES FOR EXAMPLE

X_calculated	6.48 kWh/m2/day
K_design	0.95
X_design	6.16 kWh/m2/day



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$Margin = X_{design} - X_{min}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 6.16 \text{ kWh/m}^2/\text{day} - 5.54 \text{ kWh/m}^2/\text{day} = 0.616 \text{ kWh/m}^2/\text{day}$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

6.48 kWh/m2/day

worked result

CONSERVATIVE

6.16 kWh/m2/day

factor 0.95

MINIMUM

5.54 kWh/m2/day

project criterion

MARGIN

0.616 kWh/m2/day

available difference

GCC design note: Use a validated transposition model for monthly and hourly production studies. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I GROUND-REFLECTED IRRADIANCE

FORMULA

$$G_g = GHI \rho (1 - \cos(\beta)) / 2$$

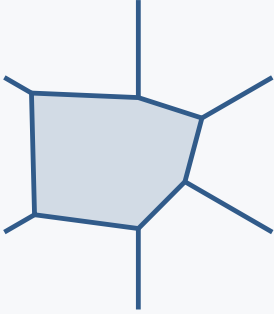
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$G_g = 960 \times 0.32 \times (1 - \cos 28) / 2 = 17.98 \text{ W/m}^2$$

Calculated result = 17.98 W/m2

C&I PV FIGURE 029



C&I GROUND-REFLECTED IRRADIANCE

EXAMPLE VALUES

GHI	960 W/m2
Albedo	0.32
Tilt	28 deg

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use measured seasonal albedo for bifacial studies. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 18 \text{ W/m}^2 \times 1.10 = 19.8 \text{ W/m}^2$$

GIVEN VALUES FOR EXAMPLE

X_calculated	18 W/m2
K_design	1.10
X_design	19.8 W/m2

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 21.8 \text{ W/m}^2 - 19.8 \text{ W/m}^2 = 1.98 \text{ W/m}^2$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

18 W/m2

worked result

REQUIRED

19.8 W/m2

factor 1.10

SELECTED

21.8 W/m2

project criterion

RESERVE

1.98 W/m2

available difference

GCC design note: Use measured seasonal albedo for bifacial studies. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I EQUIVALENT PEAK-SUN HOURS

FORMULA

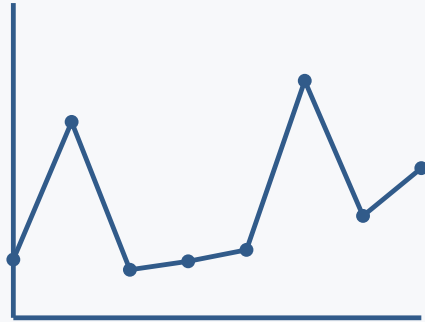
$$\text{PSH} = \text{H_daily} / \text{1kW_per_m2}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

PSH = 6.72/1 = 6.720 h
Calculated result = 6.72 h

C&I PV FIGURE 030



C&I EQUIVALENT PEAK-SUN HOURS

EXAMPLE VALUES

Daily irradiation	6.72 kWh/m2
Reference irradiance	1 kW/m2

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Peak sun hours are an energy equivalent, not daylight duration. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$\text{X_required} = \text{X_calculated} \times \text{K_design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 6.72 h x 1.10 = 7.39 h

GIVEN VALUES FOR EXAMPLE

X_calculated	6.72 h
K_design	1.10
X_design	7.39 h

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = \text{X_selected} - \text{X_required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 8.13 h - 7.39 h = 0.739 h

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

6.72 h

worked result

REQUIRED

7.39 h

factor 1.10

SELECTED

8.13 h

project criterion

RESERVE

0.739 h

available difference

GCC design note: Peak sun hours are an energy equivalent, not daylight duration. Apply one documented solar-position convention and a validated transposition model throughout the yield study. Calculate solar position and plane-of-array resource using the facility location, roof orientation, tilt, horizon and ground reflectance. Use location, roof orientation, horizon, measured resource and plane-of-array geometry to establish a traceable production basis.



1 CALCULATE C&I ONSITE SOLAR CONSUMPTION

FORMULA

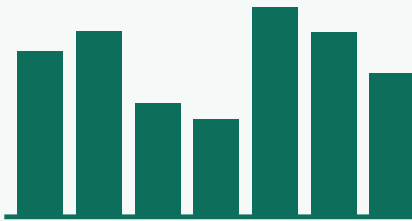
$R_{self} = E_{self} / E_{RE}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{self} = 82 \text{ GWh} / 105 \text{ GWh} = 78.10\%$
Calculated result = 78.1 %

C&I PV FIGURE 031



C&I ONSITE SOLAR CONSUMPTION

EXAMPLE VALUES

Self-consumed	82 GWh
Renewable output	105 GWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Treat storage charging and export according to the commercial boundary. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{design} = X_{calculated} \times K_{conservative}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 78.1 \% \times 0.95 = 74.2 \%$

GIVEN VALUES FOR EXAMPLE

X_calculated	78.1 %
K_design	0.95
X_design	74.2 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$Margin = X_{design} - X_{min}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 74.2 \% - 66.8 \% = 7.42 \%$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

78.1 %

worked result

CONSERVATIVE

74.2 %

factor 0.95

MINIMUM

66.8 %

project criterion

MARGIN

7.42 %

available difference

GCC design note: Treat storage charging and export according to the commercial boundary. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I EXPORTED SOLAR ENERGY

FORMULA

E_export = E_RE - E_self

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

E_export = 105 GWh - 82 GWh = 23.0 GWh
Calculated result = 23 GWh/year

C&I PV FIGURE 032



C&I EXPORTED SOLAR ENERGY

EXAMPLE VALUES

Renewable output	105 GWh
Self-consumed	82 GWh

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply export limits and curtailment before commercial valuation. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 23 GWh/year x 1.10 = 25.3 GWh/year

GIVEN VALUES FOR EXAMPLE

X_calculated	23 GWh/year
K_design	1.10
X_design	25.3 GWh/year

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 27.8 GWh/year - 25.3 GWh/year = 2.53 GWh/year

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

23 GWh/year

worked result

REQUIRED

25.3 GWh/year

factor 1.10

SELECTED

27.8 GWh/year

project criterion

RESERVE

2.53 GWh/year

available difference

GCC design note: Apply export limits and curtailment before commercial valuation. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I SOLAR-LOAD COINCIDENCE

FORMULA

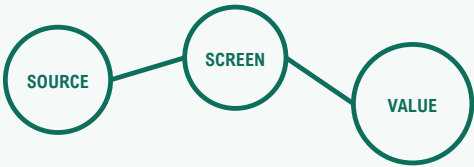
$$CF_c = P_RE,peakload / P_RE,rated$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

CF_c = 24 MW / 36 MW = 66.67%
Calculated result = 66.67 %

C&I PV FIGURE 033



C&I SOLAR-LOAD COINCIDENCE

EXAMPLE VALUES

Renewable at load peak	24 MW
Renewable rating	36 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use coincident timestamps rather than separate annual maxima. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_design = X_calculated \times K_conservative$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 66.7 % x 0.95 = 63.3 %

GIVEN VALUES FOR EXAMPLE

X_calculated	66.7 %
K_design	0.95
X_design	63.3 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$Margin = X_design - X_min$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 63.3 % - 57 % = 6.33 %



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

66.7 %

worked result

CONSERVATIVE

63.3 %

factor 0.95

MINIMUM

57 %

project criterion

MARGIN

6.33 %

available difference

GCC design note: Use coincident timestamps rather than separate annual maxima. Align the calculation boundary with the load study, offtake agreement and grid meter. Establish the facility load profile, self-consumption target, export boundary and design-horizon demand before sizing C&I; PV. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I SOLAR ENERGY-BILL SAVINGS

FORMULA

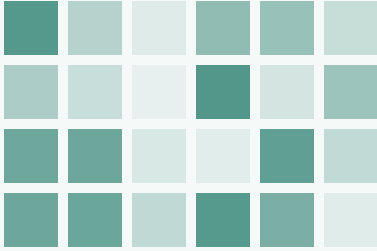
$$\text{Pay_E} = \text{E_metered T_PPA}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

Pay_E = 28,500 MWh x 112 SAR/MWh = 3.192 MSAR
Calculated result = 3.192 MSAR/month

C&I PV FIGURE 034



C&I SOLAR ENERGY-BILL SAVINGS

EXAMPLE VALUES

Metered energy	28,500 MWh
PPA tariff	112 SAR/MWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply the contract loss factor and settlement interval. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$\text{X_required} = \text{X_calculated} \times \text{K_design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 3.19 MSAR/month x 1.10 = 3.51 MSAR/month

GIVEN VALUES FOR EXAMPLE

X_calculated	3.19 MSAR/month
K_design	1.10
X_design	3.51 MSAR/month



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = \text{X_selected} - \text{X_required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 3.86 MSAR/month - 3.51 MSAR/month = 0.351 MSAR/month



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

3.19 MSAR/month

worked result

REQUIRED

3.51 MSAR/month

factor 1.10

SELECTED

3.86 MSAR/month

project criterion

RESERVE

0.351 MSAR/month

available difference

GCC design note: Apply the contract loss factor and settlement interval. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I TIME-OF-USE SOLAR VALUE

FORMULA

$$R_TOU = \sum(E_i T_i)$$

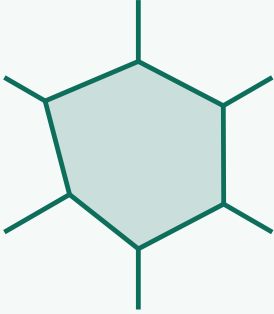
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$R_TOU = 12,000 \times 145 + 16,500 \times 90 = 3.225 \text{ MSAR}$$

Calculated result = 3.225 MSAR/month

C&I PV FIGURE 035



C&I TIME-OF-USE SOLAR VALUE

EXAMPLE VALUES

Peak	12,000 MWh at 145
Off-peak	16,500 MWh at 90



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the tariff calendar and interval meter classification. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_required = X_calculated \times K_design$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 3.23 \text{ MSAR/month} \times 1.10 = 3.55 \text{ MSAR/month}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	3.23 MSAR/month
K_design	1.10
X_design	3.55 MSAR/month



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_selected - X_required$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 3.9 \text{ MSAR/month} - 3.55 \text{ MSAR/month} = 0.355 \text{ MSAR/month}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

3.23 MSAR/month

worked result

REQUIRED

3.55 MSAR/month

factor 1.10

SELECTED

3.9 MSAR/month

project criterion

RESERVE

0.355 MSAR/month

available difference

GCC design note: Use the tariff calendar and interval meter classification. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I DEMAND-CHARGE SAVINGS

FORMULA

$$\text{Pay_cap} = \text{P_firm R_cap}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

Pay_cap = 50 MW x 180,000 SAR/MW-year = 9.00 MSAR
Calculated result = 9 MSAR/year

C&I PV FIGURE 036



C&I DEMAND-CHARGE SAVINGS

EXAMPLE VALUES

Firm capacity	50 MW
Capacity rate	180,000 SAR/MW-year



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply availability and performance deductions. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$\text{X_required} = \text{X_calculated} \times \text{K_design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 9 MSAR/year x 1.10 = 9.9 MSAR/year

GIVEN VALUES FOR EXAMPLE

X_calculated	9 MSAR/year
K_design	1.10
X_design	9.9 MSAR/year



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = \text{X_selected} - \text{X_required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 10.9 MSAR/year - 9.9 MSAR/year = 0.99 MSAR/year



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

9 MSAR/year

worked result

REQUIRED

9.9 MSAR/year

factor 1.10

SELECTED

10.9 MSAR/year

project criterion

RESERVE

0.99 MSAR/year

available difference

GCC design note: Apply availability and performance deductions. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I RENEWABLE-CERTIFICATE INCOME

FORMULA

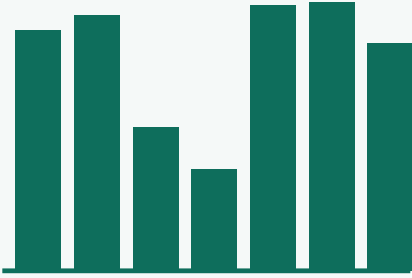
$R_REC = E_eligible \times P_REC$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_REC = 332,900 \text{ MWh} \times 6 \text{ SAR/MWh} = 1.997 \text{ MSAR}$
Calculated result = 1.997 MSAR/year

C&I PV FIGURE 037



C&I RENEWABLE-CERTIFICATE INCOME

EXAMPLE VALUES

Eligible energy	332,900 MWh
Certificate price	6 SAR/MWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Avoid double claiming environmental attributes. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_required = X_calculated \times K_design$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_design = 2 \text{ MSAR/year} \times 1.10 = 2.2 \text{ MSAR/year}$

GIVEN VALUES FOR EXAMPLE

X_calculated	2 MSAR/year
K_design	1.10
X_design	2.2 MSAR/year



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$Reserve = X_selected - X_required$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 2.42 \text{ MSAR/year} - 2.2 \text{ MSAR/year} = 0.22 \text{ MSAR/year}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

2 MSAR/year

worked result

REQUIRED

2.2 MSAR/year

factor 1.10

SELECTED

2.42 MSAR/year

project criterion

RESERVE

0.22 MSAR/year

available difference

GCC design note: Avoid double claiming environmental attributes. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I ESCALATED ELECTRICITY TARIFF

FORMULA

$T_8 = T_0(1+e)^8$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$T_8 = 112 \times (1 + 0.02)^8 = 131.2 \text{ SAR/MWh}$
Calculated result = 131.2 SAR/MWh

C&I PV FIGURE 038



C&I ESCALATED ELECTRICITY TARIFF

EXAMPLE VALUES

Base tariff	112 SAR/MWh
Escalation	2.0%
Years	8

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Follow the contract index, cap, floor and anniversary date. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 131.2 \text{ SAR/MWh} \times 1.10 = 144.3 \text{ SAR/MWh}$

GIVEN VALUES FOR EXAMPLE

X_calculated	131.2 SAR/MWh
K_design	1.10
X_design	144.3 SAR/MWh

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 158.8 \text{ SAR/MWh} - 144.3 \text{ SAR/MWh} = 14.4 \text{ SAR/MWh}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

131.2 SAR/MWh

worked result

REQUIRED

144.3 SAR/MWh

factor 1.10

SELECTED

158.8 SAR/MWh

project criterion

RESERVE

14.4 SAR/MWh

available difference

GCC design note: Follow the contract index, cap, floor and anniversary date. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I EXPORT-IMBALANCE COST

FORMULA

$$C_{imb} = \text{abs}(E_{act} - E_{sched})P_{imb}$$

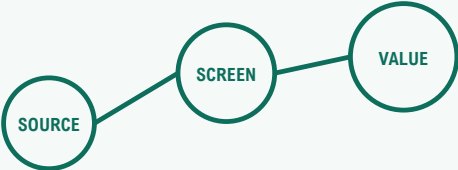
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$C_{imb} = \text{abs}(28,100 - 29,000) \times 75 = 0.0675 \text{ MSAR}$$

Calculated result = 0.0675 MSAR/month

C&I PV FIGURE 039



C&I EXPORT-IMBALANCE COST

EXAMPLE VALUES

Actual energy	28,100 MWh
Scheduled energy	29,000 MWh
Imbalance price	75 SAR/MWh

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Settlement may use directional and interval-specific prices. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 0.068 \text{ MSAR/month} \times 1.05 = 0.071 \text{ MSAR/month}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.068 MSAR/month
K_design	1.05
X_design	0.071 MSAR/month

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 0.078 \text{ MSAR/month} - 0.071 \text{ MSAR/month} = 0.007 \text{ MSAR/month}$$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

0.068 MSAR/month

worked result

DESIGN

0.071 MSAR/month

factor 1.05

LIMIT

0.078 MSAR/month

project criterion

MARGIN

0.007 MSAR/month

available difference

GCC design note: Settlement may use directional and interval-specific prices. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE C&I NET ANNUAL SOLAR BENEFIT

FORMULA

$R_{net} = R_{energy} + R_{cap} + R_{REC} - C_{imb}$

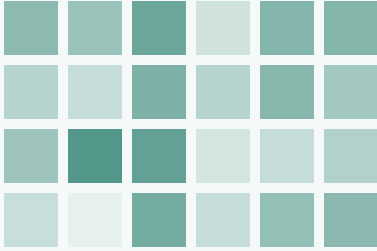
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{net} = 37.28 + 9.00 + 2.00 - 0.81 = 47.47 \text{ MSAR}$

Calculated result = 47.47 MSAR/year

C&I PV FIGURE 040



C&I NET ANNUAL SOLAR BENEFIT

EXAMPLE VALUES

Energy	37.28 MSAR
Capacity	9.00 MSAR
Certificates	2.00 MSAR
Imbalance	0.81 MSAR



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the same contract year and recognized settlement basis. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{design} = X_{calculated} \times K_{conservative}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 47.5 \text{ MSAR/year} \times 0.95 = 45.1 \text{ MSAR/year}$

GIVEN VALUES FOR EXAMPLE

X_calculated	47.5 MSAR/year
K_design	0.95
X_design	45.1 MSAR/year



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$Margin = X_{design} - X_{min}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 45.1 \text{ MSAR/year} - 40.6 \text{ MSAR/year} = 4.51 \text{ MSAR/year}$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

47.5 MSAR/year

worked result

CONSERVATIVE

45.1 MSAR/year

factor 0.95

MINIMUM

40.6 MSAR/year

project criterion

MARGIN

4.51 MSAR/year

available difference

GCC design note: Use the same contract year and recognized settlement basis. Check each revenue and exposure term against the executed offtake and project agreements. Model energy value at the applicable retail, time-of-use, demand-charge, export, certificate and escalation terms for the facility.



1 CALCULATE CONCEPT C&I PV MODULE QUANTITY

FORMULA

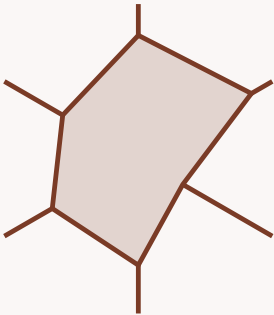
$$N_{mod} = \text{ceil}(P_{DC}/P_{mod})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_{mod} = \text{ceil}(5,000 \text{ kWp} / 0.585 \text{ kWp}) = 8,548 \text{ modules}$
Calculated result = 8,548 modules

C&I PV FIGURE 041



CONCEPT C&I PV MODULE QUANTITY

EXAMPLE VALUES

DC capacity	5,000 kWp
Module rating	0.585 kWp



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Round up, then reconcile the module count with complete strings and inverter MPPT allocations. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 8,548 \text{ modules} \times 1.10 = 9,403 \text{ modules}$

GIVEN VALUES FOR EXAMPLE

X_calculated	8,548 modules
K_design	1.10
X_design	9,403 modules



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 10,344 \text{ modules} - 9,403 \text{ modules} = 941 \text{ modules}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

8,548 modules

worked result

REQUIRED

9,403 modules

factor 1.10

SELECTED

10,344 modules

project criterion

RESERVE

941 modules

available difference

GCC design note: Round up, then reconcile the module count with complete strings and inverter MPPT allocations. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE CONCEPT C&I INVERTER QUANTITY

FORMULA

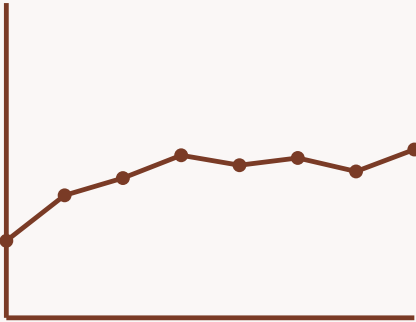
$$N_{inv} = \text{ceil}(P_{ac} / P_{inv})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_{inv} = \text{ceil}(5,000 / 250) = 20$ inverters
Calculated result = 20 inverters

C&I PV FIGURE 042



CONCEPT C&I INVERTER QUANTITY

EXAMPLE VALUES

P_ac	5,000 kW
P_inv	250 kW

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Consider maintenance redundancy and block transformer arrangement. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 20 \text{ inverters} \times 1.10 = 22 \text{ inverters}$

GIVEN VALUES FOR EXAMPLE

X_calculated	20 inverters
K_design	1.10
X_design	22 inverters

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 25 \text{ inverters} - 22 \text{ inverters} = 3 \text{ inverters}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

20 inverters

worked result

REQUIRED

22 inverters

factor 1.10

SELECTED

25 inverters

project criterion

RESERVE

3 inverters

available difference

GCC design note: Consider maintenance redundancy and block transformer arrangement. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE CONCEPT C&I BESS ENERGY RATING

FORMULA

$$E_{nom} = P_{BESS} t / (DoD \eta)$$

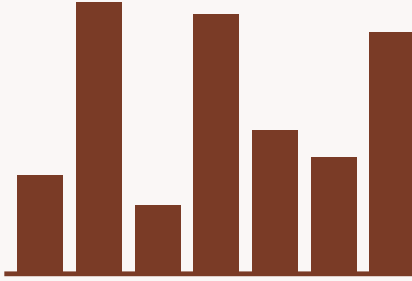
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$E_{nom} = 2 \times 2 / (0.90 \times 0.94) = 4.73 \text{ MWh}$$

Calculated result = 4.728 MWh

C&I PV FIGURE 043



CONCEPT C&I BESS ENERGY RATING

EXAMPLE VALUES

Discharge power	2 MW
Duration	2 h
Depth of discharge	90%
Discharge efficiency	94%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add degradation, reserve and end-of-life capacity requirements before procurement. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 4.73 \text{ MWh} \times 1.10 = 5.2 \text{ MWh}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	4.73 MWh
K_design	1.10
X_design	5.2 MWh



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 5.72 \text{ MWh} - 5.2 \text{ MWh} = 0.52 \text{ MWh}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

4.73 MWh

worked result

REQUIRED

5.2 MWh

factor 1.10

SELECTED

5.72 MWh

project criterion

RESERVE

0.52 MWh

available difference

GCC design note: Add degradation, reserve and end-of-life capacity requirements before procurement. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE C&I ARCHITECTURE DC-TO-AC RATIO

FORMULA

$$R_DCAC = P_DC / P_AC$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

R_DCAC = 5.0 MWp / 4.0 MWac = 1.250
Calculated result = 1.25 ratio

C&I PV FIGURE 044



C&I ARCHITECTURE DC-TO-AC RATIO

EXAMPLE VALUES

DC capacity	5.0 MWp
AC capacity	4.0 MW

i

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Optimize the ratio against clipping, temperature, tariff and inverter-loading studies. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_required = X_calculated \times K_design$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 1.25 ratio x 1.10 = 1.38 ratio

GIVEN VALUES FOR EXAMPLE

X_calculated	1.25 ratio
K_design	1.10
X_design	1.38 ratio

i

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_selected - X_required$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 1.51 ratio - 1.38 ratio = 0.138 ratio

i

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

i

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK

SUMMARY

CALCULATED

1.25 ratio

worked result

REQUIRED

1.38 ratio

factor 1.10

SELECTED

1.51 ratio

project criterion

RESERVE

0.138 ratio

available difference

GCC design note: Optimize the ratio against clipping, temperature, tariff and inverter-loading studies. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE C&I MAIN TRANSFORMER RATING

FORMULA

$$S_{tx} = P_{export} / (PF \cdot \eta)$$

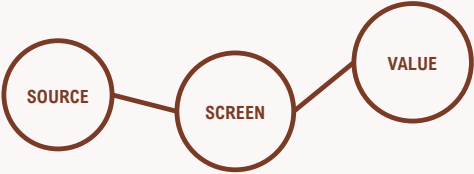
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$S_{tx} = 4.0 / (0.98 \times 0.99) = 4.123 \text{ MVA}$$

Calculated result = 4.123 MVA

C&I PV FIGURE 045



C&I MAIN TRANSFORMER RATING

EXAMPLE VALUES

Export power	4.0 MW
Power factor	0.98
Efficiency	99%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check ambient derating, harmonic heating, future load and the available standard transformer rating. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 4.12 \text{ MVA} \times 1.10 = 4.54 \text{ MVA}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	4.12 MVA
K_design	1.10
X_design	4.54 MVA



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 4.99 \text{ MVA} - 4.54 \text{ MVA} = 0.454 \text{ MVA}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

4.12 MVA

worked result

REQUIRED

4.54 MVA

factor 1.10

SELECTED

4.99 MVA

project criterion

RESERVE

0.454 MVA

available difference

GCC design note: Check ambient derating, harmonic heating, future load and the available standard transformer rating. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE C&I MODULAR POWER-BLOCK QUANTITY

FORMULA

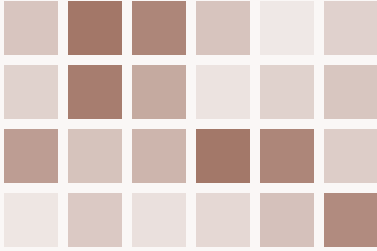
$$N_{\text{block}} = \text{ceil}(P_{\text{AC}}/P_{\text{block}})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_{\text{block}} = \text{ceil}(4.0 \text{ MW} / 1.0 \text{ MW}) = 4 \text{ blocks}$
Calculated result = 4 blocks

C&I PV FIGURE 046



C&I MODULAR POWER-BLOCK QUANTITY

EXAMPLE VALUES

System AC capacity	4.0 MW
Block rating	1.0 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Coordinate block quantity with feeder, transformer, redundancy and maintenance architecture. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 4 \text{ blocks} \times 1.10 = 5 \text{ blocks}$

GIVEN VALUES FOR EXAMPLE

X_calculated	4 blocks
K_design	1.10
X_design	5 blocks



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 6 \text{ blocks} - 5 \text{ blocks} = 1 \text{ block}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

4 blocks

worked result

REQUIRED

5 blocks

factor 1.10

SELECTED

6 blocks

project criterion

RESERVE

1 block

available difference

GCC design note: Coordinate block quantity with feeder, transformer, redundancy and maintenance architecture. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE C&I SYSTEM AUXILIARY DEMAND

FORMULA

$$P_{aux} = f_{aux} P_{gross}$$

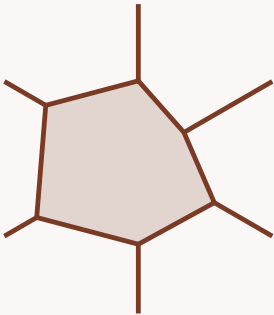
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{aux} = 0.018 \times 4,000 \text{ kW} = 72.0 \text{ kW}$$

Calculated result = 72 kW

C&I PV FIGURE 047



C&I SYSTEM AUXILIARY DEMAND

EXAMPLE VALUES

Auxiliary fraction	1.8%
Gross output	4,000 kW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Separate continuous, intermittent and startup auxiliaries in the facility energy balance. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 72 \text{ kW} \times 1.10 = \mathbf{79.2 \text{ kW}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	72 kW
K_design	1.10
X_design	79.2 kW



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 87.1 \text{ kW} - 79.2 \text{ kW} = \mathbf{7.92 \text{ kW}}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

72 kW

worked result

REQUIRED

79.2 kW

factor 1.10

SELECTED

87.1 kW

project criterion

RESERVE

7.92 kW

available difference

GCC design note: Separate continuous, intermittent and startup auxiliaries in the facility energy balance. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE C&I N-1 FIRM CAPACITY

FORMULA

$$P_{firm} = (N-1)P_{unit}$$

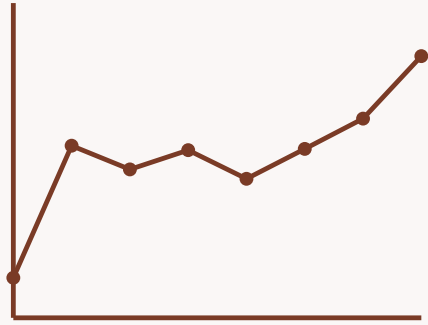
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{firm} = (4-1) \times 1.25 \text{ MVA} = 3.75 \text{ MVA}$$

Calculated result = 3.75 MVA

C&I PV FIGURE 048



C&I N-1 FIRM CAPACITY

EXAMPLE VALUES

Parallel units	4
Unit rating	1.25 MVA

i

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Verify overload capability, protection selectivity and common-mode failure exposure. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 3.75 \text{ MVA} \times 1.10 = 4.12 \text{ MVA}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	3.75 MVA
K_design	1.10
X_design	4.12 MVA

i

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 4.54 \text{ MVA} - 4.12 \text{ MVA} = 0.413 \text{ MVA}$$

i

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

i

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK

SUMMARY

CALCULATED

3.75 MVA

worked result

REQUIRED

4.12 MVA

factor 1.10

SELECTED

4.54 MVA

project criterion

RESERVE

0.413 MVA

available difference

GCC design note: Verify overload capability, protection selectivity and common-mode failure exposure. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE C&I TECHNOLOGY SELECTION SCORE

FORMULA

$$S_{tech} = \sum(w_i s_i)$$

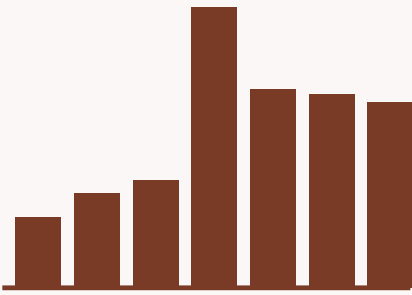
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$S_{tech} = 0.25 \times 88 + 0.25 \times 84 + 0.20 \times 80 + 0.15 \times 92 + 0.15 \times 78 = 84.5$$

Calculated result = 84.5 score

C&I PV FIGURE 049



C&I TECHNOLOGY SELECTION SCORE

EXAMPLE VALUES

Energy	25% at 88
Cost	25% at 84
Maturity	20% at 80
GCC fit	15% at 92; ESG 15% at 78



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply mandatory technical thresholds before weighted ranking. Record the selected architecture, alternatives and decision criteria in the concept report. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 84.5 \text{ score} \times 0.95 = 80.3 \text{ score}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	84.5 score
K_design	0.95
X_design	80.3 score



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 80.3 \text{ score} - 72.2 \text{ score} = 8.03 \text{ score}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

84.5 score

worked result

CONSERVATIVE

80.3 score

factor 0.95

MINIMUM

72.2 score

project criterion

MARGIN

8.03 score

available difference

GCC design note: Apply mandatory technical thresholds before weighted ranking. Record the selected architecture, alternatives and decision criteria in the concept report. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE C&I INSTALLED DC CAPACITY

FORMULA

$$P_{DC} = N_s N_p P_m / 1000$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{DC} = 26 \times 329 \times 0.585 / 1,000 = 5.004 \text{ MWp}$$

Calculated result = 5.004 MWp

C&I PV FIGURE 050



C&I INSTALLED DC CAPACITY

EXAMPLE VALUES

Modules/string	26
Strings	329
Module power	0.585 kWp



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: State capacity at STC and reconcile it with the selected inverter operating window. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 5 \text{ MWp} \times 1.10 = 5.5 \text{ MWp}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	5 MWp
K_design	1.10
X_design	5.5 MWp



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 6.05 \text{ MWp} - 5.5 \text{ MWp} = 0.55 \text{ MWp}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

5 MWp

worked result

REQUIRED

5.5 MWp

factor 1.10

SELECTED

6.05 MWp

project criterion

RESERVE

0.55 MWp

available difference

GCC design note: State capacity at STC and reconcile it with the selected inverter operating window. Select a modular architecture that fits the facility load, connection limit, resilience target, space, equipment ratings and service strategy.



1 CALCULATE C&I PV MODULE STC POWER

FORMULA

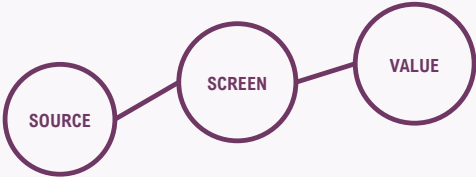
$$P_m = V_{mp} I_{mp}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$P_m = 43.8 \times 13.25 = 580.4 \text{ W}$
Calculated result = 580.3 W

C&I PV FIGURE 051



C&I PV MODULE STC POWER

EXAMPLE VALUES

MPP voltage	43.8 V
MPP current	13.25 A



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Certified nameplate power includes measurement tolerance. Check module values at matching irradiance, spectrum and cell temperature and retain certified tolerance data. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 580.3 \text{ W} \times 1.10 = \mathbf{638.4 \text{ W}}$

GIVEN VALUES FOR EXAMPLE

$X_{\text{calculated}}$	580.3 W
K_{design}	1.10
X_{design}	638.4 W



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 702.2 \text{ W} - 638.4 \text{ W} = \mathbf{63.8 \text{ W}}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

580.3 W

worked result

REQUIRED

638.4 W

factor 1.10

SELECTED

702.2 W

project criterion

RESERVE

63.8 W

available difference

GCC design note: Certified nameplate power includes measurement tolerance. Check module values at matching irradiance, spectrum and cell temperature and retain certified tolerance data. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I PV MODULE MAXIMUM-POWER POINT

FORMULA

$$P_{mp} = V_{mp} \times I_{mp}$$

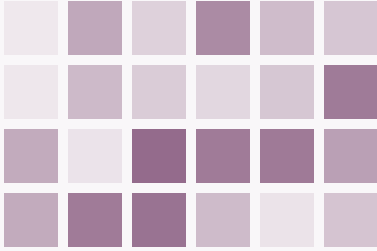
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{mp} = 41.2 \text{ V} \times 13.1 \text{ A} = 540 \text{ W}$$

Calculated result = 539.7 W

C&I PV FIGURE 052



C&I PV MODULE MAXIMUM-POWER POINT

EXAMPLE VALUES

V _{mp}	41.2 V
I _{mp}	13.1 A



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use values from the same irradiance and temperature condition. Check module values at matching irradiance, spectrum and cell temperature and retain certified tolerance data. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 539.7 \text{ W} \times 0.95 = \mathbf{512.7 \text{ W}}$$

GIVEN VALUES FOR EXAMPLE

X _{calculated}	539.7 W
K _{design}	0.95
X _{design}	512.7 W



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 512.7 \text{ W} - 461.5 \text{ W} = \mathbf{51.3 \text{ W}}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

539.7 W

worked result

CONSERVATIVE

512.7 W

factor 0.95

MINIMUM

461.5 W

project criterion

MARGIN

51.3 W

available difference

GCC design note: Use values from the same irradiance and temperature condition. Check module values at matching irradiance, spectrum and cell temperature and retain certified tolerance data. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I PV MODULE TOTAL AREA

FORMULA

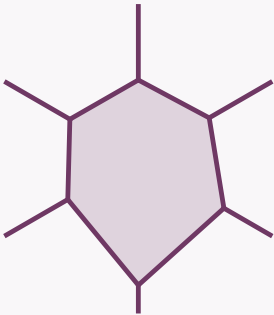
A = L W

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

A = 2.28x1.13 = 2.576 m2
Calculated result = 2.576 m2

C&I PV FIGURE 053



C&I PV MODULE TOTAL AREA

EXAMPLE VALUES

Length	2.28 m
Width	1.13 m



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use certified outer dimensions for layout checks. Check module values at matching irradiance, spectrum and cell temperature and retain certified tolerance data. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 2.58 m2 x 1.10 = 2.83 m2

GIVEN VALUES FOR EXAMPLE

X_calculated	2.58 m2
K_design	1.10
X_design	2.83 m2



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 3.12 m2 - 2.83 m2 = 0.283 m2



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

2.58 m2

worked result

REQUIRED

2.83 m2

factor 1.10

SELECTED

3.12 m2

project criterion

RESERVE

0.283 m2

available difference

GCC design note: Use certified outer dimensions for layout checks. Check module values at matching irradiance, spectrum and cell temperature and retain certified tolerance data. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I MODULE APERTURE EFFICIENCY

FORMULA

$$\text{eta_mod} = \text{P_STC} / (\text{G_STC} \times \text{A_mod})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$\text{eta_mod} = 575 / (1,000 \times 2.58) = 22.3\%$$

Calculated result = 22.29 %

C&I PV FIGURE 054



C&I MODULE APERTURE EFFICIENCY

EXAMPLE VALUES

P_STC	575 W
G_STC	1,000 W/m2
A_mod	2.58 m2

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the certified module aperture or total area consistently when comparing products. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$\text{X_design} = \text{X_calculated} \times \text{K_conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$\text{X_design} = 22.3 \% \times 0.95 = 21.2 \%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	22.3 %
K_design	0.95
X_design	21.2 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = \text{X_design} - \text{X_min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 21.2 \% - 19.1 \% = 2.12 \%$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

22.3 %

worked result

CONSERVATIVE

21.2 %

factor 0.95

MINIMUM

19.1 %

project criterion

MARGIN

2.12 %

available difference

GCC design note: Use the certified module aperture or total area consistently when comparing products. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I HOT-CONDITION MODULE OUTPUT

FORMULA

$$P_T = P_STC \times [1 - \gamma_P(T_cell - 25)]$$

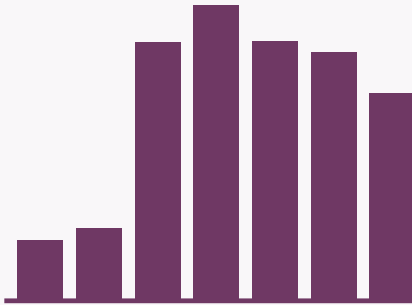
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_T = 550 \times [1 - 0.0034(65 - 25)] = 475 \text{ W}$$

Calculated result = 475.2 W

C&I PV FIGURE 055



C&I HOT-CONDITION MODULE OUTPUT

EXAMPLE VALUES

P_STC	550 W
gamma_P	0.34%/C
T_cell	65 C

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Cell temperature, not ambient temperature, belongs in the module-power equation. Check module values at matching irradiance, spectrum and cell temperature and retain certified tolerance data. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_design = X_calculated \times K_conservative$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 475.2 \text{ W} \times 0.95 = 451.4 \text{ W}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	475.2 W
K_design	0.95
X_design	451.4 W

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_design - X_min$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 451.4 \text{ W} - 406.3 \text{ W} = 45.1 \text{ W}$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

475.2 W

worked result

CONSERVATIVE

451.4 W

factor 0.95

MINIMUM

406.3 W

project criterion

MARGIN

45.1 W

available difference

GCC design note: Cell temperature, not ambient temperature, belongs in the module-power equation. Check module values at matching irradiance, spectrum and cell temperature and retain certified tolerance data. Select modules and mounting arrangements using certified ratings, temperature behavior, available roof area, tolerances and mismatch limits. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I CRITICAL-TIME SHADOW LENGTH

FORMULA

$L_{\text{shadow}} = H / \tan(\alpha)$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$L_{\text{shadow}} = 2.2 / \tan(18 \text{ deg}) = 6.77 \text{ m}$
Calculated result = 6.771 m

C&I PV FIGURE 056



C&I CRITICAL-TIME SHADOW LENGTH

EXAMPLE VALUES

H	2.2 m
alpha	18 deg

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the critical design date and solar altitude selected by the project criteria. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 6.77 \text{ m} \times 1.10 = 7.45 \text{ m}$

GIVEN VALUES FOR EXAMPLE

X_calculated	6.77 m
K_design	1.10
X_design	7.45 m

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 8.19 \text{ m} - 7.45 \text{ m} = 0.745 \text{ m}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

6.77 m

worked result

REQUIRED

7.45 m

factor 1.10

SELECTED

8.19 m

project criterion

RESERVE

0.745 m

available difference

GCC design note: Use the critical design date and solar altitude selected by the project criteria. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I MINIMUM FIXED-TILT PITCH

FORMULA

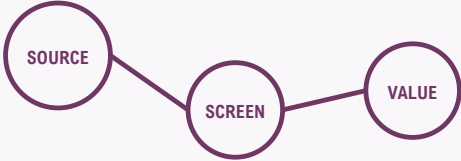
$$\text{Pitch} = L \times \cos(\text{beta}) + H / \tan(\text{alpha})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

Pitch = 2.4 cos 20 deg + 0.821 / tan 18 deg = 4.78 m
Calculated result = 4.782 m

C&I PV FIGURE 057



C&I MINIMUM FIXED-TILT PITCH

EXAMPLE VALUES

L	2.4 m
beta	20 deg
alpha	18 deg

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Confirm the reference points used for front-edge and rear-edge clearance. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 4.78 m x 1.10 = 5.26 m

GIVEN VALUES FOR EXAMPLE

X_calculated	4.78 m
K_design	1.10
X_design	5.26 m

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 5.79 m - 5.26 m = 0.526 m

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

4.78 m

worked result

REQUIRED

5.26 m

factor 1.10

SELECTED

5.79 m

project criterion

RESERVE

0.526 m

available difference

GCC design note: Confirm the reference points used for front-edge and rear-edge clearance. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I OBSTRUCTION HORIZON ANGLE

FORMULA

$$\alpha_h = \text{atan}(H / D)$$

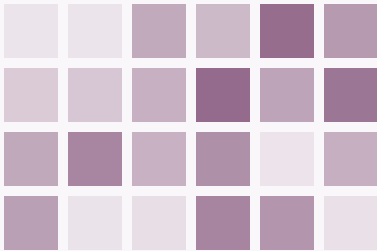
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$\alpha_h = \text{atan}(18 / 120) = 8.53 \text{ deg}$$

Calculated result = 8.531 deg

C&I PV FIGURE 058



C&I OBSTRUCTION HORIZON ANGLE

EXAMPLE VALUES

H	18 m
D	120 m



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Survey terrain and nearby structures in all relevant azimuth directions. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{upper}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 8.53 \text{ deg} \times 1.05 = 8.96 \text{ deg}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	8.53 deg
K_design	1.05
X_design	8.96 deg



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{\text{limit}} - X_{\text{design}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 9.85 \text{ deg} - 8.96 \text{ deg} = 0.896 \text{ deg}$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

8.53 deg

worked result

DESIGN

8.96 deg

factor 1.05

LIMIT

9.85 deg

project criterion

MARGIN

0.896 deg

available difference

GCC design note: Survey terrain and nearby structures in all relevant azimuth directions. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I PARTIAL-SHADING ENERGY LOSS

FORMULA

$$L_{sh} = f_{shaded} \times K_{electrical}$$

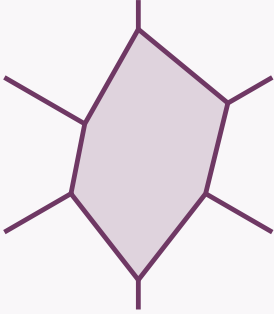
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$L_{sh} = (12 / 144) \times 0.85 = 7.08\%$$

Calculated result = 7.083 %

C&I PV FIGURE 059



C&I PARTIAL-SHADING ENERGY LOSS

EXAMPLE VALUES

Shaded cells	12
Total cells	144
K_electrical	0.85

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Bypass-diode topology and string mismatch can make shading loss nonlinear. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 7.08\% \times 1.05 = 7.44\%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	7.08 %
K_design	1.05
X_design	7.44 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 8.18\% - 7.44\% = 0.744\%$$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

7.08 %

worked result

DESIGN

7.44 %

factor 1.05

LIMIT

8.18 %

project criterion

MARGIN

0.744 %

available difference

GCC design note: Bypass-diode topology and string mismatch can make shading loss nonlinear. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I USABLE ROOF AREA AFTER SETBACKS

FORMULA

A_use = A_roof(1-f_excl)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

A_use = 4,800x(1-0.22) = 3,744 m2
Calculated result = 3,744 m2

C&I PV FIGURE 060



C&I USABLE ROOF AREA AFTER SETBACKS

EXAMPLE VALUES

Gross roof	4,800 m2
Excluded fraction	22%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include access, fire paths, equipment and shading exclusions. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 3,744 m2 x 0.95 = **3,557 m2**

GIVEN VALUES FOR EXAMPLE

X_calculated	3,744 m2
K_design	0.95
X_design	3,557 m2



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 3,557 m2 - 3,201 m2 = **355.7 m2**



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

3,744 m2

worked result

CONSERVATIVE

3,557 m2

factor 0.95

MINIMUM

3,201 m2

project criterion

MARGIN

355.7 m2

available difference

GCC design note: Include access, fire paths, equipment and shading exclusions. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Preserve fire access, maintenance paths, drainage routes, parapet clearance and shade-free roof zones in the final array layout. Select modules and arrange arrays using certified ratings, hot-condition output, roof constraints, access, shading and maintainability.



1 CALCULATE C&I STRING OPEN-CIRCUIT VOLTAGE

FORMULA

$$V_{oc,string} = N_s \times V_{oc,module}$$

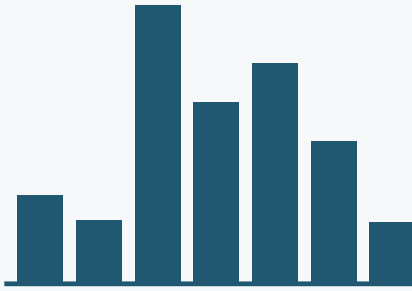
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$V_{oc,string} = 24 \times 49.8 = 1,195 \text{ V}$$

Calculated result = 1,195.2 V

C&I PV FIGURE 061



C&I STRING OPEN-CIRCUIT VOLTAGE

EXAMPLE VALUES

N_s	24
V_oc,module	49.8 V



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Cold-temperature correction is still required before checking the inverter maximum voltage. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 1,195 \text{ V} \times 1.05 = 1,255 \text{ V}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	1,195 V
K_design	1.05
X_design	1,255 V



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 1,380 \text{ V} - 1,255 \text{ V} = 125.5 \text{ V}$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

1,195 V

worked result

DESIGN

1,255 V

factor 1.05

LIMIT

1,380 V

project criterion

MARGIN

125.5 V

available difference

GCC design note: Cold-temperature correction is still required before checking the inverter maximum voltage. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE COLD-CONDITION C&I STRING VOLTAGE

FORMULA

$$V_{oc,cold} = N_s V_{oc}[1 + \text{beta}(25 - T_{min})]$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$V_{oc,cold} = 24 \times 49.8 \times [1 + 0.0028(25 - 5)] = 1,262 \text{ V}$
Calculated result = 1,262.1 V

C&I PV FIGURE 062



COLD-CONDITION C&I STRING VOLTAGE

EXAMPLE VALUES

N_s	24
T_min	5 C
beta	0.28%/C

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the lowest credible cell temperature, including clear-sky radiative cooling. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 1,262 \text{ V} \times 1.05 = 1,325 \text{ V}$

GIVEN VALUES FOR EXAMPLE

X_calculated	1,262 V
K_design	1.05
X_design	1,325 V

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Margin} = 1,458 \text{ V} - 1,325 \text{ V} = 132.5 \text{ V}$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

1,262 V

worked result

DESIGN

1,325 V

factor 1.05

LIMIT

1,458 V

project criterion

MARGIN

132.5 V

available difference

GCC design note: Use the lowest credible cell temperature, including clear-sky radiative cooling. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE HOT-CONDITION C&I STRING MPP VOLTAGE

FORMULA

$$V_{mp,hot} = N_s V_{mp}[1 - \beta_{mp}(T_{hot} - 25)]$$

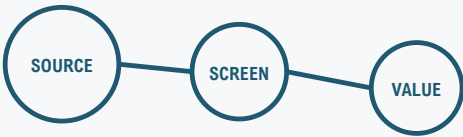
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$V_{mp,hot} = 24 \times 41.2 \times [1 - 0.0030(70 - 25)] = 855 \text{ V}$$

Calculated result = 855.3 V

C&I PV FIGURE 063



HOT-CONDITION C&I STRING MPP VOLTAGE

EXAMPLE VALUES

N_s	24
T_hot	70 C
beta_mp	0.30%/C

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: The hot string MPP voltage must stay above the inverter MPPT minimum. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 855.3 \text{ V} \times 0.95 = 812.5 \text{ V}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	855.3 V
K_design	0.95
X_design	812.5 V

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 812.5 \text{ V} - 731.3 \text{ V} = 81.3 \text{ V}$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

855.3 V

worked result

CONSERVATIVE

812.5 V

factor 0.95

MINIMUM

731.3 V

project criterion

MARGIN

81.3 V

available difference

GCC design note: The hot string MPP voltage must stay above the inverter MPPT minimum. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE MAXIMUM MODULES PER C&I STRING

FORMULA

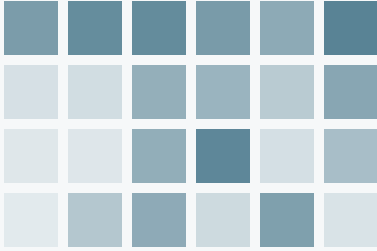
$$N_{max} = \text{floor}[V_{dc,max} / V_{oc,cold,module}]$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_{max} = \text{floor}[1,500 / (49.8 \times 1.056)] = 28$ modules
Calculated result = 28 modules

C&I PV FIGURE 064



MAXIMUM MODULES PER C&I STRING

EXAMPLE VALUES

V _{dc,max}	1,500 V
V _{oc}	49.8 V
Cold factor	1.056

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include measurement tolerance and applicable design margin. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 28 \text{ modules} \times 1.10 = 31$ modules

GIVEN VALUES FOR EXAMPLE

X _{calculated}	28 modules
K _{design}	1.10
X _{design}	31 modules

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 35 \text{ modules} - 31 \text{ modules} = 4$ modules

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

28 modules

worked result

REQUIRED

31 modules

factor 1.10

SELECTED

35 modules

project criterion

RESERVE

4 modules

available difference

GCC design note: Include measurement tolerance and applicable design margin. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE MINIMUM MODULES PER C&I STRING

FORMULA

$$N_{min} = \text{ceil}[V_{MPPT,min} / V_{mp,hot,module}]$$

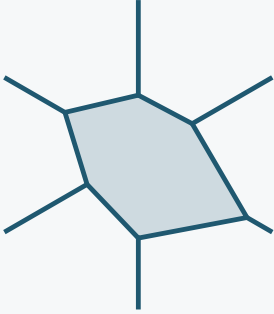
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$N_{min} = \text{ceil}[600 / (41.2 \times 0.865)] = 17 \text{ modules}$$

Calculated result = 17 modules

C&I PV FIGURE 065



MINIMUM MODULES PER C&I STRING

EXAMPLE VALUES

V_MPPT,min	600 V
V_mp	41.2 V
Hot factor	0.865

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Also verify start voltage and maximum MPPT current. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 17 \text{ modules} \times 1.10 = 19 \text{ modules}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	17 modules
K_design	1.10
X_design	19 modules

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 21 \text{ modules} - 19 \text{ modules} = 2 \text{ modules}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

17 modules

worked result

REQUIRED

19 modules

factor 1.10

SELECTED

21 modules

project criterion

RESERVE

2 modules

available difference

GCC design note: Also verify start voltage and maximum MPPT current. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE CONFIGURED C&I ARRAY DC CAPACITY

FORMULA

$$P_{DC} = N_s N_p P_m / 1000$$

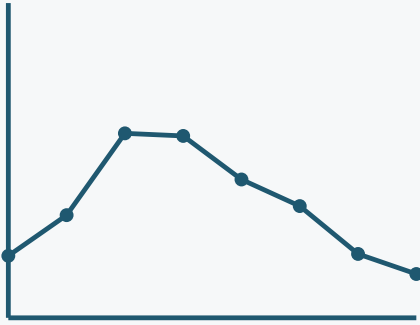
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{DC} = 26 \times 329 \times 0.585 / 1,000 = 5.004 \text{ MWp}$$

Calculated result = 5.004 MWp

C&I PV FIGURE 066



CONFIGURED C&I ARRAY DC CAPACITY

EXAMPLE VALUES

Modules/string	26
Strings	329
Module power	0.585 kWp

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Confirm the configured capacity against complete strings, MPPT allocations and nameplate reporting rules. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 5 \text{ MWp} \times 1.10 = 5.5 \text{ MWp}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	5 MWp
K_design	1.10
X_design	5.5 MWp

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 6.05 \text{ MWp} - 5.5 \text{ MWp} = 0.55 \text{ MWp}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

5 MWp

worked result

REQUIRED

5.5 MWp

factor 1.10

SELECTED

6.05 MWp

project criterion

RESERVE

0.55 MWp

available difference

GCC design note: Confirm the configured capacity against complete strings, MPPT allocations and nameplate reporting rules. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE REQUIRED C&I PARALLEL STRING COUNT

FORMULA

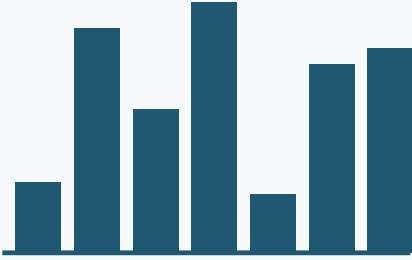
$$N_strings = \text{ceil}[P_dc / (N_s \times P_module)]$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_strings = \text{ceil}[5,000 / (28 \times 0.55)] = 325 \text{ strings}$
Calculated result = 325 strings

C&I PV FIGURE 067



REQUIRED C&I PARALLEL STRING COUNT

EXAMPLE VALUES

P_dc	5,000 kW
N_s	28
P_module	0.55 kW

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Balance strings evenly across MPPT inputs wherever practical. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_required = X_calculated \times K_design$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_design = 325 \text{ strings} \times 1.10 = 358 \text{ strings}$

GIVEN VALUES FOR EXAMPLE

X_calculated	325 strings
K_design	1.10
X_design	358 strings

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_selected - X_required$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 394 \text{ strings} - 358 \text{ strings} = 36 \text{ strings}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

325 strings

worked result

REQUIRED

358 strings

factor 1.10

SELECTED

394 strings

project criterion

RESERVE

36 strings

available difference

GCC design note: Balance strings evenly across MPPT inputs wherever practical. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE C&I ARRAY SHORT-CIRCUIT CURRENT

FORMULA

$I_{sc,array} = N_p I_{sc,module}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$I_{sc,array} = 18 \times 14.1 = 253.8 \text{ A}$
Calculated result = 253.8 A

C&I PV FIGURE 068



C&I ARRAY SHORT-CIRCUIT CURRENT

EXAMPLE VALUES

Parallel strings	18
Module Isc	14.1 A



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply current multipliers required for conductor and protection design. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{design} = X_{calculated} \times K_{upper}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 253.8 \text{ A} \times 1.05 = 266.5 \text{ A}$

GIVEN VALUES FOR EXAMPLE

X_calculated	253.8 A
K_design	1.05
X_design	266.5 A



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$Margin = X_{limit} - X_{design}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 293.1 \text{ A} - 266.5 \text{ A} = 26.6 \text{ A}$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

253.8 A

worked result

DESIGN

266.5 A

factor 1.05

LIMIT

293.1 A

project criterion

MARGIN

26.6 A

available difference

GCC design note: Apply current multipliers required for conductor and protection design. Verify every series and parallel limit at the project minimum and maximum credible cell temperatures. Verify string voltage, current, module count, parallel circuits and inverter loading at the facility's credible cell-temperature limits. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE C&I STRINGS FROM TARGET CAPACITY

FORMULA

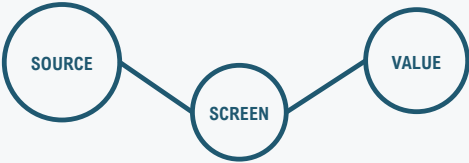
$$N_p = \text{ceil}(P_{DC} / (N_s P_m))$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_p = \text{ceil}(5,000 / (26 \times 0.585)) = 329$ strings
Calculated result = 329 strings

C&I PV FIGURE 069



C&I STRINGS FROM TARGET CAPACITY

EXAMPLE VALUES

DC capacity	5,000 kWp
Modules/string	26
Module power	0.585 kWp

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Reconcile the rounded string count with inverter MPPT and combiner input quantities. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 329 \text{ strings} \times 1.10 = 362$ strings

GIVEN VALUES FOR EXAMPLE

$X_{\text{calculated}}$	329 strings
K_{design}	1.10
X_{design}	362 strings

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 399 \text{ strings} - 362 \text{ strings} = 37$ strings

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

329 strings

worked result

REQUIRED

362 strings

factor 1.10

SELECTED

399 strings

project criterion

RESERVE

37 strings

available difference

GCC design note: Reconcile the rounded string count with inverter MPPT and combiner input quantities. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE C&I ARRAY DC-TO-AC RATIO

FORMULA

$$R_DCAC = P_DC / P_AC$$

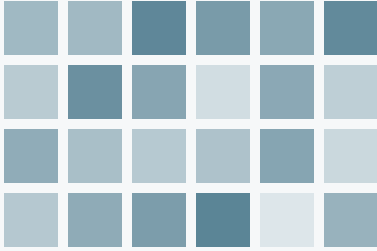
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$R_DCAC = 5.004 \text{ MWp} / 4.0 \text{ MWac} = 1.251$$

Calculated result = 1.251 ratio

C&I PV FIGURE 070



C&I ARRAY DC-TO-AC RATIO

EXAMPLE VALUES

DC capacity	5.004 MWp
AC capacity	4.0 MW

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Optimize against clipping, temperature, self-consumption, export limits and equipment cost. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_required = X_calculated \times K_design$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 1.25 \text{ ratio} \times 1.10 = \mathbf{1.38 \text{ ratio}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	1.25 ratio
K_design	1.10
X_design	1.38 ratio

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_selected - X_required$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 1.51 \text{ ratio} - 1.38 \text{ ratio} = \mathbf{0.138 \text{ ratio}}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

1.25 ratio

worked result

REQUIRED

1.38 ratio

factor 1.10

SELECTED

1.51 ratio

project criterion

RESERVE

0.138 ratio

available difference

GCC design note: Optimize against clipping, temperature, self-consumption, export limits and equipment cost. Check module temperature limits, inverter operating windows, series count, parallel paths, array current and loading ratio for every C&I; array block.



1 CALCULATE C&I PV SOURCE-CIRCUIT CURRENT

FORMULA

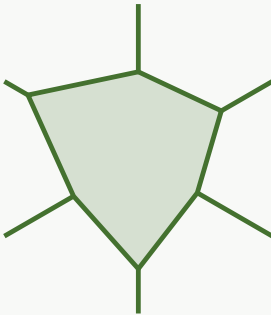
I_design = 1.25 x 1.25 x I_sc

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

I_design = 1.25 x 1.25 x 13.8 = 21.6 A
Calculated result = 21.56 A

C&I PV FIGURE 071



C&I PV SOURCE-CIRCUIT CURRENT

EXAMPLE VALUES

I_sc	13.8 A
Continuous	1.25
Irradiance	1.25



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Confirm multipliers against the adopted wiring standard and authority requirements. Use conductor resistance at operating temperature and the complete route length for every DC circuit check. Size C&I; source circuits and routes for ampacity, voltage drop, loss, containment, reel logistics and combiner output current. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 21.6 A x 1.10 = 23.7 A

GIVEN VALUES FOR EXAMPLE

X_calculated	21.6 A
K_design	1.10
X_design	23.7 A



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 26.1 A - 23.7 A = 2.37 A



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

21.6 A

worked result

REQUIRED

23.7 A

factor 1.10

SELECTED

26.1 A

project criterion

RESERVE

2.37 A

available difference

GCC design note: Confirm multipliers against the adopted wiring standard and authority requirements. Use conductor resistance at operating temperature and the complete route length for every DC circuit check. Size C&I; source circuits and routes for ampacity, voltage drop, loss, containment, reel logistics and combiner output current. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I TWO-WIRE DC VOLTAGE DROP

FORMULA

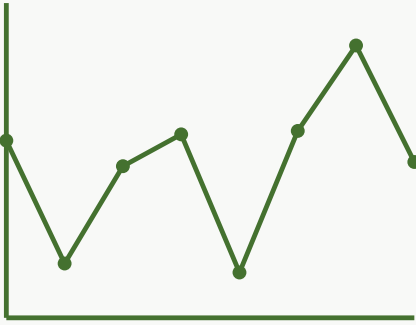
$\Delta V = 2 I \rho L/A$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$\Delta V = 2 \times 85 \times 0.0175 \times 120 / 70 = 5.100 \text{ V}$
Calculated result = 5.1 V

C&I PV FIGURE 072



C&I TWO-WIRE DC VOLTAGE DROP

EXAMPLE VALUES

Current	85 A
Resistivity	0.0175 ohm-mm2/m
Length	120 m
Area	70 mm2

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use operating-temperature resistivity and actual route length. Use conductor resistance at operating temperature and the complete route length for every DC circuit check. Size C&I; source circuits and routes for ampacity, voltage drop, loss, containment, reel logistics and combiner output current. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{upper}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 5.1 \text{ V} \times 1.05 = \mathbf{5.35 \text{ V}}$

GIVEN VALUES FOR EXAMPLE

X_calculated	5.1 V
K_design	1.05
X_design	5.35 V

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$\text{Margin} = X_{\text{limit}} - X_{\text{design}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Margin} = 5.89 \text{ V} - 5.35 \text{ V} = \mathbf{0.536 \text{ V}}$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

5.1 V

worked result

DESIGN

5.35 V

factor 1.05

LIMIT

5.89 V

project criterion

MARGIN

0.536 V

available difference

GCC design note: Use operating-temperature resistivity and actual route length. Use conductor resistance at operating temperature and the complete route length for every DC circuit check. Size C&I; source circuits and routes for ampacity, voltage drop, loss, containment, reel logistics and combiner output current. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I PV DC CABLE POWER LOSS

FORMULA

$$P_{loss} = I^2 R$$

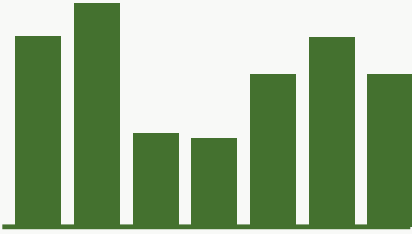
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{loss} = 85^2 \times 0.060 = 433.5 \text{ W}$$

Calculated result = 433.5 W

C&I PV FIGURE 073



C&I PV DC CABLE POWER LOSS

EXAMPLE VALUES

Current	85 A
Loop resistance	0.060 ohm



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Compare losses at the design current and conductor temperature. Use conductor resistance at operating temperature and the complete route length for every DC circuit check. Size C&I; source circuits and routes for ampacity, voltage drop, loss, containment, reel logistics and combiner output current. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 433.5 \text{ W} \times 1.05 = 455.2 \text{ W}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	433.5 W
K_design	1.05
X_design	455.2 W



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 500.7 \text{ W} - 455.2 \text{ W} = 45.5 \text{ W}$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

433.5 W

worked result

DESIGN

455.2 W

factor 1.05

LIMIT

500.7 W

project criterion

MARGIN

45.5 W

available difference

GCC design note: Compare losses at the design current and conductor temperature. Use conductor resistance at operating temperature and the complete route length for every DC circuit check. Size C&I; source circuits and routes for ampacity, voltage drop, loss, containment, reel logistics and combiner output current. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I INSTALLED DC CABLE ROUTE

FORMULA

$$L_{DC} = N_{string} L_{avg} / 1000$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$L_{DC} = 329 \times 35 \text{ m} / 1,000 = 11.52 \text{ km}$$

Calculated result = 11.52 km

C&I PV FIGURE 074



C&I INSTALLED DC CABLE ROUTE

EXAMPLE VALUES

PV strings	329
Average route	35 m



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include positive and negative conductors consistently and use the complete routed length for loss checks. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 11.5 \text{ km} \times 1.10 = 12.7 \text{ km}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	11.5 km
K_design	1.10
X_design	12.7 km



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 13.9 \text{ km} - 12.7 \text{ km} = 1.27 \text{ km}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

11.5 km

worked result

REQUIRED

12.7 km

factor 1.10

SELECTED

13.9 km

project criterion

RESERVE

1.27 km

available difference

GCC design note: Include positive and negative conductors consistently and use the complete routed length for loss checks. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I COMBINER OUTPUT CURRENT

FORMULA

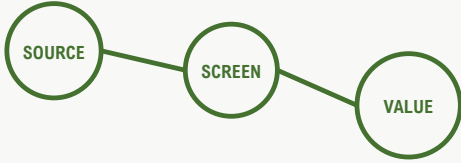
I_out = N_strings x I_sc x 1.25

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

I_out = 24 x 13.8 x 1.25 = 414 A
Calculated result = 414 A

C&I PV FIGURE 075



C&I COMBINER OUTPUT CURRENT

EXAMPLE VALUES

Strings	24
I_sc	13.8 A
Factor	1.25

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Verify connector, busbar, isolator and cable ratings at maximum temperature. Use conductor resistance at operating temperature and the complete route length for every DC circuit check. Size C&I; source circuits and routes for ampacity, voltage drop, loss, containment, reel logistics and combiner output current. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 414 A x 1.10 = 455.4 A

GIVEN VALUES FOR EXAMPLE

X_calculated	414 A
K_design	1.10
X_design	455.4 A

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 500.9 A - 455.4 A = 45.5 A

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

414 A

worked result

REQUIRED

455.4 A

factor 1.10

SELECTED

500.9 A

project criterion

RESERVE

45.5 A

available difference

GCC design note: Verify connector, busbar, isolator and cable ratings at maximum temperature. Use conductor resistance at operating temperature and the complete route length for every DC circuit check. Size C&I; source circuits and routes for ampacity, voltage drop, loss, containment, reel logistics and combiner output current. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I PV STRING FUSE RATING

FORMULA

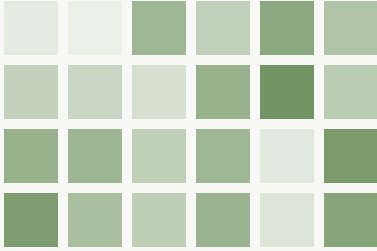
I_fuse,min = 1.25 x I_sc

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

I_fuse,min = 1.25 x 13.8 = 17.3 A
Calculated result = 17.25 A

C&I PV FIGURE 076



C&I PV STRING FUSE RATING

EXAMPLE VALUES

I_sc	13.8 A
Factor	1.25



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: The selected fuse must also remain below the module maximum series-fuse rating. Coordinate module limits, conductor ampacity, protective devices, isolation and surge withstand at maximum DC voltage. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 17.2 A x 1.10 = 19 A

GIVEN VALUES FOR EXAMPLE

X_calculated	17.2 A
K_design	1.10
X_design	19 A



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 20.9 A - 19 A = 1.9 A



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

17.2 A

worked result

REQUIRED

19 A

factor 1.10

SELECTED

20.9 A

project criterion

RESERVE

1.9 A

available difference

GCC design note: The selected fuse must also remain below the module maximum series-fuse rating. Coordinate module limits, conductor ampacity, protective devices, isolation and surge withstand at maximum DC voltage. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I DC ISOLATOR UTILIZATION

FORMULA

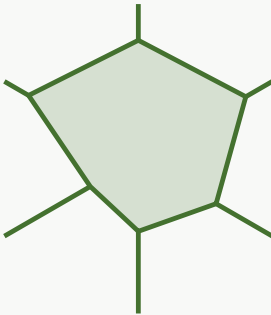
U_I = I_design / I_rated

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

U_I = 21.9 / 32 = 68.4%
Calculated result = 68.44 %

C&I PV FIGURE 077



C&I DC ISOLATOR UTILIZATION

EXAMPLE VALUES

I_design	21.9 A
I_rated	32 A

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Verify the isolator DC utilization category, voltage, polarity, enclosure and ambient derating. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

X_design = X_calculated x K_upper

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 68.4 % x 1.05 = 71.9 %

GIVEN VALUES FOR EXAMPLE

X_calculated	68.4 %
K_design	1.05
X_design	71.9 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

Margin = X_limit - X_design

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 79 % - 71.9 % = 7.19 %

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

68.4 %

worked result

DESIGN

71.9 %

factor 1.05

LIMIT

79 %

project criterion

MARGIN

7.19 %

available difference

GCC design note: Verify the isolator DC utilization category, voltage, polarity, enclosure and ambient derating. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I DC SURGE-DEVICE RATING

FORMULA

$$U_{cpV} \geq 1.20 \times V_{oc,string}$$

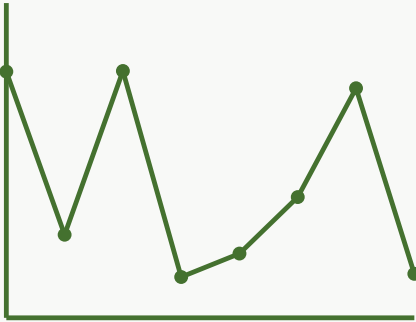
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$U_{cpV} \geq 1.20 \times 1,195 = 1,434 \text{ V}$$

Calculated result = 1,434 V

C&I PV FIGURE 078



C&I DC SURGE-DEVICE RATING

EXAMPLE VALUES

V _{oc,string}	1,195 V
Margin	20%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Coordinate U_{cpV}, protection level and equipment impulse withstand. Coordinate module limits, conductor ampacity, protective devices, isolation and surge withstand at maximum DC voltage. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 1,434 \text{ V} \times 1.10 = 1,577 \text{ V}$$

GIVEN VALUES FOR EXAMPLE

X _{calculated}	1,434 V
K _{design}	1.10
X _{design}	1,577 V



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 1,735 \text{ V} - 1,577 \text{ V} = 157.7 \text{ V}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

1,434 V

worked result

REQUIRED

1,577 V

factor 1.10

SELECTED

1,735 V

project criterion

RESERVE

157.7 V

available difference

GCC design note: Coordinate U_{cpV}, protection level and equipment impulse withstand. Coordinate module limits, conductor ampacity, protective devices, isolation and surge withstand at maximum DC voltage. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I PV INSULATION RESISTANCE

FORMULA

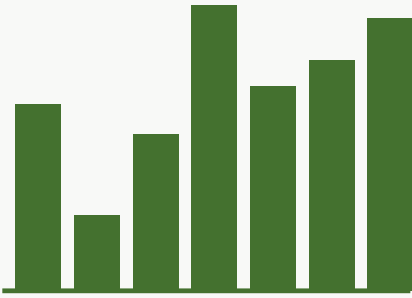
$R_{ins} = V_{test} / I_{leak}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{ins} = 1,000 / (2.5 \times 10^{-6}) = 400.0 \text{ Mohm}$
Calculated result = 400 Mohm

C&I PV FIGURE 079



C&I PV INSULATION RESISTANCE

EXAMPLE VALUES

Test voltage	1,000 V
Leakage current	2.5 uA



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Observe discharge, temperature correction and equipment limits. Coordinate module limits, conductor ampacity, protective devices, isolation and surge withstand at maximum DC voltage. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{design} = X_{calculated} \times K_{conservative}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 400 \text{ Mohm} \times 0.95 = 380 \text{ Mohm}$

GIVEN VALUES FOR EXAMPLE

X_calculated	400 Mohm
K_design	0.95
X_design	380 Mohm



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$Margin = X_{design} - X_{min}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 380 \text{ Mohm} - 342 \text{ Mohm} = 38 \text{ Mohm}$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

400 Mohm

worked result

CONSERVATIVE

380 Mohm

factor 0.95

MINIMUM

342 Mohm

project criterion

MARGIN

38 Mohm

available difference

GCC design note: Observe discharge, temperature correction and equipment limits. Coordinate module limits, conductor ampacity, protective devices, isolation and surge withstand at maximum DC voltage. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE C&I PV BONDING-CONDUCTOR AREA

FORMULA

$$A = I_f \sqrt{t} / k$$

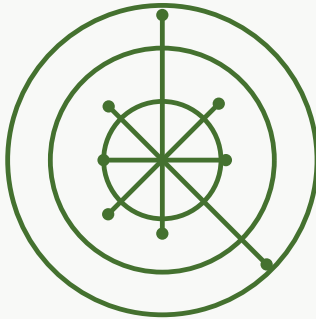
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$A = 25,000 \times \sqrt{1.0} / 143 = 174.8 \text{ mm}^2$$

Calculated result = 174.8 mm2

C&I PV FIGURE 080



C&I PV BONDING-CONDUCTOR AREA

EXAMPLE VALUES

Fault current	25,000 A
Clearing time	1.0 s
Material factor	143

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Select the next standard conductor size after checking mechanical and corrosion allowances. Coordinate module limits, conductor ampacity, protective devices, isolation and surge withstand at maximum DC voltage. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 174.8 \text{ mm}^2 \times 1.10 = 192.3 \text{ mm}^2$$

GIVEN VALUES FOR EXAMPLE

X_calculated	174.8 mm2
K_design	1.10
X_design	192.3 mm2

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 211.5 \text{ mm}^2 - 192.3 \text{ mm}^2 = 19.2 \text{ mm}^2$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

174.8 mm2

worked result

REQUIRED

192.3 mm2

factor 1.10

SELECTED

211.5 mm2

project criterion

RESERVE

19.2 mm2

available difference

GCC design note: Select the next standard conductor size after checking mechanical and corrosion allowances. Coordinate module limits, conductor ampacity, protective devices, isolation and surge withstand at maximum DC voltage. Coordinate C&I; fuses, isolators, interrupting ratings, surge protection, insulation and bonding with fire and maintenance access. Coordinate ampacity, resistance, voltage drop, energy loss, routing, isolation, overcurrent protection, surge protection and bonding.



1 CALCULATE REQUIRED C&I PV INVERTER QUANTITY

FORMULA

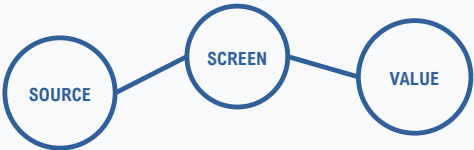
$$N_{inv} = \text{ceil}(P_{ac} / P_{inv})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_{inv} = \text{ceil}(5,000 / 250) = 20$ inverters
Calculated result = 20 inverters

C&I PV FIGURE 081



REQUIRED C&I PV INVERTER QUANTITY

EXAMPLE VALUES

P_ac	5,000 kW
P_inv	250 kW

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Consider maintenance redundancy and block transformer arrangement. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 20 \text{ inverters} \times 1.10 = 22 \text{ inverters}$

GIVEN VALUES FOR EXAMPLE

X_calculated	20 inverters
K_design	1.10
X_design	22 inverters

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 25 \text{ inverters} - 22 \text{ inverters} = 3 \text{ inverters}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

20 inverters

worked result

REQUIRED

22 inverters

factor 1.10

SELECTED

25 inverters

project criterion

RESERVE

3 inverters

available difference

GCC design note: Consider maintenance redundancy and block transformer arrangement. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I INVERTER DC INPUT CURRENT

FORMULA

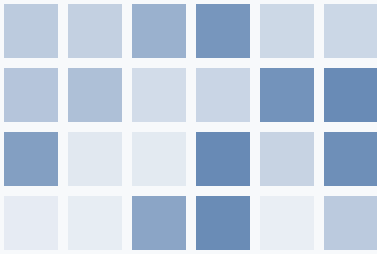
I_in = P_out / (V_in eta)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

I_in = 500 kW / (900 V x 0.96) = 578.7 A
Calculated result = 578.7 A

C&I PV FIGURE 082



C&I INVERTER DC INPUT CURRENT

EXAMPLE VALUES

Output power	500 kW
Input voltage	900 V
Efficiency	96%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Rate cables and switches for ripple and transient current. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 578.7 A x 1.10 = 636.6 A

GIVEN VALUES FOR EXAMPLE

X_calculated	578.7 A
K_design	1.10
X_design	636.6 A

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 700.2 A - 636.6 A = 63.7 A

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

578.7 A

worked result

REQUIRED

636.6 A

factor 1.10

SELECTED

700.2 A

project criterion

RESERVE

63.7 A

available difference

GCC design note: Rate cables and switches for ripple and transient current. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I INVERTER AC OUTPUT CURRENT

FORMULA

$$I_{AC} = P / (\sqrt{3} \times V_{LL} \times PF \times \eta)$$

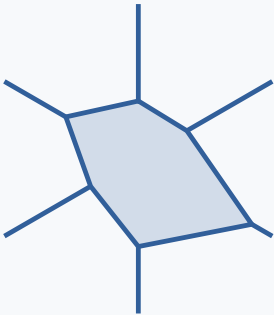
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$I_{AC} = 2 \text{ MW} / (\sqrt{3} \times 690 \times 0.98 \times 0.97) = 1,758 \text{ A}$$

Calculated result = 1,760.4 A

C&I PV FIGURE 083



C&I INVERTER AC OUTPUT CURRENT

EXAMPLE VALUES

Power	2 MW
Line voltage	690 V
Power factor	0.98
Efficiency	97%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check continuous, overload and harmonic RMS current. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 1,760 \text{ A} \times 1.10 = 1,936 \text{ A}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	1,760 A
K_design	1.10
X_design	1,936 A



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 2,130 \text{ A} - 1,936 \text{ A} = 193.6 \text{ A}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

1,760 A

worked result

REQUIRED

1,936 A

factor 1.10

SELECTED

2,130 A

project criterion

RESERVE

193.6 A

available difference

GCC design note: Check continuous, overload and harmonic RMS current. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I INVERTER CONVERSION EFFICIENCY

FORMULA

$$\text{eta_inv} = \text{P_AC} / \text{P_DC}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

eta_inv = 980 kW / 1,000 kW = 98.0%
Calculated result = 98 %

C&I PV FIGURE 084



C&I INVERTER CONVERSION EFFICIENCY

EXAMPLE VALUES

AC output	980 kW
DC input	1,000 kW

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include cooling and internal auxiliaries according to the test boundary. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$\text{X_design} = \text{X_calculated} \times \text{K_conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 98 % x 0.95 = 93.1 %

GIVEN VALUES FOR EXAMPLE

X_calculated	98 %
K_design	0.95
X_design	93.1 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = \text{X_design} - \text{X_min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 93.1 % - 83.8 % = 9.31 %

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

98 %

worked result

CONSERVATIVE

93.1 %

factor 0.95

MINIMUM

83.8 %

project criterion

MARGIN

9.31 %

available difference

GCC design note: Include cooling and internal auxiliaries according to the test boundary. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE LOAD-WEIGHTED C&I INVERTER EFFICIENCY

FORMULA

$$\eta_w = \sum(w_i \eta_i)$$

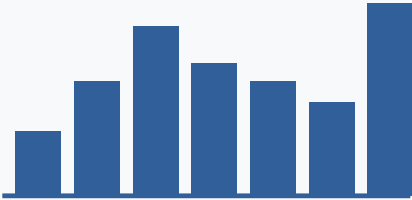
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$\eta_w = 0.05 \times 92 + 0.20 \times 96.5 + 0.30 \times 98 + 0.30 \times 98.5 + 0.15 \times 98.2 = 97.59\%$$

Calculated result = 97.58 %

C&I PV FIGURE 085



LOAD-WEIGHTED C&I INVERTER EFFICIENCY

EXAMPLE VALUES

Low load	5% at 92%
Mid load	50% at 96.5-98%
High load	45% at 98.2-98.5%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Weights must represent the intended operating profile. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 97.6\% \times 0.95 = 92.7\%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	97.6 %
K_design	0.95
X_design	92.7 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{\text{design}} - X_{\text{min}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 92.7\% - 83.4\% = 9.27\%$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

97.6 %

worked result

CONSERVATIVE

92.7 %

factor 0.95

MINIMUM

83.4 %

project criterion

MARGIN

9.27 %

available difference

GCC design note: Weights must represent the intended operating profile. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I INVERTER MODULATION INDEX

FORMULA

$$m_a = 2 \sqrt{2} \, V_{LL} / (\sqrt{3} \, V_{DC})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$m_a = 2\sqrt{2} \times 690 / (\sqrt{3} \times 1,200) = 0.939$$

Calculated result = 0.939 ratio

C&I PV FIGURE 086



C&I INVERTER MODULATION INDEX

EXAMPLE VALUES

Line voltage	690 V
DC voltage	1,200 V



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Keep sinusoidal PWM within its linear modulation range. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 0.939 \text{ ratio} \times 0.95 = 0.892 \text{ ratio}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.939 ratio
K_design	0.95
X_design	0.892 ratio



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{\text{design}} - X_{\text{min}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 0.892 \text{ ratio} - 0.803 \text{ ratio} = 0.089 \text{ ratio}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

0.939 ratio

worked result

CONSERVATIVE

0.892 ratio

factor 0.95

MINIMUM

0.803 ratio

project criterion

MARGIN

0.089 ratio

available difference

GCC design note: Keep sinusoidal PWM within its linear modulation range. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I INVERTER MPPT CONDITION

FORMULA

$$\text{abs}(dI/dV) = I/V \text{ at MPP}$$

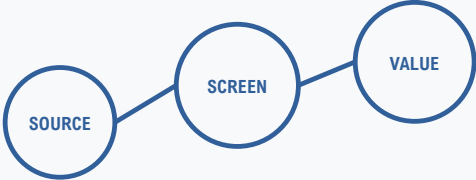
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$\text{abs}(dI/dV) = 12.4 \text{ A} / 41.5 \text{ V} = 0.299 \text{ A/V}$$

Calculated result = 0.2988 A/V magnitude

C&I PV FIGURE 087



C&I INVERTER MPPT CONDITION

EXAMPLE VALUES

MPP current	12.4 A
MPP voltage	41.5 V



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: The actual derivative is negative; filter measurement noise before applying the slope criterion. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 0.299 \text{ A/V magnitude} \times 1.10 = \mathbf{0.329 \text{ A/V magnitude}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.299 A/V magnitude
K_design	1.10
X_design	0.329 A/V magnitude



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 0.362 \text{ A/V magnitude} - 0.329 \text{ A/V magnitude} = \mathbf{0.033 \text{ A/V magnitude}}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

0.299 A/V magnitude

worked result

REQUIRED

0.329 A/V magnitude

factor 1.10

SELECTED

0.362 A/V magnitude

project criterion

RESERVE

0.033 A/V magnitude

available difference

GCC design note: The actual derivative is negative; filter measurement noise before applying the slope criterion. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I PV INVERTER CLIPPING LOSS

FORMULA

$$L_{clip} = (E_{potential} - E_{actual}) / E_{potential}$$

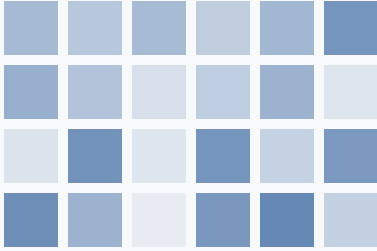
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$L_{clip} = (32.0 - 30.5) / 32.0 = 4.69\%$$

Calculated result = 4.688 %

C&I PV FIGURE 088



C&I PV INVERTER CLIPPING LOSS

EXAMPLE VALUES

E_potential	32.0 MWh
E_actual	30.5 MWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use high-resolution simulation to capture seasonal clipping accurately. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 4.69 \% \times 1.05 = \mathbf{4.92 \%}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	4.69 %
K_design	1.05
X_design	4.92 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 5.41 \% - 4.92 \% = \mathbf{0.492 \%}$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

4.69 %

worked result

DESIGN

4.92 %

factor 1.05

LIMIT

5.41 %

project criterion

MARGIN

0.492 %

available difference

GCC design note: Use high-resolution simulation to capture seasonal clipping accurately. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I INVERTER REACTIVE CAPABILITY

FORMULA

$$Q_{\text{max}} = \sqrt{S^2 - P^2}$$

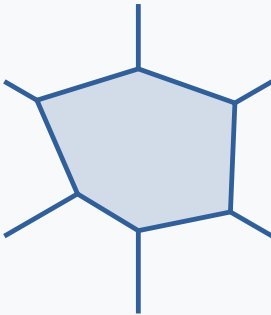
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$Q_{\text{max}} = \sqrt{5.5^2 - 5.0^2} = 2.29 \text{ MVar}$$

Calculated result = 2.291 MVar

C&I PV FIGURE 089



C&I INVERTER REACTIVE CAPABILITY

EXAMPLE VALUES

S	5.5 MVA
P	5.0 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Capability curves can reduce reactive output at temperature and voltage limits. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 2.29 \text{ MVar} \times 1.10 = \mathbf{2.52 \text{ MVar}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	2.29 MVar
K_design	1.10
X_design	2.52 MVar



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 2.77 \text{ MVar} - 2.52 \text{ MVar} = \mathbf{0.252 \text{ MVar}}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

2.29 MVar

worked result

REQUIRED

2.52 MVar

factor 1.10

SELECTED

2.77 MVar

project criterion

RESERVE

0.252 MVar

available difference

GCC design note: Capability curves can reduce reactive output at temperature and voltage limits. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I INVERTER JUNCTION TEMPERATURE

FORMULA

T_j = T_case + P_loss R_theta,jc

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

T_j = 72 C + 850 W x 0.035 C/W = 101.75 C
Calculated result = 101.8 C

C&I PV FIGURE 090



C&I INVERTER JUNCTION TEMPERATURE

EXAMPLE VALUES

Case temperature	72 C
Loss	850 W
Thermal resistance	0.035 C/W

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check transient thermal impedance for cyclic loads. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

X_design = X_calculated x K_upper

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 101.8 C x 1.05 = 106.8 C

GIVEN VALUES FOR EXAMPLE

X_calculated	101.8 C
K_design	1.05
X_design	106.8 C

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

Margin = X_limit - X_design

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 117.5 C - 106.8 C = 10.7 C

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

101.8 C

worked result

DESIGN

106.8 C

factor 1.05

LIMIT

117.5 C

project criterion

MARGIN

10.7 C

available difference

GCC design note: Check transient thermal impedance for cyclic loads. Check inverter operation across the full DC voltage, current, temperature and grid-voltage envelope. Select C&I; inverters for DC window, AC current, efficiency, clipping, reactive capability, heat rejection, access and acoustic constraints. Select inverter quantity, current ratings, conversion performance, MPPT behavior, clipping, reactive capability and thermal limits.



1 CALCULATE C&I INVERTER THREE-PHASE POWER

FORMULA

$$P = \sqrt{3} \, V \, I \, PF$$

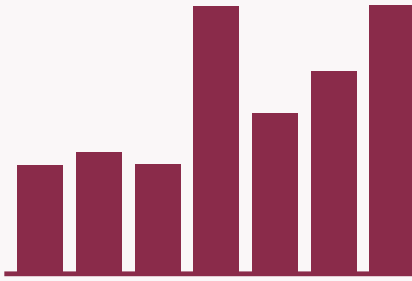
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P = \sqrt{3} \times 33 \, \text{kV} \times 500 \, \text{A} \times 0.95 = 27.1 \, \text{MW}$$

Calculated result = 27.15 MW

C&I PV FIGURE 091



C&I INVERTER THREE-PHASE POWER

EXAMPLE VALUES

V	33 kV
I	500 A
PF	0.95

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use line-to-line voltage and line current for this equation. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 27.1 \, \text{MW} \times 1.10 = \mathbf{29.9 \, \text{MW}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	27.1 MW
K_design	1.10
X_design	29.9 MW

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 32.9 \, \text{MW} - 29.9 \, \text{MW} = \mathbf{2.99 \, \text{MW}}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

27.1 MW

worked result

REQUIRED

29.9 MW

factor 1.10

SELECTED

32.9 MW

project criterion

RESERVE

2.99 MW

available difference

GCC design note: Use line-to-line voltage and line current for this equation. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I PV FEEDER CURRENT FROM MVA

FORMULA

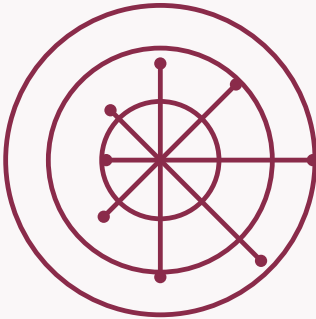
I = S / (sqrt(3) V)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

I = 40 MVA / (sqrt(3) x 33 kV) = 700 A
Calculated result = 699.8 A

C&I PV FIGURE 092



C&I PV FEEDER CURRENT FROM MVA

EXAMPLE VALUES

S	40 MVA
V	33 kV

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check continuous and emergency ratings of all series equipment. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 699.8 A x 1.10 = 769.8 A

GIVEN VALUES FOR EXAMPLE

X_calculated	699.8 A
K_design	1.10
X_design	769.8 A

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 846.8 A - 769.8 A = 77 A

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

699.8 A

worked result

REQUIRED

769.8 A

factor 1.10

SELECTED

846.8 A

project criterion

RESERVE

77 A

available difference

GCC design note: Check continuous and emergency ratings of all series equipment. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I PV FEEDER VOLTAGE DROP

FORMULA

$\Delta V = \sqrt{3} \times I \times L (R \cos\phi + X \sin\phi)$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$\Delta V = \sqrt{3} \times 180 \times 0.095 \times (0.195 \times 0.90 + 0.080 \times 0.436) = 6.23 \text{ V}$
Calculated result = 6.231 V

C&I PV FIGURE 093



C&I PV FEEDER VOLTAGE DROP

EXAMPLE VALUES

I	180 A
L	0.095 km
R	0.195 ohm/km
X	0.080 ohm/km

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include source and transformer impedance where required by the study. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 6.23 \text{ V} \times 1.10 = 6.85 \text{ V}$

GIVEN VALUES FOR EXAMPLE

X_calculated	6.23 V
K_design	1.10
X_design	6.85 V

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 7.54 \text{ V} - 6.85 \text{ V} = 0.685 \text{ V}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

6.23 V

worked result

REQUIRED

6.85 V

factor 1.10

SELECTED

7.54 V

project criterion

RESERVE

0.685 V

available difference

GCC design note: Include source and transformer impedance where required by the study. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I PV FEEDER POWER LOSS

FORMULA

$$P_{loss} = 3 I^2 R L$$

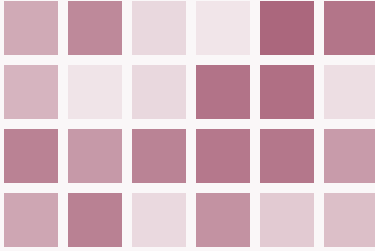
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{loss} = 3 \times 180^2 \times 0.195 \times 0.095 = 1.80 \text{ kW}$$

Calculated result = 1.801 kW

C&I PV FIGURE 094



C&I PV FEEDER POWER LOSS

EXAMPLE VALUES

I	180 A
R	0.195 ohm/km
L	0.095 km

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use AC resistance including temperature and skin-effect corrections. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 1.8 \text{ kW} \times 1.10 = 1.98 \text{ kW}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	1.8 kW
K_design	1.10
X_design	1.98 kW

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 2.18 \text{ kW} - 1.98 \text{ kW} = 0.198 \text{ kW}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

1.8 kW

worked result

REQUIRED

1.98 kW

factor 1.10

SELECTED

2.18 kW

project criterion

RESERVE

0.198 kW

available difference

GCC design note: Use AC resistance including temperature and skin-effect corrections. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I PV DISTRIBUTION TRANSFORMER RATING

FORMULA

$$S_{tr} = P_{ac} / (PF \times \eta_{tr})$$

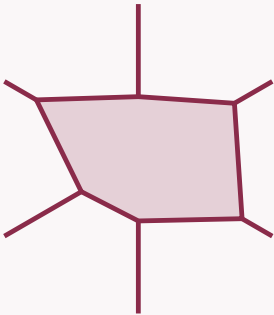
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$S_{tr} = 5,000 / (0.98 \times 0.99) = 5,153 \text{ kVA}$$

Calculated result = 5,153.6 kVA

C&I PV FIGURE 095



C&I PV DISTRIBUTION TRANSFORMER RATING

EXAMPLE VALUES

P_ac	5,000 kW
PF	0.98
eta_tr	99%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include harmonic heating, ambient-temperature derating and future overload criteria. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 5,154 \text{ kVA} \times 1.10 = 5,669 \text{ kVA}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	5,154 kVA
K_design	1.10
X_design	5,669 kVA

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 6,236 \text{ kVA} - 5,669 \text{ kVA} = 566.9 \text{ kVA}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

5,154 kVA

worked result

REQUIRED

5,669 kVA

factor 1.10

SELECTED

6,236 kVA

project criterion

RESERVE

566.9 kVA

available difference

GCC design note: Include harmonic heating, ambient-temperature derating and future overload criteria. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I TRANSFORMER LV CURRENT

FORMULA

$I = S / (\text{sqrt}(3) \text{ V_LV})$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$I = 50 \text{ MVA} / (\text{sqrt}(3) \times 0.4 \text{ kV}) = 72.2 \text{ kA}$
Calculated result = 72.17 kA

C&I PV FIGURE 096



C&I TRANSFORMER LV CURRENT

EXAMPLE VALUES

S	50 MVA
V_LV	0.4 kV

i

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: A 50 MVA transformer at 400 V is unusual; verify the selected voltage level. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 72.2 \text{ kA} \times 1.10 = 79.4 \text{ kA}$

GIVEN VALUES FOR EXAMPLE

X_calculated	72.2 kA
K_design	1.10
X_design	79.4 kA

i

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 87.3 \text{ kA} - 79.4 \text{ kA} = 7.94 \text{ kA}$

i

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

i

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK

SUMMARY

CALCULATED

72.2 kA

worked result

REQUIRED

79.4 kA

factor 1.10

SELECTED

87.3 kA

project criterion

RESERVE

7.94 kA

available difference

GCC design note: A 50 MVA transformer at 400 V is unusual; verify the selected voltage level. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I TRANSFORMER FAULT CURRENT

FORMULA

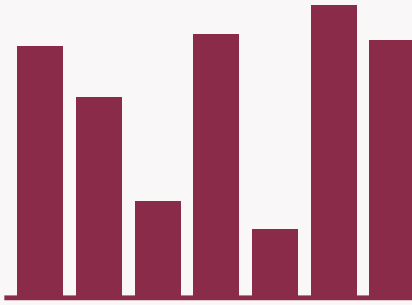
$I_{sc} = S_{rated} / (\sqrt{3}) V Z_{pu}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$I_{sc} = 50 \text{ MVA} / (\sqrt{3}) \times 33 \text{ kV} \times 0.10 = 8.75 \text{ kA}$
Calculated result = 8.748 kA

C&I PV FIGURE 097



C&I TRANSFORMER FAULT CURRENT

EXAMPLE VALUES

S	50 MVA
V	33 kV
Z	10%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add upstream source impedance and motor contribution for a complete study. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{design} = X_{calculated} \times K_{upper}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 8.75 \text{ kA} \times 1.05 = 9.19 \text{ kA}$

GIVEN VALUES FOR EXAMPLE

X_calculated	8.75 kA
K_design	1.05
X_design	9.19 kA

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$Margin = X_{limit} - X_{design}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 10.1 \text{ kA} - 9.19 \text{ kA} = 0.919 \text{ kA}$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

8.75 kA

worked result

DESIGN

9.19 kA

factor 1.05

LIMIT

10.1 kA

project criterion

MARGIN

0.919 kA

available difference

GCC design note: Add upstream source impedance and motor contribution for a complete study. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I PV TRANSFORMER EFFICIENCY

FORMULA

$$\text{eta} = \text{P_out}/(\text{P_out}+\text{P_loss})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$\text{eta} = 18.5/(18.5+0.24) = 98.72\%$$

Calculated result = 98.72 %

C&I PV FIGURE 098



C&I PV TRANSFORMER EFFICIENCY

EXAMPLE VALUES

Output	18.5 MW
Total loss	0.24 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Separate load loss and no-load loss for duty-cycle studies. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$\text{X_design} = \text{X_calculated} \times \text{K_conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$\text{X_design} = 98.7 \% \times 0.95 = \textbf{93.8 \%}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	98.7 %
K_design	0.95
X_design	93.8 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = \text{X_design} - \text{X_min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 93.8 \% - 84.4 \% = \textbf{9.38 \%}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

98.7 %

worked result

CONSERVATIVE

93.8 %

factor 0.95

MINIMUM

84.4 %

project criterion

MARGIN

9.38 %

available difference

GCC design note: Separate load loss and no-load loss for duty-cycle studies. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I PV TRANSFORMER REGULATION

FORMULA

$$VR = R_{pu} PF + X_{pu} \sin(\phi)$$

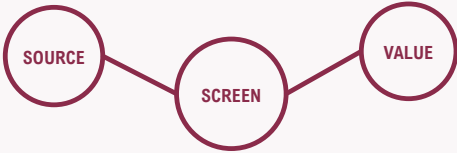
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$VR = 0.012 \times 0.90 + 0.078 \times 0.436 = 4.480\%$$

Calculated result = 4.48 %

C&I PV FIGURE 099



C&I PV TRANSFORMER REGULATION

EXAMPLE VALUES

R 0.012 pu

X 0.078 pu

Power factor 0.90 lag

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the appropriate sign for leading power factor. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 4.48\% \times 1.05 = 4.7\%$$

GIVEN VALUES FOR EXAMPLE

X_calculated 4.48 %

K_design 1.05

X_design 4.7 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 5.17\% - 4.7\% = 0.47\%$$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

4.48 %

worked result

DESIGN

4.7 %

factor 1.05

LIMIT

5.17 %

project criterion

MARGIN

0.47 %

available difference

GCC design note: Use the appropriate sign for leading power factor. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I PV TRANSFORMER QUANTITY

FORMULA

$$N_{tx} = \text{ceil}(P_{AC}/P_{tx})$$

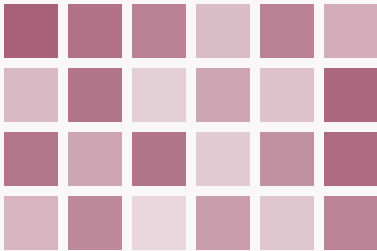
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$N_{tx} = \text{ceil}(180 \text{ MW} / 4.5 \text{ MW}) = 40 \text{ transformers}$$

Calculated result = 40 transformers

C&I PV FIGURE 100



C&I PV TRANSFORMER QUANTITY

EXAMPLE VALUES

Plant power	180 MW
Transformer block	4.5 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Coordinate spare philosophy and feeder segmentation. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 40 \text{ transformers} \times 1.10 = \textbf{44 transformers}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	40 transformers
K_design	1.10
X_design	44 transformers



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 48.4 \text{ transformers} - 44 \text{ transformers} = \textbf{4.4 transformers}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

40 transformers

worked result

REQUIRED

44 transformers

factor 1.10

SELECTED

48.4 transformers

project criterion

RESERVE

4.4 transformers

available difference

GCC design note: Coordinate spare philosophy and feeder segmentation. Apply operating-temperature impedances, harmonic duty and credible overload conditions to the AC collection design. Coordinate inverter outputs, AC feeders, distribution boards and transformers with the facility voltage, fault level and operating duty. Integrate inverter feeders with the facility distribution system using verified currents, voltage drop, losses, transformer duty and fault levels.



1 CALCULATE C&I PV BLOCK TRANSFORMER DESIGN RATING

FORMULA

$$S_{tr} = P_{ac} / (PF \times \eta_{tr})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$S_{tr} = 5,000 / (0.98 \times 0.99) = 5,153 \text{ kVA}$$

Calculated result = 5,153.6 kVA

C&I PV FIGURE 101



C&I PV BLOCK TRANSFORMER DESIGN RATING

EXAMPLE VALUES

P_ac	5,000 kW
PF	0.98
eta_tr	99%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include harmonic heating, ambient-temperature derating and future overload criteria. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 5,154 \text{ kVA} \times 1.10 = 5,669 \text{ kVA}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	5,154 kVA
K_design	1.10
X_design	5,669 kVA

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 6,236 \text{ kVA} - 5,669 \text{ kVA} = 566.9 \text{ kVA}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

5,154 kVA

worked result

REQUIRED

5,669 kVA

factor 1.10

SELECTED

6,236 kVA

project criterion

RESERVE

566.9 kVA

available difference

GCC design note: Include harmonic heating, ambient-temperature derating and future overload criteria. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I EXISTING TRANSFORMER DESIGN RATING

FORMULA

$$S = P / (PF \times \eta)$$

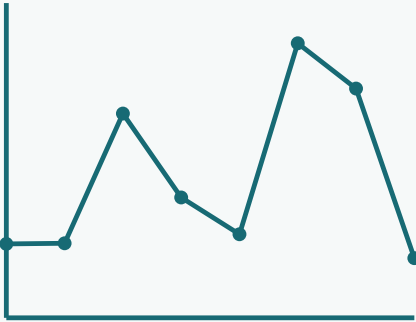
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$S = 36 / (0.98 \times 0.99) = 37.1 \text{ MVA}$$

Calculated result = 37.11 MVA

C&I PV FIGURE 102



C&I EXISTING TRANSFORMER DESIGN RATING

EXAMPLE VALUES

P	36 MW
PF	0.98
eta	99%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Evaluate overload, harmonic, ambient and redundancy requirements. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 37.1 \text{ MVA} \times 1.10 = \mathbf{40.8 \text{ MVA}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	37.1 MVA
K_design	1.10
X_design	40.8 MVA



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 44.9 \text{ MVA} - 40.8 \text{ MVA} = \mathbf{4.08 \text{ MVA}}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

37.1 MVA

worked result

REQUIRED

40.8 MVA

factor 1.10

SELECTED

44.9 MVA

project criterion

RESERVE

4.08 MVA

available difference

GCC design note: Evaluate overload, harmonic, ambient and redundancy requirements. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I TRANSFORMER FULL-LOAD CURRENT

FORMULA

$$I = S / (\text{sqrt}(3) \text{ V_LV})$$

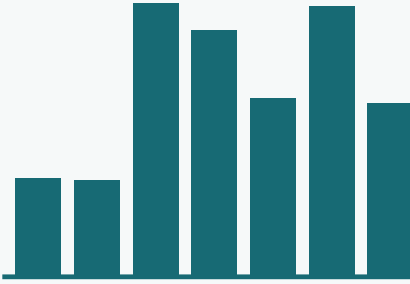
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$I = 50 \text{ MVA} / (\text{sqrt}(3) \times 0.4 \text{ kV}) = 72.2 \text{ kA}$$

Calculated result = 72.17 kA

C&I PV FIGURE 103



C&I TRANSFORMER FULL-LOAD CURRENT

EXAMPLE VALUES

S	50 MVA
V_LV	0.4 kV



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: A 50 MVA transformer at 400 V is unusual; verify the selected voltage level. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 72.2 \text{ kA} \times 1.10 = 79.4 \text{ kA}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	72.2 kA
K_design	1.10
X_design	79.4 kA



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 87.3 \text{ kA} - 79.4 \text{ kA} = 7.94 \text{ kA}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

72.2 kA

worked result

REQUIRED

79.4 kA

factor 1.10

SELECTED

87.3 kA

project criterion

RESERVE

7.94 kA

available difference

GCC design note: A 50 MVA transformer at 400 V is unusual; verify the selected voltage level. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I TRANSFORMER TERMINAL FAULT DUTY

FORMULA

$I_{sc} = S_{rated} / (\sqrt{3}) V Z_{pu}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$I_{sc} = 50 \text{ MVA} / (\sqrt{3}) \times 33 \text{ kV} \times 0.10 = 8.75 \text{ kA}$
Calculated result = 8.748 kA

C&I PV FIGURE 104



C&I TRANSFORMER TERMINAL FAULT DUTY

EXAMPLE VALUES

S	50 MVA
V	33 kV
Z	10%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add upstream source impedance and motor contribution for a complete study. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{design} = X_{calculated} \times K_{upper}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 8.75 \text{ kA} \times 1.05 = 9.19 \text{ kA}$

GIVEN VALUES FOR EXAMPLE

X_calculated	8.75 kA
K_design	1.05
X_design	9.19 kA

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$Margin = X_{limit} - X_{design}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 10.1 \text{ kA} - 9.19 \text{ kA} = 0.919 \text{ kA}$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

8.75 kA

worked result

DESIGN

9.19 kA

factor 1.05

LIMIT

10.1 kA

project criterion

MARGIN

0.919 kA

available difference

GCC design note: Add upstream source impedance and motor contribution for a complete study. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I EQUIPMENT PER-UNIT BASE IMPEDANCE

FORMULA

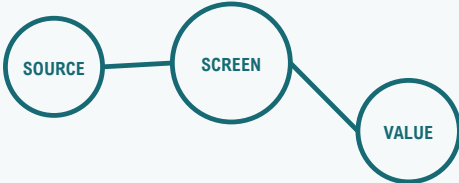
$$Z_{base} = V_{base}^2 / S_{base}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$Z_{base} = 33^2 / 100 = 10.89 \text{ ohm}$
Calculated result = 10.89 ohm

C&I PV FIGURE 105



C&I EQUIPMENT PER-UNIT BASE IMPEDANCE

EXAMPLE VALUES

V_base	33 kV
S_base	100 MVA



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use consistent three-phase MVA and line-to-line kV bases. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 10.9 \text{ ohm} \times 1.10 = 12 \text{ ohm}$

GIVEN VALUES FOR EXAMPLE

X_calculated	10.9 ohm
K_design	1.10
X_design	12 ohm



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 13.2 \text{ ohm} - 12 \text{ ohm} = 1.2 \text{ ohm}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

10.9 ohm

worked result

REQUIRED

12 ohm

factor 1.10

SELECTED

13.2 ohm

project criterion

RESERVE

1.2 ohm

available difference

GCC design note: Use consistent three-phase MVA and line-to-line kV bases. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I SWITCHGEAR INTERRUPTING DUTY

FORMULA

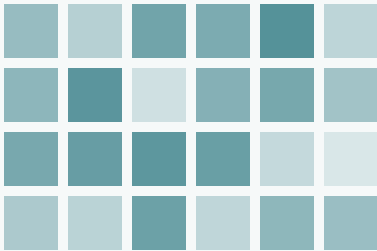
$I_{break} = S_{sc} / (\sqrt{3}V)$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$I_{break} = 500 \text{ MVA} / (\sqrt{3} \times 33 \text{ kV}) = 8.75 \text{ kA}$
Calculated result = 8.748 kA

C&I PV FIGURE 106



C&I SWITCHGEAR INTERRUPTING DUTY

EXAMPLE VALUES

S_sc	500 MVA
V	33 kV



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Account for X/R ratio and required asymmetrical making current. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{design} = X_{calculated} \times K_{upper}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 8.75 \text{ kA} \times 1.05 = 9.19 \text{ kA}$

GIVEN VALUES FOR EXAMPLE

X_calculated	8.75 kA
K_design	1.05
X_design	9.19 kA



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$Margin = X_{limit} - X_{design}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 10.1 \text{ kA} - 9.19 \text{ kA} = 0.919 \text{ kA}$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

8.75 kA

worked result

DESIGN

9.19 kA

factor 1.05

LIMIT

10.1 kA

project criterion

MARGIN

0.919 kA

available difference

GCC design note: Account for X/R ratio and required asymmetrical making current. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I CAPACITOR-BANK DESIGN CURRENT

FORMULA

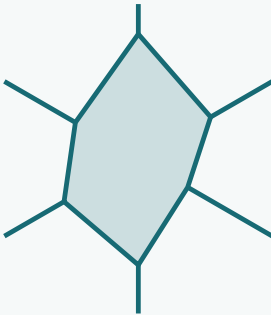
I_c = Q / (sqrt(3)V)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

I_c = 10 MVar / (sqrt(3)x33 kV) = 175 A
Calculated result = 175 A

C&I PV FIGURE 107



C&I CAPACITOR-BANK DESIGN CURRENT

EXAMPLE VALUES

Q	10 MVar
V	33 kV



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Rate capacitor equipment for harmonic and voltage tolerances. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 175 A x 1.10 = 192.5 A

GIVEN VALUES FOR EXAMPLE

X_calculated	175 A
K_design	1.10
X_design	192.5 A



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 211.7 A - 192.5 A = 19.2 A



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK

SUMMARY

CALCULATED

175 A

worked result

REQUIRED

192.5 A

factor 1.10

SELECTED

211.7 A

project criterion

RESERVE

19.2 A

available difference

GCC design note: Rate capacitor equipment for harmonic and voltage tolerances. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I NEUTRAL-GROUNDING RESISTOR VALUE

FORMULA

$$R_NGR = V_phase / I_g$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$R_NGR = (11 \text{ kV}/\sqrt{3}) / 10 \text{ A} = 635 \text{ ohm}$$

Calculated result = 635.1 ohm

C&I PV FIGURE 108



C&I NEUTRAL-GROUNDING RESISTOR VALUE

EXAMPLE VALUES

V_LL	11 kV
I_g	10 A



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Select time rating and insulation level for the grounding method. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_required = X_calculated \times K_design$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 635.1 \text{ ohm} \times 1.10 = 698.6 \text{ ohm}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	635.1 ohm
K_design	1.10
X_design	698.6 ohm



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_selected - X_required$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 768.5 \text{ ohm} - 698.6 \text{ ohm} = 69.9 \text{ ohm}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

635.1 ohm

worked result

REQUIRED

698.6 ohm

factor 1.10

SELECTED

768.5 ohm

project criterion

RESERVE

69.9 ohm

available difference

GCC design note: Select time rating and insulation level for the grounding method. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I MAIN TRANSFORMER QUANTITY

FORMULA

$$N_{tx} = \text{ceil}(P_{AC}/P_{tx})$$

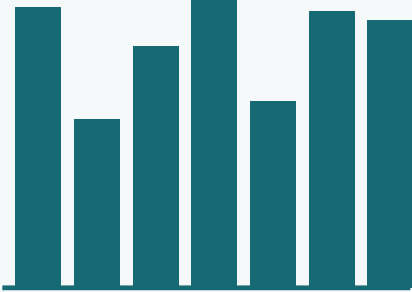
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$N_{tx} = \text{ceil}(180 \text{ MW} / 4.5 \text{ MW}) = 40 \text{ transformers}$$

Calculated result = 40 transformers

C&I PV FIGURE 109



C&I MAIN TRANSFORMER QUANTITY

EXAMPLE VALUES

Plant power	180 MW
Transformer block	4.5 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Coordinate spare philosophy and feeder segmentation. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 40 \text{ transformers} \times 1.10 = \textbf{44 transformers}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	40 transformers
K_design	1.10
X_design	44 transformers



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 48.4 \text{ transformers} - 44 \text{ transformers} = \textbf{4.4 transformers}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

40 transformers

worked result

REQUIRED

44 transformers

factor 1.10

SELECTED

48.4 transformers

project criterion

RESERVE

4.4 transformers

available difference

GCC design note: Coordinate spare philosophy and feeder segmentation. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I EMERGENCY DC-SYSTEM BATTERY ENERGY

FORMULA

$E_{bat} = P_{load} \times t / \eta$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$E_{bat} = 15 \text{ kW} \times 3 \text{ h} / 0.90 = 50.0 \text{ kWh}$
Calculated result = 50 kWh

C&I PV FIGURE 110



C&I EMERGENCY DC-SYSTEM BATTERY ENERGY

EXAMPLE VALUES

P_load	15 kW
t	3 h
eta	90%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply aging, temperature, minimum voltage and code-required margins. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{required} = X_{calculated} \times K_{design}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 50 \text{ kWh} \times 1.10 = 55 \text{ kWh}$

GIVEN VALUES FOR EXAMPLE

X_calculated	50 kWh
K_design	1.10
X_design	55 kWh

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$Reserve = X_{selected} - X_{required}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 60.5 \text{ kWh} - 55 \text{ kWh} = 5.5 \text{ kWh}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

50 kWh

worked result

REQUIRED

55 kWh

factor 1.10

SELECTED

60.5 kWh

project criterion

RESERVE

5.5 kWh

available difference

GCC design note: Apply aging, temperature, minimum voltage and code-required margins. Apply equipment-specific temperature, harmonic, altitude and duty-cycle derating. Coordinate main transformer, switchgear, capacitor-bank, grounding-resistor and emergency DC duties with the existing facility network.



1 CALCULATE C&I GRID POWER-FACTOR CORRECTION

FORMULA

$$Q_c = P[\tan(\phi_1) - \tan(\phi_2)]$$

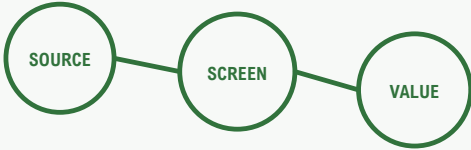
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$Q_c = 20[\tan \cos 0.85 - \tan \cos 0.98] = 8.34 \text{ MVar}$$

Calculated result = 8.334 MVar

C&I PV FIGURE 111



C&I GRID POWER-FACTOR CORRECTION

EXAMPLE VALUES

P	20 MW
PF_1	0.85
PF_2	0.98

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check voltage, harmonics and switching steps before selecting capacitor banks. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 8.33 \text{ MVar} \times 1.10 = \mathbf{9.17 \text{ MVar}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	8.33 MVar
K_design	1.10
X_design	9.17 MVar

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 10.1 \text{ MVar} - 9.17 \text{ MVar} = \mathbf{0.917 \text{ MVar}}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

8.33 MVar

worked result

REQUIRED

9.17 MVar

factor 1.10

SELECTED

10.1 MVar

project criterion

RESERVE

0.917 MVar

available difference

GCC design note: Check voltage, harmonics and switching steps before selecting capacitor banks. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I GRID-SUPPORT REACTIVE CAPABILITY

FORMULA

$$Q_{\text{max}} = \sqrt{S^2 - P^2}$$

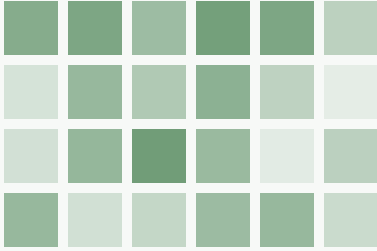
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$Q_{\text{max}} = \sqrt{5.5^2 - 5.0^2} = 2.29 \text{ MVar}$$

Calculated result = 2.291 MVar

C&I PV FIGURE 112



C&I GRID-SUPPORT REACTIVE CAPABILITY

EXAMPLE VALUES

S	5.5 MVA
P	5.0 MW

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Capability curves can reduce reactive output at temperature and voltage limits. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 2.29 \text{ MVar} \times 1.10 = 2.52 \text{ MVar}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	2.29 MVar
K_design	1.10
X_design	2.52 MVar

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 2.77 \text{ MVar} - 2.52 \text{ MVar} = 0.252 \text{ MVar}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

2.29 MVar

worked result

REQUIRED

2.52 MVar

factor 1.10

SELECTED

2.77 MVar

project criterion

RESERVE

0.252 MVar

available difference

GCC design note: Capability curves can reduce reactive output at temperature and voltage limits. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1

CALCULATE C&I POINT-OF-CONNECTION VOLTAGE RISE

FORMULA

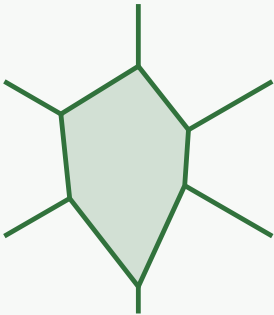
$$\Delta V_{pu} = R_{pu} P_{pu} + X_{pu} Q_{pu}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$\Delta V = 0.020 \times 0.80 + 0.050 \times 0.20 = 2.60\%$
Calculated result = 2.6 %

C&I PV FIGURE 113



C&I POINT-OF-CONNECTION VOLTAGE RISE

EXAMPLE VALUES

R	0.020 pu
X	0.050 pu
P	0.80 pu
Q	0.20 pu



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use full load flow for meshed systems and voltage-dependent controls. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2

APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 2.6\% \times 1.05 = 2.73\%$

GIVEN VALUES FOR EXAMPLE

X_calculated	2.6 %
K_design	1.05
X_design	2.73 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3

CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Margin} = 3\% - 2.73\% = 0.273\%$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

2.6 %

worked result

DESIGN

2.73 %

factor 1.05

LIMIT

3 %

project criterion

MARGIN

0.273 %

available difference

GCC design note: Use full load flow for meshed systems and voltage-dependent controls. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I VOLTAGE-LIMITED EXPORT CAPACITY

FORMULA

$$P_{\text{host}} = (V_{\text{lim}} - V_{\text{base}}) / \text{sensitivity}$$

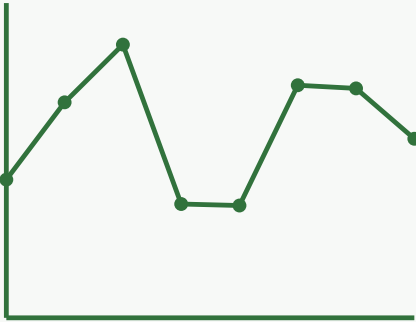
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{\text{host}} = (1.05 - 1.00) / 0.008 = 6.25 \text{ MW}$$

Calculated result = 6.25 MW

C&I PV FIGURE 114



C&I VOLTAGE-LIMITED EXPORT CAPACITY

EXAMPLE VALUES

V_lim	1.05 pu
V_base	1.00 pu
Sensitivity	0.008 pu/MW

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Confirm thermal, fault-level, protection and power-quality limits separately. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 6.25 \text{ MW} \times 1.10 = \mathbf{6.88 \text{ MW}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	6.25 MW
K_design	1.10
X_design	6.88 MW

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 7.56 \text{ MW} - 6.88 \text{ MW} = \mathbf{0.688 \text{ MW}}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

6.25 MW

worked result

REQUIRED

6.88 MW

factor 1.10

SELECTED

7.56 MW

project criterion

RESERVE

0.688 MW

available difference

GCC design note: Confirm thermal, fault-level, protection and power-quality limits separately. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I ACTIVE-POWER RAMP RATE

FORMULA

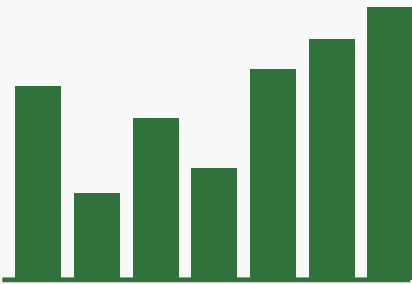
$R = \Delta P / \Delta t$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R = 20 \text{ MW} / 5 \text{ min} = 4.00 \text{ MW/min}$
Calculated result = 4 MW/min

C&I PV FIGURE 115



C&I ACTIVE-POWER RAMP RATE

EXAMPLE VALUES

DeltaP	20 MW
Delta t	5 min



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply both upward and downward grid-code ramp limits. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 4 \text{ MW/min} \times 1.10 = \mathbf{4.4 \text{ MW/min}}$

GIVEN VALUES FOR EXAMPLE

X_calculated	4 MW/min
K_design	1.10
X_design	4.4 MW/min



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 4.84 \text{ MW/min} - 4.4 \text{ MW/min} = \mathbf{0.44 \text{ MW/min}}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

4 MW/min

worked result

REQUIRED

4.4 MW/min

factor 1.10

SELECTED

4.84 MW/min

project criterion

RESERVE

0.44 MW/min

available difference

GCC design note: Apply both upward and downward grid-code ramp limits. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I GRID-CURTAILMENT ALLOWANCE

FORMULA

$E_{\text{curt}} = P_{\text{curt}} \times t$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$E_{\text{curt}} = 3 \text{ MW} \times 180 \text{ h} = 540 \text{ MWh}$
Calculated result = 540 MWh

C&I PV FIGURE 116



C&I GRID-CURTAILMENT ALLOWANCE

EXAMPLE VALUES

P_curt	3 MW
t	180 h



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use interval data when curtailment power varies with time. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{upper}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 540 \text{ MWh} \times 1.05 = 567 \text{ MWh}$

GIVEN VALUES FOR EXAMPLE

X_calculated	540 MWh
K_design	1.05
X_design	567 MWh



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$\text{Margin} = X_{\text{limit}} - X_{\text{design}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Margin} = 623.7 \text{ MWh} - 567 \text{ MWh} = 56.7 \text{ MWh}$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

540 MWh

worked result

DESIGN

567 MWh

factor 1.05

LIMIT

623.7 MWh

project criterion

MARGIN

56.7 MWh

available difference

GCC design note: Use interval data when curtailment power varies with time. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I FREQUENCY-DROOP RESPONSE

FORMULA

$$\Delta P = P_{\text{rated}} \Delta f / (R_d f_n)$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$\Delta P = 100 \times 0.2 / (0.05 \times 50) = 8.0 \text{ MW}$
Calculated result = 8 MW

C&I PV FIGURE 117



C&I FREQUENCY-DROOP RESPONSE

EXAMPLE VALUES

P _{rated}	100 MW
Δf	0.2 Hz
R _d	5%
f _n	50 Hz

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Available headroom limits upward active-power response. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 8 \text{ MW} \times 1.10 = \mathbf{8.8 \text{ MW}}$

GIVEN VALUES FOR EXAMPLE

X _{calculated}	8 MW
K _{design}	1.10
X _{design}	8.8 MW

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 9.68 \text{ MW} - 8.8 \text{ MW} = \mathbf{0.88 \text{ MW}}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

8 MW

worked result

REQUIRED

8.8 MW

factor 1.10

SELECTED

9.68 MW

project criterion

RESERVE

0.88 MW

available difference

GCC design note: Available headroom limits upward active-power response. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I GRID SHORT-CIRCUIT RATIO

FORMULA

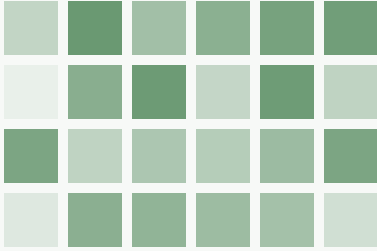
SCR = S_sc / P_plant

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

SCR = 1,500 MVA / 200 MW = 7.50
Calculated result = 7.5 ratio

C&I PV FIGURE 118



C&I GRID SHORT-CIRCUIT RATIO

EXAMPLE VALUES

S_sc	1,500 MVA
P_plant	200 MW

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Converter controls and grid-code definitions may use weighted or effective SCR. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 7.5 ratio x 0.95 = 7.12 ratio

GIVEN VALUES FOR EXAMPLE

X_calculated	7.5 ratio
K_design	0.95
X_design	7.12 ratio

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 7.12 ratio - 6.41 ratio = 0.712 ratio

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

7.5 ratio

worked result

CONSERVATIVE

7.12 ratio

factor 0.95

MINIMUM

6.41 ratio

project criterion

MARGIN

0.712 ratio

available difference

GCC design note: Converter controls and grid-code definitions may use weighted or effective SCR. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I PV CURRENT HARMONIC DISTORTION

FORMULA

$$THD_I = \sqrt{\sum I_h^2} / I_1$$

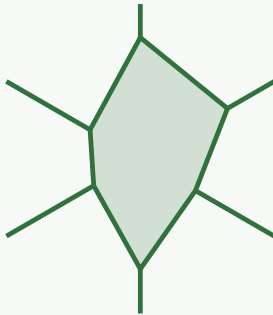
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$THD_I = \sqrt{8^2 + 5^2 + 3^2} / 100 = 9.90\%$$

Calculated result = 9.899 %

C&I PV FIGURE 119



C&I PV CURRENT HARMONIC DISTORTION

EXAMPLE VALUES

L_1	100 A
L_5	8 A
L_7	5 A
L_11	3 A



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply the adopted standard at the specified assessment point and loading. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 9.9 \% \times 1.05 = \mathbf{10.4 \%}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	9.9 %
K_design	1.05
X_design	10.4 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 11.4 \% - 10.4 \% = \mathbf{1.04 \%}$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

9.9 %

worked result

DESIGN

10.4 %

factor 1.05

LIMIT

11.4 %

project criterion

MARGIN

1.04 %

available difference

GCC design note: Apply the adopted standard at the specified assessment point and loading. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I PV VOLTAGE HARMONIC DISTORTION

FORMULA

$$THD_V = \sqrt{\sum V_h^2} / V_1$$

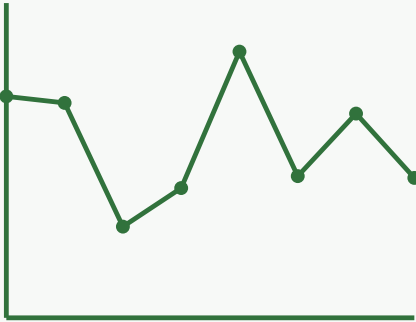
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$THD_V = \sqrt{2.5^2 + 1.8^2 + 1.0^2} = 3.24\%$$

Calculated result = 3.239 %

C&I PV FIGURE 120



C&I PV VOLTAGE HARMONIC DISTORTION

EXAMPLE VALUES

V_5	2.5%
V_7	1.8%
V_11	1.0%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include background distortion when evaluating plant contribution. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_design = X_calculated \times K_upper$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 3.24 \% \times 1.05 = 3.4 \%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	3.24 %
K_design	1.05
X_design	3.4 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_limit - X_design$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 3.74 \% - 3.4 \% = 0.34 \%$$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

3.24 %

worked result

DESIGN

3.4 %

factor 1.05

LIMIT

3.74 %

project criterion

MARGIN

0.34 %

available difference

GCC design note: Include background distortion when evaluating plant contribution. Coordinate the values with the current utility grid code and validated network models. Verify point-of-connection voltage, export limits, power factor, ramps, curtailment and harmonic performance against the local utility rules. Check the utility point of connection for power factor, voltage rise, hosting capacity, ramp rate, curtailment, frequency response and harmonics.



1 CALCULATE C&I PV FEEDER CT SECONDARY CURRENT

FORMULA

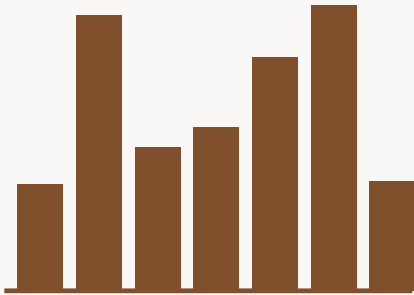
$I_s = I_p / CTR$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$I_s = 600 / 800 = 0.750 \text{ A}$
Calculated result = 0.75 A

C&I PV FIGURE 121



C&I PV FEEDER CT SECONDARY CURRENT

EXAMPLE VALUES

I _p	600 A
CTR	800/1

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check CT burden, accuracy class and transient performance. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 0.75 \text{ A} \times 1.10 = \mathbf{0.825 \text{ A}}$

GIVEN VALUES FOR EXAMPLE

X _{calculated}	0.75 A
K _{design}	1.10
X _{design}	0.825 A

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 0.908 \text{ A} - 0.825 \text{ A} = \mathbf{0.083 \text{ A}}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

0.75 A

worked result

REQUIRED

0.825 A

factor 1.10

SELECTED

0.908 A

project criterion

RESERVE

0.083 A

available difference

GCC design note: Check CT burden, accuracy class and transient performance. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I PV OVERCURRENT PICKUP

FORMULA

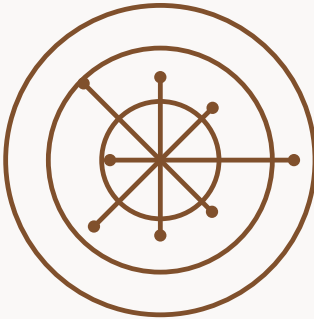
$I_{pickup} = 1.25 I_{load} / CTR$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$I_{pickup} = 1.25 \times 600 / 800 = 0.938 \text{ A}$
Calculated result = 0.9375 A secondary

C&I PV FIGURE 122



C&I PV OVERCURRENT PICKUP

EXAMPLE VALUES

I_load	600 A
CTR	800/1
Margin	1.25



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Pickup must remain above maximum load and below minimum fault current. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{required} = X_{calculated} \times K_{design}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 0.938 \text{ A secondary} \times 1.10 = 1.03 \text{ A secondary}$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.938 A secondary
K_design	1.10
X_design	1.03 A secondary



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$Reserve = X_{selected} - X_{required}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 1.13 \text{ A secondary} - 1.03 \text{ A secondary} = 0.103 \text{ A secondary}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

0.938 A secondary

worked result

REQUIRED

1.03 A secondary

factor 1.10

SELECTED

1.13 A secondary

project criterion

RESERVE

0.103 A secondary

available difference

GCC design note: Pickup must remain above maximum load and below minimum fault current. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I PV RELAY OPERATING TIME

FORMULA

$$t = 0.14 \text{ TMS} / (M^{0.02} - 1)$$

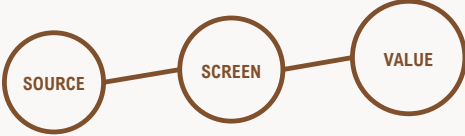
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$t = 0.14 \times 0.10 / (5^{0.02} - 1) = 0.428 \text{ s}$$

Calculated result = 0.428 s

C&I PV FIGURE 123



C&I PV RELAY OPERATING TIME

EXAMPLE VALUES

TMS	0.10
M	5.0



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Coordinate relay time with downstream clearing and breaker operating time. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 0.428 \text{ s} \times 1.10 = 0.471 \text{ s}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.428 s
K_design	1.10
X_design	0.471 s



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 0.518 \text{ s} - 0.471 \text{ s} = 0.047 \text{ s}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

0.428 s

worked result

REQUIRED

0.471 s

factor 1.10

SELECTED

0.518 s

project criterion

RESERVE

0.047 s

available difference

GCC design note: Coordinate relay time with downstream clearing and breaker operating time. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I PV SWITCHGEAR INTERRUPTING DUTY

FORMULA

$$I_{break} = S_{sc} / (\sqrt{3}V)$$

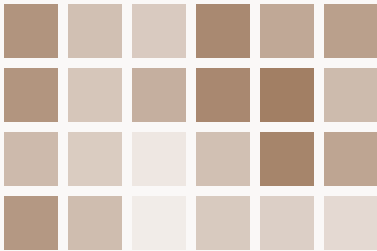
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$I_{break} = 500 \text{ MVA} / (\sqrt{3} \times 33 \text{ kV}) = 8.75 \text{ kA}$$

Calculated result = 8.748 kA

C&I PV FIGURE 124



C&I PV SWITCHGEAR INTERRUPTING DUTY

EXAMPLE VALUES

S_sc	500 MVA
V	33 kV



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Account for X/R ratio and required asymmetrical making current. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 8.75 \text{ kA} \times 1.05 = \mathbf{9.19 \text{ kA}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	8.75 kA
K_design	1.05
X_design	9.19 kA



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 10.1 \text{ kA} - 9.19 \text{ kA} = \mathbf{0.919 \text{ kA}}$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

8.75 kA

worked result

DESIGN

9.19 kA

factor 1.05

LIMIT

10.1 kA

project criterion

MARGIN

0.919 kA

available difference

GCC design note: Account for X/R ratio and required asymmetrical making current. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I PV SINGLE-ROD RESISTANCE

FORMULA

$$R_{rod} = \rho [\ln(4L/d) - 1] / (2 \pi L)$$

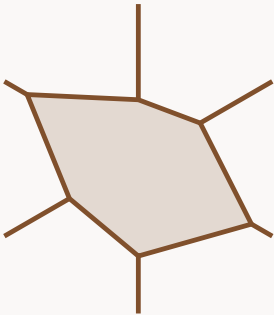
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$R_{rod} = 100 [\ln(4 \times 3 / 0.016) - 1] / (2 \pi \times 3) = 29.82 \text{ ohm}$$

Calculated result = 29.82 ohm

C&I PV FIGURE 125



C&I PV SINGLE-ROD RESISTANCE

EXAMPLE VALUES

Soil resistivity	100 ohm-m
Rod length	3 m
Rod diameter	0.016 m



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use measured seasonal soil resistivity and the adopted earthing standard. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 29.8 \text{ ohm} \times 1.05 = 31.3 \text{ ohm}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	29.8 ohm
K_design	1.05
X_design	31.3 ohm



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 34.4 \text{ ohm} - 31.3 \text{ ohm} = 3.13 \text{ ohm}$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

29.8 ohm

worked result

DESIGN

31.3 ohm

factor 1.05

LIMIT

34.4 ohm

project criterion

MARGIN

3.13 ohm

available difference

GCC design note: Use measured seasonal soil resistivity and the adopted earthing standard. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I PV PARALLEL-ROD RESISTANCE

FORMULA

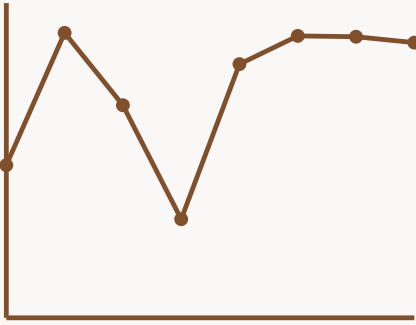
$R_{group} = R_{rod} / (n \cdot \eta_g)$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{group} = 29.815 / (6 \times 0.72) = 6.902 \text{ ohm}$
Calculated result = 6.902 ohm

C&I PV FIGURE 126



C&I PV PARALLEL-ROD RESISTANCE

EXAMPLE VALUES

Single rod	29.815 ohm
Rod quantity	6
Group efficiency	0.72



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Confirm rod spacing and mutual resistance with a detailed grid model. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{design} = X_{calculated} \times K_{upper}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 6.9 \text{ ohm} \times 1.05 = 7.25 \text{ ohm}$

GIVEN VALUES FOR EXAMPLE

X_calculated	6.9 ohm
K_design	1.05
X_design	7.25 ohm



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$Margin = X_{limit} - X_{design}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 7.97 \text{ ohm} - 7.25 \text{ ohm} = 0.725 \text{ ohm}$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

6.9 ohm

worked result

DESIGN

7.25 ohm

factor 1.05

LIMIT

7.97 ohm

project criterion

MARGIN

0.725 ohm

available difference

GCC design note: Confirm rod spacing and mutual resistance with a detailed grid model. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I EARTH CONDUCTOR LENGTH

FORMULA

$$L_g = N_x L_x + N_y L_y$$

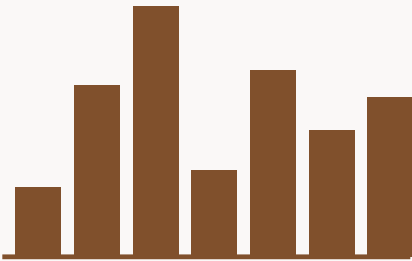
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$L_g = 8 \times 120 + 6 \times 160 = 1,920 \text{ m}$$

Calculated result = 1,920 m

C&I PV FIGURE 127



C&I EARTH CONDUCTOR LENGTH

EXAMPLE VALUES

X conductors	8 at 120 m
Y conductors	6 at 160 m



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add risers, tails, equipment bonds and the perimeter conductor to the material schedule. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 1,920 \text{ m} \times 1.10 = 2,112 \text{ m}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	1,920 m
K_design	1.10
X_design	2,112 m



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 2,323 \text{ m} - 2,112 \text{ m} = 211.2 \text{ m}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

1,920 m

worked result

REQUIRED

2,112 m

factor 1.10

SELECTED

2,323 m

project criterion

RESERVE

211.2 m

available difference

GCC design note: Add risers, tails, equipment bonds and the perimeter conductor to the material schedule. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I EARTHING THERMAL AREA

FORMULA

$$A = I_f \sqrt{t} / k$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$A = 25,000 \times \sqrt{1.0} / 143 = 174.8 \text{ mm}^2$$

Calculated result = 174.8 mm2

C&I PV FIGURE 128



C&I EARTHING THERMAL AREA

EXAMPLE VALUES

Fault current	25,000 A
Clearing time	1.0 s
Material factor	143

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Select the next standard conductor size after checking mechanical and corrosion allowances. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 174.8 \text{ mm}^2 \times 1.10 = 192.3 \text{ mm}^2$$

GIVEN VALUES FOR EXAMPLE

X_calculated	174.8 mm2
K_design	1.10
X_design	192.3 mm2

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 211.5 \text{ mm}^2 - 192.3 \text{ mm}^2 = 19.2 \text{ mm}^2$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

174.8 mm2

worked result

REQUIRED

192.3 mm2

factor 1.10

SELECTED

211.5 mm2

project criterion

RESERVE

19.2 mm2

available difference

GCC design note: Select the next standard conductor size after checking mechanical and corrosion allowances. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I LIGHTNING PROTECTION REACH

FORMULA

$$x = \text{sqrt}(2 \text{ r h-h}^2)$$

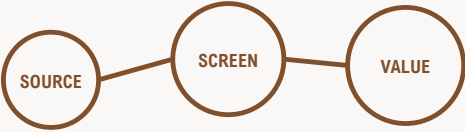
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$x = \text{sqrt}(2 \times 45 \times 20 - 20^2) = 37.42 \text{ m}$$

Calculated result = 37.42 m

C&I PV FIGURE 129



C&I LIGHTNING PROTECTION REACH

EXAMPLE VALUES

Rolling radius	45 m
Air-terminal height	20 m



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply the selected lightning-protection level and verify the complete three-dimensional geometry. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 37.4 \text{ m} \times 0.95 = 35.5 \text{ m}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	37.4 m
K_design	0.95
X_design	35.5 m



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{\text{design}} - X_{\text{min}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 35.5 \text{ m} - 32 \text{ m} = 3.55 \text{ m}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

37.4 m

worked result

CONSERVATIVE

35.5 m

factor 0.95

MINIMUM

32 m

project criterion

MARGIN

3.55 m

available difference

GCC design note: Apply the selected lightning-protection level and verify the complete three-dimensional geometry. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I NEUTRAL-GROUNDING RESISTANCE

FORMULA

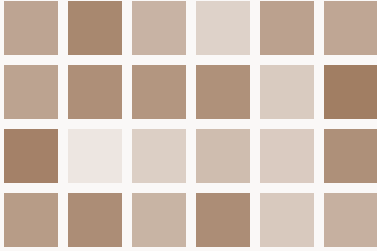
$R_{NGR} = V_{phase} / I_g$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{NGR} = (11 \text{ kV}/\sqrt{3}) / 10 \text{ A} = 635 \text{ ohm}$
Calculated result = 635.1 ohm

C&I PV FIGURE 130



C&I NEUTRAL-GROUNDING RESISTANCE

EXAMPLE VALUES

V_LL	11 kV
I_g	10 A



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Select time rating and insulation level for the grounding method. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{required} = X_{calculated} \times K_{design}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 635.1 \text{ ohm} \times 1.10 = 698.6 \text{ ohm}$

GIVEN VALUES FOR EXAMPLE

X_calculated	635.1 ohm
K_design	1.10
X_design	698.6 ohm



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$Reserve = X_{selected} - X_{required}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 768.5 \text{ ohm} - 698.6 \text{ ohm} = 69.9 \text{ ohm}$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

635.1 ohm

worked result

REQUIRED

698.6 ohm

factor 1.10

SELECTED

768.5 ohm

project criterion

RESERVE

69.9 ohm

available difference

GCC design note: Select time rating and insulation level for the grounding method. Coordinate settings and physical protection with the approved fault study, grounding model and lightning-risk assessment. Coordinate protective relays, equipment bonding, roof conductors, earth electrodes, lightning zones and transformer grounding. Coordinate CT ratios, relay settings, interrupting duty, grounding, bonding, lightning protection and touch-voltage control with the facility study.



1 CALCULATE C&I ROOF DESIGN WIND PRESSURE

FORMULA

$$q = 0.613 K_z V^2 / 1000$$

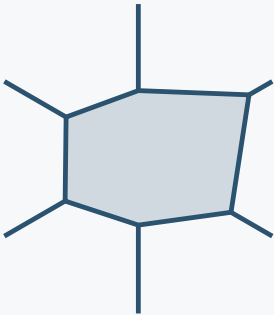
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$q = 0.613 \times 1.12 \times 48^2 / 1000 = 1.582 \text{ kPa}$$

Calculated result = 1.582 kPa

C&I PV FIGURE 131



C&I ROOF DESIGN WIND PRESSURE

EXAMPLE VALUES

Exposure factor	1.12
Wind speed	48 m/s



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply the governing code coefficients and gust definition. Use site-specific gusts, terrain exposure, stow logic, thermal movement and certified structural capacities. Coordinate structural records, roof zones, uplift, ballast, anchors, rail movement and allowable capacity with the facility engineer. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 1.58 \text{ kPa} \times 1.10 = 1.74 \text{ kPa}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	1.58 kPa
K_design	1.10
X_design	1.74 kPa



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 1.91 \text{ kPa} - 1.74 \text{ kPa} = 0.174 \text{ kPa}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

1.58 kPa

worked result

REQUIRED

1.74 kPa

factor 1.10

SELECTED

1.91 kPa

project criterion

RESERVE

0.174 kPa

available difference

GCC design note: Apply the governing code coefficients and gust definition. Use site-specific gusts, terrain exposure, stow logic, thermal movement and certified structural capacities. Coordinate structural records, roof zones, uplift, ballast, anchors, rail movement and allowable capacity with the facility engineer. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I PV MODULE WIND FORCE

FORMULA

$$F = q \ C_f \ A$$

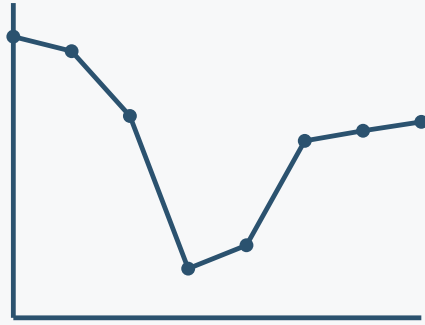
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$F = 1.582 \times 1.35 \times 2.58 = 5.510 \text{ kN}$$

Calculated result = 5.51 kN

C&I PV FIGURE 132



C&I PV MODULE WIND FORCE

EXAMPLE VALUES

Wind pressure	1.582 kPa
Force coefficient	1.35
Module area	2.58 m2

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check front and rear pressure zones and connection loads. Use site-specific gusts, terrain exposure, stow logic, thermal movement and certified structural capacities. Coordinate structural records, roof zones, uplift, ballast, anchors, rail movement and allowable capacity with the facility engineer. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 5.51 \text{ kN} \times 1.10 = 6.06 \text{ kN}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	5.51 kN
K_design	1.10
X_design	6.06 kN

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 6.67 \text{ kN} - 6.06 \text{ kN} = 0.606 \text{ kN}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

5.51 kN

worked result

REQUIRED

6.06 kN

factor 1.10

SELECTED

6.67 kN

project criterion

RESERVE

0.606 kN

available difference

GCC design note: Check front and rear pressure zones and connection loads. Use site-specific gusts, terrain exposure, stow logic, thermal movement and certified structural capacities. Coordinate structural records, roof zones, uplift, ballast, anchors, rail movement and allowable capacity with the facility engineer. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I BALLAST BEARING PRESSURE

FORMULA

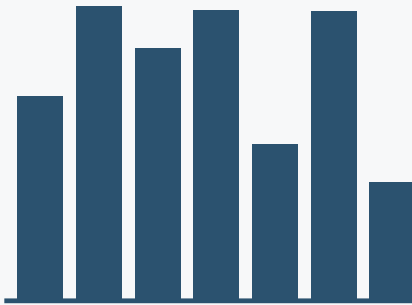
$q = W / A_base$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

q = 6,400 kN / 64 m2 = 100.0 kPa
Calculated result = 100 kPa

C&I PV FIGURE 133



C&I BALLAST BEARING PRESSURE

EXAMPLE VALUES

Service load	6,400 kN
Base area	64 m2



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check eccentricity, groundwater and settlement as well as capacity. Verify geotechnical, hydrological and structural inputs for the selected GCC site. Coordinate structural records, roof zones, uplift, ballast, anchors, rail movement and allowable capacity with the facility engineer. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_design = X_calculated \times K_upper$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 100 kPa x 1.05 = 105 kPa

GIVEN VALUES FOR EXAMPLE

X_calculated	100 kPa
K_design	1.05
X_design	105 kPa



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$Margin = X_limit - X_design$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 115.5 kPa - 105 kPa = 10.5 kPa



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

100 kPa

worked result

DESIGN

105 kPa

factor 1.05

LIMIT

115.5 kPa

project criterion

MARGIN

10.5 kPa

available difference

GCC design note: Check eccentricity, groundwater and settlement as well as capacity. Verify geotechnical, hydrological and structural inputs for the selected GCC site. Coordinate structural records, roof zones, uplift, ballast, anchors, rail movement and allowable capacity with the facility engineer. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I STRUCTURAL CAPACITY MARGIN

FORMULA

$$M_{struct} = R_{design} / S_{demand} - 1$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$M_{struct} = 82 \text{ kN} / 64.8 \text{ kN} - 1 = 26.54\%$$

Calculated result = 26.54 %

C&I PV FIGURE 134



C&I STRUCTURAL CAPACITY MARGIN

EXAMPLE VALUES

Design resistance	82 kN
Factored demand	64.8 kN



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use code-defined load and resistance factors. Use site-specific gusts, terrain exposure, stow logic, thermal movement and certified structural capacities. Coordinate structural records, roof zones, uplift, ballast, anchors, rail movement and allowable capacity with the facility engineer. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 26.5 \% \times 1.10 = 29.2 \%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	26.5 %
K_design	1.10
X_design	29.2 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 32.1 \% - 29.2 \% = 2.92 \%$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

26.5 %

worked result

REQUIRED

29.2 %

factor 1.10

SELECTED

32.1 %

project criterion

RESERVE

2.92 %

available difference

GCC design note: Use code-defined load and resistance factors. Use site-specific gusts, terrain exposure, stow logic, thermal movement and certified structural capacities. Coordinate structural records, roof zones, uplift, ballast, anchors, rail movement and allowable capacity with the facility engineer. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I FIRE ACCESS PATHWAY AREA

FORMULA

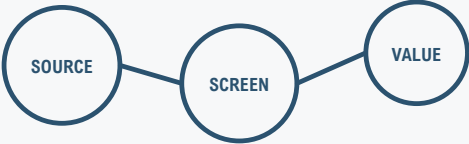
A_net = A_gross(1-f_excl)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

A_net = 4.32 x (1-0.22) = 3.370 km2
Calculated result = 3.37 km2

C&I PV FIGURE 135



C&I FIRE ACCESS PATHWAY AREA

EXAMPLE VALUES

Gross area	4.32 km2
Excluded fraction	22%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Map environmental, geotechnical, access and setback exclusions. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Coordinate fire pathways, DC isolation, emergency power, ventilation, water provision, insulation integrity and first-response readiness. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 3.37 km2 x 0.95 = **3.2 km2**

GIVEN VALUES FOR EXAMPLE

X_calculated	3.37 km2
K_design	0.95
X_design	3.2 km2



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 3.2 km2 - 2.88 km2 = **0.32 km2**



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

3.37 km2

worked result

CONSERVATIVE

3.2 km2

factor 0.95

MINIMUM

2.88 km2

project criterion

MARGIN

0.32 km2

available difference

GCC design note: Map environmental, geotechnical, access and setback exclusions. Coordinate the solar geometry, mechanical envelope, access requirements and land constraints in one array layout. Coordinate fire pathways, DC isolation, emergency power, ventilation, water provision, insulation integrity and first-response readiness. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I RAPID-SHUTDOWN COMPLETION

FORMULA

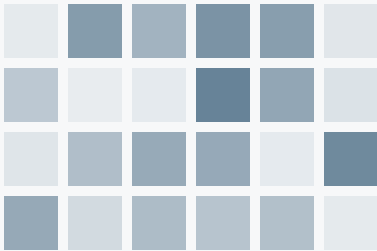
C_check = N_signed / N_total

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

C_check = 3,420 / 3,600 = 95.0%
Calculated result = 95 %

C&I PV FIGURE 136



C&I RAPID-SHUTDOWN COMPLETION

EXAMPLE VALUES

Signed checks	3,420
Total checks	3,600



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Blocking checks must be closed before energization. Use calibrated instruments, approved procedures and contractual acceptance criteria. Coordinate fire pathways, DC isolation, emergency power, ventilation, water provision, insulation integrity and first-response readiness. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 95 % x 0.95 = 90.2 %

GIVEN VALUES FOR EXAMPLE

X_calculated	95 %
K_design	0.95
X_design	90.2 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 90.2 % - 81.2 % = 9.02 %



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

95 %

worked result

CONSERVATIVE

90.2 %

factor 0.95

MINIMUM

81.2 %

project criterion

MARGIN

9.02 %

available difference

GCC design note: Blocking checks must be closed before energization. Use calibrated instruments, approved procedures and contractual acceptance criteria. Coordinate fire pathways, DC isolation, emergency power, ventilation, water provision, insulation integrity and first-response readiness. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I EMERGENCY RESPONSE READINESS

FORMULA

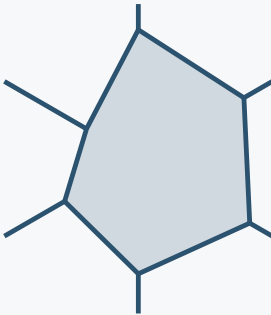
$R_{\text{energ}} = N_{\text{ready}} / N_{\text{required}}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{\text{energ}} = 186 / 200 = 93.0\%$
Calculated result = 93 %

C&I PV FIGURE 137



C&I EMERGENCY RESPONSE READINESS

EXAMPLE VALUES

Ready items	186
Required items	200



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Every mandatory safety and protection prerequisite must be complete. Use approved shop drawings, material records and installation measurements for turnover. Coordinate fire pathways, DC isolation, emergency power, ventilation, water provision, insulation integrity and first-response readiness. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 93 \% \times 0.95 = 88.3 \%$

GIVEN VALUES FOR EXAMPLE

X_calculated	93 %
K_design	0.95
X_design	88.3 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$\text{Margin} = X_{\text{design}} - X_{\text{min}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Margin} = 88.3 \% - 79.5 \% = 8.83 \%$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

93 %

worked result

CONSERVATIVE

88.3 %

factor 0.95

MINIMUM

79.5 %

project criterion

MARGIN

8.83 %

available difference

GCC design note: Every mandatory safety and protection prerequisite must be complete. Use approved shop drawings, material records and installation measurements for turnover. Coordinate fire pathways, DC isolation, emergency power, ventilation, water provision, insulation integrity and first-response readiness. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I PV CELL TEMPERATURE

FORMULA

$$T_{cell} = T_{amb} + (NOCT - 20)G / 800$$

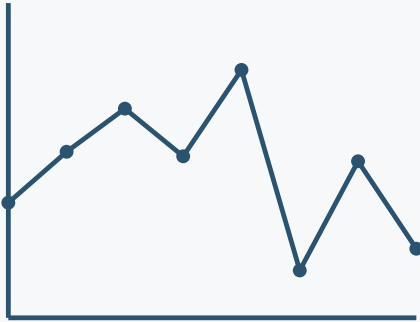
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$T_{cell} = 45 + (45 - 20) \times 1,000 / 800 = 76.25 \text{ C}$$

Calculated result = 76.25 C

C&I PV FIGURE 138



C&I PV CELL TEMPERATURE

EXAMPLE VALUES

Ambient	45 C
NOCT	45 C
Irradiance	1,000 W/m2

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use a validated thermal model for mounting and wind conditions. Use credible cell-temperature models, certified coefficients and ventilation assumptions for GCC operating conditions. Protect roof temperature limits, waterproofing, drainage falls, penetrations and equipment supports throughout the PV service life. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 76.2 \text{ C} \times 1.05 = 80.1 \text{ C}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	76.2 C
K_design	1.05
X_design	80.1 C

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 88.1 \text{ C} - 80.1 \text{ C} = 8.01 \text{ C}$$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

76.2 C

worked result

DESIGN

80.1 C

factor 1.05

LIMIT

88.1 C

project criterion

MARGIN

8.01 C

available difference

GCC design note: Use a validated thermal model for mounting and wind conditions. Use credible cell-temperature models, certified coefficients and ventilation assumptions for GCC operating conditions. Protect roof temperature limits, waterproofing, drainage falls, penetrations and equipment supports throughout the PV service life. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I ROOF PEAK RAIN RUNOFF

FORMULA

$$Q = 0.278 C i A$$

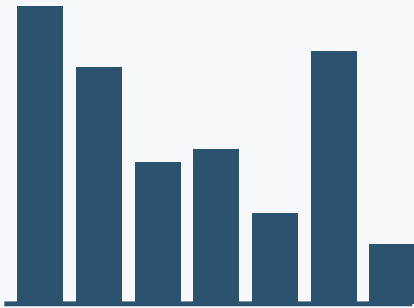
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$Q = 0.278 \times 0.62 \times 110 \times 2.4 = 45.51 \text{ m}^3/\text{s}$$

Calculated result = 45.5 m3/s

C&I PV FIGURE 139



C&I ROOF PEAK RAIN RUNOFF

EXAMPLE VALUES

Runoff coefficient	0.62
Rain intensity	110 mm/h
Catchment	2.4 km2

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the authority return period and concentration time. Use geotechnical tests, dry-soil thermal properties, flood hydrology and dune movement in the GCC civil design. Protect roof temperature limits, waterproofing, drainage falls, penetrations and equipment supports throughout the PV service life. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 45.5 \text{ m}^3/\text{s} \times 1.10 = \mathbf{50.1 \text{ m}^3/\text{s}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	45.5 m3/s
K_design	1.10
X_design	50.1 m3/s

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 55.1 \text{ m}^3/\text{s} - 50.1 \text{ m}^3/\text{s} = \mathbf{5.01 \text{ m}^3/\text{s}}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

45.5 m3/s

worked result

REQUIRED

50.1 m3/s

factor 1.10

SELECTED

55.1 m3/s

project criterion

RESERVE

5.01 m3/s

available difference

GCC design note: Use the authority return period and concentration time. Use geotechnical tests, dry-soil thermal properties, flood hydrology and dune movement in the GCC civil design. Protect roof temperature limits, waterproofing, drainage falls, penetrations and equipment supports throughout the PV service life. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I WATERPROOFING INSPECTION PASS RATE

FORMULA

$$FPY = N_{pass1} / N_{inspected}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$FPY = 4,620 / 4,900 = 94.29\%$$

Calculated result = 94.29 %

C&I PV FIGURE 140



C&I WATERPROOFING INSPECTION PASS RATE

EXAMPLE VALUES

First-pass accepted	4,620
Inspected	4,900

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use consistent inspection lots and acceptance criteria. Trend the metric by contractor, system and reporting period and close adverse findings promptly. Protect roof temperature limits, waterproofing, drainage falls, penetrations and equipment supports throughout the PV service life. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 94.3\% \times 0.95 = 89.6\%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	94.3 %
K_design	0.95
X_design	89.6 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$Margin = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 89.6\% - 80.6\% = 8.96\%$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

94.3 %

worked result

CONSERVATIVE

89.6 %

factor 0.95

MINIMUM

80.6 %

project criterion

MARGIN

8.96 %

available difference

GCC design note: Use consistent inspection lots and acceptance criteria. Trend the metric by contractor, system and reporting period and close adverse findings promptly. Protect roof temperature limits, waterproofing, drainage falls, penetrations and equipment supports throughout the PV service life. Coordinate structural capacity, wind, fire access, shutdown, drainage, waterproofing and heat management with approved building information.



1 CALCULATE C&I BATTERY PACK NOMINAL ENERGY

FORMULA

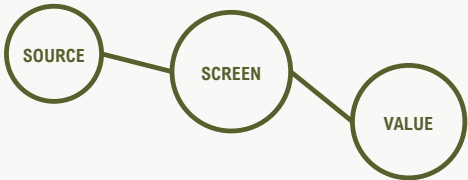
E = V x Ah / 1,000

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

E = 768 V x 280 Ah / 1,000 = 215 kWh
Calculated result = 215 kWh

C&I PV FIGURE 141



C&I BATTERY PACK NOMINAL ENERGY

EXAMPLE VALUES

V	768 V
Capacity	280 Ah

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Nominal DC energy is not the same as usable AC energy. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 215 kWh x 1.10 = 236.5 kWh

GIVEN VALUES FOR EXAMPLE

X_calculated	215 kWh
K_design	1.10
X_design	236.5 kWh

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 260.2 kWh - 236.5 kWh = 23.7 kWh

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

215 kWh

worked result

REQUIRED

236.5 kWh

factor 1.10

SELECTED

260.2 kWh

project criterion

RESERVE

23.7 kWh

available difference

GCC design note: Nominal DC energy is not the same as usable AC energy. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I BATTERY SERIES CELL COUNT

FORMULA

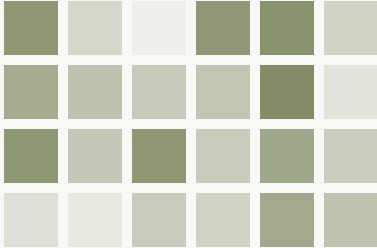
$$N_s = \text{ceil}(V_{\text{pack}} / V_{\text{cell}})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_s = \text{ceil}(768 / 3.2) = 240$ cells
Calculated result = 240 cells

C&I PV FIGURE 142



C&I BATTERY SERIES CELL COUNT

EXAMPLE VALUES

V_pack	768 V
V_cell	3.2 V



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Verify maximum and minimum cell voltage across the operating SoC range. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 240 \text{ cells} \times 1.10 = 264$ cells

GIVEN VALUES FOR EXAMPLE

X_calculated	240 cells
K_design	1.10
X_design	264 cells



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 291 \text{ cells} - 264 \text{ cells} = 27$ cells



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

240 cells

worked result

REQUIRED

264 cells

factor 1.10

SELECTED

291 cells

project criterion

RESERVE

27 cells

available difference

GCC design note: Verify maximum and minimum cell voltage across the operating SoC range. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I PARALLEL BATTERY STRING COUNT

FORMULA

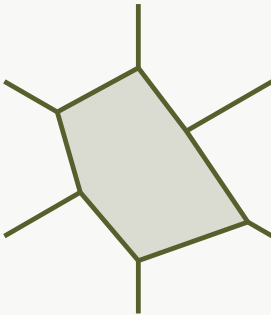
$$N_p = \text{ceil}(E_{\text{req}} / E_{\text{string}})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_p = \text{ceil}(1,000 / 215) = 5$ strings
Calculated result = 5 strings

C&I PV FIGURE 143



C&I PARALLEL BATTERY STRING COUNT

EXAMPLE VALUES

E_req	1,000 kWh
E_string	215 kWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check current sharing, protection and isolation for each parallel string. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 5 \text{ strings} \times 1.10 = 6$ strings

GIVEN VALUES FOR EXAMPLE

X_calculated	5 strings
K_design	1.10
X_design	6 strings



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 7 \text{ strings} - 6 \text{ strings} = 1$ string



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

5 strings

worked result

REQUIRED

6 strings

factor 1.10

SELECTED

7 strings

project criterion

RESERVE

1 string

available difference

GCC design note: Check current sharing, protection and isolation for each parallel string. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I BATTERY DESIGN C-RATE

FORMULA

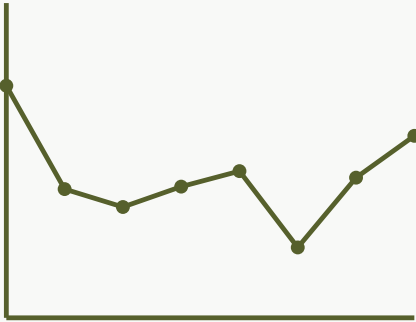
C_rate = P / E_nom

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

C_rate = 2 MW / 10 MWh = 0.20 C
Calculated result = 0.2 C

C&I PV FIGURE 144



C&I BATTERY DESIGN C-RATE

EXAMPLE VALUES

P	2 MW
E_nom	10 MWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Confirm whether the supplier defines C-rate on nominal or usable energy. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 0.2 C x 1.10 = 0.22 C

GIVEN VALUES FOR EXAMPLE

X_calculated	0.2 C
K_design	1.10
X_design	0.22 C



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 0.242 C - 0.22 C = 0.022 C



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

0.2 C

worked result

REQUIRED

0.22 C

factor 1.10

SELECTED

0.242 C

project criterion

RESERVE

0.022 C

available difference

GCC design note: Confirm whether the supplier defines C-rate on nominal or usable energy. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I GUARANTEED USABLE AC ENERGY

FORMULA

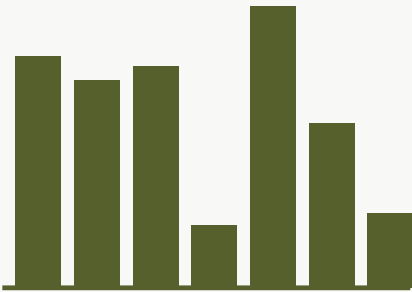
$E_{use} = E_{nom} \times DoD \times \eta_d$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$E_{use} = 10 \times 0.90 \times 0.94 = 8.46 \text{ MWh}$
Calculated result = 8.46 MWh

C&I PV FIGURE 145



C&I GUARANTEED USABLE AC ENERGY

EXAMPLE VALUES

E_nom	10 MWh
DoD	90%
eta_d	94%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include PCS and auxiliary consumption at the intended metering point. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{design} = X_{calculated} \times K_{conservative}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 8.46 \text{ MWh} \times 0.95 = 8.04 \text{ MWh}$

GIVEN VALUES FOR EXAMPLE

X_calculated	8.46 MWh
K_design	0.95
X_design	8.04 MWh



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$Margin = X_{design} - X_{min}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 8.04 \text{ MWh} - 7.23 \text{ MWh} = 0.804 \text{ MWh}$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

8.46 MWh

worked result

CONSERVATIVE

8.04 MWh

factor 0.95

MINIMUM

7.23 MWh

project criterion

MARGIN

0.804 MWh

available difference

GCC design note: Include PCS and auxiliary consumption at the intended metering point. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I BATTERY OPERATING DEPTH OF DISCHARGE

FORMULA

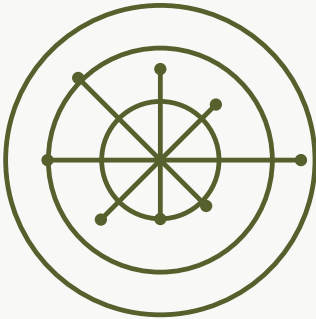
DoD = SoC_max - SoC_min

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

DoD = 95% - 10% = 85%
Calculated result = 85 %

C&I PV FIGURE 146



C&I BATTERY OPERATING DEPTH OF DISCHARGE

EXAMPLE VALUES

SoC_max	95%
SoC_min	10%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Operating-window limits may vary with warranty mode and temperature. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

X_design = X_calculated x K_upper

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 85 % x 1.05 = 89.2 %

GIVEN VALUES FOR EXAMPLE

X_calculated	85 %
K_design	1.05
X_design	89.2 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

Margin = X_limit - X_design

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 98.2 % - 89.2 % = 8.93 %



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

85 %

worked result

DESIGN

89.2 %

factor 1.05

LIMIT

98.2 %

project criterion

MARGIN

8.93 %

available difference

GCC design note: Operating-window limits may vary with warranty mode and temperature. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I GUARANTEED ROUND-TRIP EFFICIENCY

FORMULA

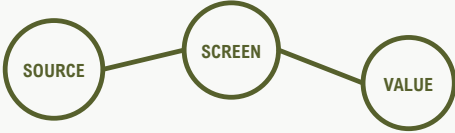
RTE = E_out / E_in

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

RTE = 8.4 / 9.3 = 90.3%
Calculated result = 90.32 %

C&I PV FIGURE 147



C&I GUARANTEED ROUND-TRIP EFFICIENCY

EXAMPLE VALUES

E_out	8.4 MWh
E_in	9.3 MWh

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use identical AC or DC boundaries for charge and discharge energy. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 90.3 % x 0.95 = 85.8 %

GIVEN VALUES FOR EXAMPLE

X_calculated	90.3 %
K_design	0.95
X_design	85.8 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 85.8 % - 77.2 % = 8.58 %

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

90.3 %

worked result

CONSERVATIVE

85.8 %

factor 0.95

MINIMUM

77.2 %

project criterion

MARGIN

8.58 %

available difference

GCC design note: Use identical AC or DC boundaries for charge and discharge energy. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I REQUIRED STORAGE AUTONOMY

FORMULA

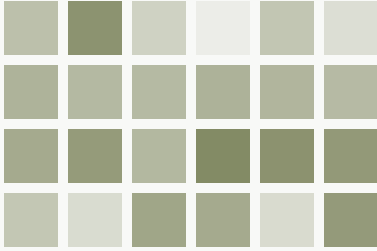
t = E_use / P_load

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

t = 8.46 MWh / 2.0 MW = 4.23 h
Calculated result = 4.23 h

C&I PV FIGURE 148



C&I REQUIRED STORAGE AUTONOMY

EXAMPLE VALUES

E_use	8.46 MWh
P_load	2.0 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check whether the load is constant or time-varying. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 4.23 h x 0.95 = 4.02 h

GIVEN VALUES FOR EXAMPLE

X_calculated	4.23 h
K_design	0.95
X_design	4.02 h



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 4.02 h - 3.62 h = 0.402 h



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

4.23 h

worked result

CONSERVATIVE

4.02 h

factor 0.95

MINIMUM

3.62 h

project criterion

MARGIN

0.402 h

available difference

GCC design note: Check whether the load is constant or time-varying. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I BESS POWER-CONVERSION RATING

FORMULA

$$P_{PCS} = P_{load} / \eta_{PCS}$$

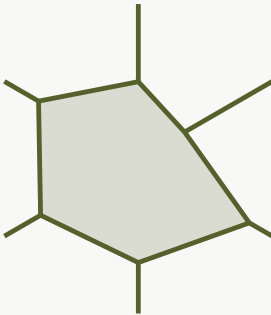
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{PCS} = 2.0 / 0.97 = 2.06 \text{ MW}$$

Calculated result = 2.062 MW

C&I PV FIGURE 149



C&I BESS POWER-CONVERSION RATING

EXAMPLE VALUES

P_load	2.0 MW
eta_PCS	97%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Reactive-power and overload duty can increase the PCS MVA requirement. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 2.06 \text{ MW} \times 1.10 = 2.27 \text{ MW}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	2.06 MW
K_design	1.10
X_design	2.27 MW



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 2.49 \text{ MW} - 2.27 \text{ MW} = 0.227 \text{ MW}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

2.06 MW

worked result

REQUIRED

2.27 MW

factor 1.10

SELECTED

2.49 MW

project criterion

RESERVE

0.227 MW

available difference

GCC design note: Reactive-power and overload duty can increase the PCS MVA requirement. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I BESS CONTAINER QUANTITY

FORMULA

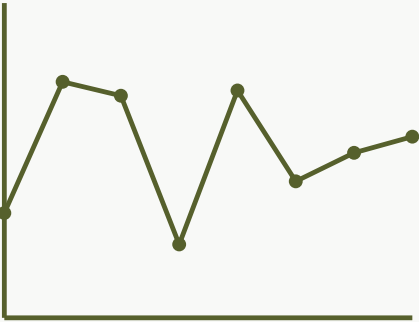
$$N = \text{ceil}(E_{\text{design}} / E_{\text{container}})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N = \text{ceil}(11.42 / 3.8) = 4$ containers
Calculated result = 4 containers

C&I PV FIGURE 150



C&I BESS CONTAINER QUANTITY

EXAMPLE VALUES

E_design	11.42 MWh
E_container	3.8 MWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Allow for unavailable strings and container-level warranty limits. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 4 \text{ containers} \times 1.10 = 5$ containers

GIVEN VALUES FOR EXAMPLE

X_calculated	4 containers
K_design	1.10
X_design	5 containers



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 6 \text{ containers} - 5 \text{ containers} = 1$ container



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

4 containers

worked result

REQUIRED

5 containers

factor 1.10

SELECTED

6 containers

project criterion

RESERVE

1 container

available difference

GCC design note: Allow for unavailable strings and container-level warranty limits. Coordinate battery, PCS, thermal, fire and control ratings at the same duty point. Size storage and conversion equipment for peak shaving, load shifting, resilience, operating limits, efficiency and modular installation.



1 CALCULATE C&I PV MONITORING POINT COUNT

FORMULA

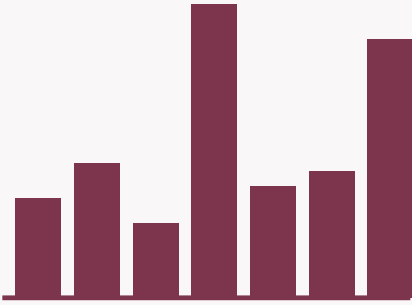
$$N_{total} = N_{AI} + N_{AO} + N_{DI} + N_{DO}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$N_{total} = 420 + 60 + 1,280 + 240 = 2,000$ points
Calculated result = 2,000 points

C&I PV FIGURE 151



C&I PV MONITORING POINT COUNT

EXAMPLE VALUES

Analog inputs	420
Analog outputs	60
Digital inputs	1,280
Digital outputs	240



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add spare capacity, calculated tags and protocol-quality attributes to the final database. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 2,000 \text{ points} \times 1.10 = 2,200$ points

GIVEN VALUES FOR EXAMPLE

X_calculated	2,000 points
K_design	1.10
X_design	2,200 points



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 2,420 \text{ points} - 2,200 \text{ points} = 220$ points



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

2,000 points

worked result

REQUIRED

2,200 points

factor 1.10

SELECTED

2,420 points

project criterion

RESERVE

220 points

available difference

GCC design note: Add spare capacity, calculated tags and protocol-quality attributes to the final database. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I PV TELEMETRY BANDWIDTH

FORMULA

$$B = N_p S_p f_s / K_u$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$B = 900 \times 64 \times 1 / 0.70 = 82.29 \text{ kbit/s}$$

Calculated result = 82.29 kbit/s

C&I PV FIGURE 152



C&I PV TELEMETRY BANDWIDTH

EXAMPLE VALUES

Points	900
Packet size	64 bit
Sample rate	1 Hz
Utilization	0.70

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include protocol overhead, events, retries, engineering access and future expansion. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 82.3 \text{ kbit/s} \times 1.10 = 90.5 \text{ kbit/s}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	82.3 kbit/s
K_design	1.10
X_design	90.5 kbit/s

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 99.6 \text{ kbit/s} - 90.5 \text{ kbit/s} = 9.05 \text{ kbit/s}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

82.3 kbit/s

worked result

REQUIRED

90.5 kbit/s

factor 1.10

SELECTED

99.6 kbit/s

project criterion

RESERVE

9.05 kbit/s

available difference

GCC design note: Include protocol overhead, events, retries, engineering access and future expansion. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I DEVICE POLLING CYCLE

FORMULA

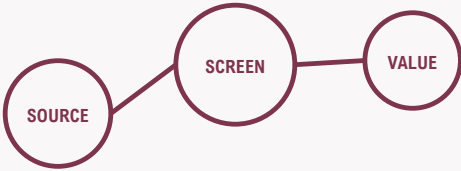
t_cycle = N_d(t_req+t_resp+t_gap)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

t_cycle = 40x(0.020+0.040+0.010) = 2.800 s
Calculated result = 2.8 s

C&I PV FIGURE 153



C&I DEVICE POLLING CYCLE

EXAMPLE VALUES

Devices	40
Request	0.020 s
Response	0.040 s
Gap	0.010 s

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: The polling cycle must satisfy the fastest required control and alarm response. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

X_design = X_calculated x K_upper

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 2.8 s x 1.05 = 2.94 s

GIVEN VALUES FOR EXAMPLE

X_calculated	2.8 s
K_design	1.05
X_design	2.94 s

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

Margin = X_limit - X_design

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 3.23 s - 2.94 s = 0.294 s

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

2.8 s

worked result

DESIGN

2.94 s

factor 1.05

LIMIT

3.23 s

project criterion

MARGIN

0.294 s

available difference

GCC design note: The polling cycle must satisfy the fastest required control and alarm response. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I HISTORIAN DAILY STORAGE

FORMULA

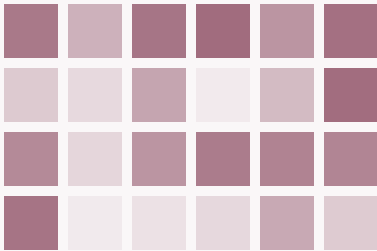
$$V_{\text{day}} = N_p \times b \times f_s \times 86400 / (8 \times 10^6)$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$V_{\text{day}} = 1,200 \times 16 \times 0.2 \times 86,400 / (8 \times 10^6) = 41.47 \text{ MB/day}$
Calculated result = 41.47 MB/day

C&I PV FIGURE 154



C&I HISTORIAN DAILY STORAGE

EXAMPLE VALUES

Points	1,200
Value size	16 bit
Sample rate	0.2 Hz

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply compression, metadata, events, replicas and database overhead separately. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 41.5 \text{ MB/day} \times 1.10 = 45.6 \text{ MB/day}$

GIVEN VALUES FOR EXAMPLE

$X_{\text{calculated}}$	41.5 MB/day
K_{design}	1.10
X_{design}	45.6 MB/day

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 50.2 \text{ MB/day} - 45.6 \text{ MB/day} = 4.56 \text{ MB/day}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

41.5 MB/day

worked result

REQUIRED

45.6 MB/day

factor 1.10

SELECTED

50.2 MB/day

project criterion

RESERVE

4.56 MB/day

available difference

GCC design note: Apply compression, metadata, events, replicas and database overhead separately. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I HISTORIAN RETENTION CAPACITY

FORMULA

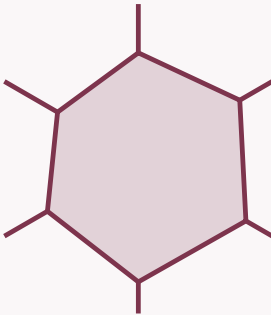
$$V_{ret} = V_{day} \times 365 \times y / 1024$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$V_{ret} = 41.47 \times 365 \times 3 / 1,024 = 44.35 \text{ GB}$
Calculated result = 44.35 GB

C&I PV FIGURE 155



C&I HISTORIAN RETENTION CAPACITY

EXAMPLE VALUES

Daily storage	41.47 MB/day
Retention	3 years
Conversion	1,024 MB/GB

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Provide mirrored capacity and backup retention in addition to the live historian volume. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 44.3 \text{ GB} \times 1.10 = 48.8 \text{ GB}$

GIVEN VALUES FOR EXAMPLE

X_calculated	44.3 GB
K_design	1.10
X_design	48.8 GB

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 53.7 \text{ GB} - 48.8 \text{ GB} = 4.88 \text{ GB}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

44.3 GB

worked result

REQUIRED

48.8 GB

factor 1.10

SELECTED

53.7 GB

project criterion

RESERVE

4.88 GB

available difference

GCC design note: Provide mirrored capacity and backup retention in addition to the live historian volume. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I FIBER-OPTIC LINK MARGIN

FORMULA

M_link = P_tx-P_rx,min-L_link

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

M_link = 3-(-18)-11 = 10.00 dB
Calculated result = 10 dB

C&I PV FIGURE 156



C&I FIBER-OPTIC LINK MARGIN

EXAMPLE VALUES

Transmit power	3 dBm
Receiver minimum	-18 dBm
Link loss	11 dB

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Reserve margin for connector aging, repairs, temperature and measurement uncertainty. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 10 dB x 0.95 = 9.5 dB

GIVEN VALUES FOR EXAMPLE

X_calculated	10 dB
K_design	0.95
X_design	9.5 dB

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 9.5 dB - 8.55 dB = 0.95 dB

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

10 dB

worked result

CONSERVATIVE

9.5 dB

factor 0.95

MINIMUM

8.55 dB

project criterion

MARGIN

0.95 dB

available difference

GCC design note: Reserve margin for connector aging, repairs, temperature and measurement uncertainty. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I EVENT-CLOCK DRIFT

FORMULA

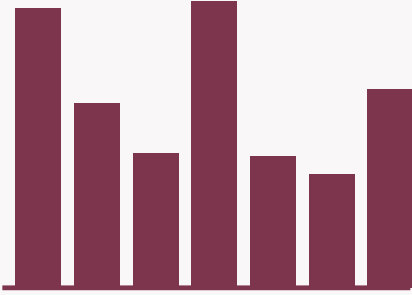
$\Delta t = r_{ppm} \cdot t / 10^6$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$\Delta t = 2 \times 86,400 / 10^6 = 0.1728 \text{ s/day}$
Calculated result = 0.1728 s/day

C&I PV FIGURE 157



C&I EVENT-CLOCK DRIFT

EXAMPLE VALUES

Clock drift	2 ppm
Elapsed time	86,400 s



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Event-sequence recording may require sub-millisecond synchronized accuracy. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{design} = X_{calculated} \times K_{upper}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 0.173 \text{ s/day} \times 1.05 = 0.181 \text{ s/day}$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.173 s/day
K_design	1.05
X_design	0.181 s/day



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$\text{Margin} = X_{limit} - X_{design}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Margin} = 0.2 \text{ s/day} - 0.181 \text{ s/day} = 0.018 \text{ s/day}$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

0.173 s/day

worked result

DESIGN

0.181 s/day

factor 1.05

LIMIT

0.2 s/day

project criterion

MARGIN

0.018 s/day

available difference

GCC design note: Event-sequence recording may require sub-millisecond synchronized accuracy. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I CONTROLLER UPDATE CAPACITY

FORMULA

$$N_rate = B \times K_u / S_msg$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$N_rate = 1,000,000 \times 0.60 / 800 = 750 \text{ updates/s}$$

Calculated result = 750 updates/s

C&I PV FIGURE 158



C&I CONTROLLER UPDATE CAPACITY

EXAMPLE VALUES

Available bandwidth	1,000,000 bit/s
Utilization	0.60
Message	800 bit

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Check processor loading, deterministic latency and protocol overhead as separate constraints. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_design = X_calculated \times K_conservative$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 750 \text{ updates/s} \times 0.95 = 712.5 \text{ updates/s}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	750 updates/s
K_design	0.95
X_design	712.5 updates/s

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_design - X_min$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 712.5 \text{ updates/s} - 641.2 \text{ updates/s} = 71.2 \text{ updates/s}$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

750 updates/s

worked result

CONSERVATIVE

712.5 updates/s

factor 0.95

MINIMUM

641.2 updates/s

project criterion

MARGIN

71.2 updates/s

available difference

GCC design note: Check processor loading, deterministic latency and protocol overhead as separate constraints. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I PV MONITORING AVAILABILITY

FORMULA

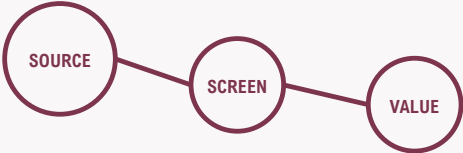
A = MTBF/(MTBF+MTTR)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

A = 4,380/(4,380+4) = 99.91%
Calculated result = 99.91 %

C&I PV FIGURE 159



C&I PV MONITORING AVAILABILITY

EXAMPLE VALUES

MTBF	4,380 h
MTTR	4 h

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Model servers, networks, power supplies and common-cause failures in the final architecture. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 99.9 % x 0.95 = 94.9 %

GIVEN VALUES FOR EXAMPLE

X_calculated	99.9 %
K_design	0.95
X_design	94.9 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 94.9 % - 85.4 % = 9.49 %

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

99.9 %

worked result

CONSERVATIVE

94.9 %

factor 0.95

MINIMUM

85.4 %

project criterion

MARGIN

9.49 %

available difference

GCC design note: Model servers, networks, power supplies and common-cause failures in the final architecture. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I MONITORING QUALITY SCORE

FORMULA

$$Q = 100 - w_r F_r - w_p F_p - w_m F_m$$

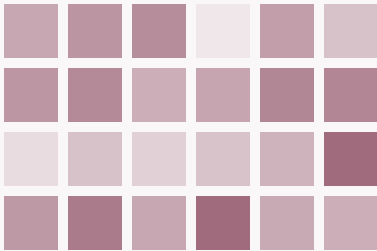
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$Q = 100 - 1 \times 0.8 - 1 \times 1.2 - 1 \times 2.0 = 96.0$$

Calculated result = 96 score

C&I PV FIGURE 160



C&I MONITORING QUALITY SCORE

EXAMPLE VALUES

Range penalty	0.8
Persistence	1.2
Missing	2.0

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Publish weights, thresholds and score interpretation. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 96 \text{ score} \times 1.10 = \mathbf{105.6 \text{ score}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	96 score
K_design	1.10
X_design	105.6 score

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 116.2 \text{ score} - 105.6 \text{ score} = \mathbf{10.6 \text{ score}}$$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

96 score

worked result

REQUIRED

105.6 score

factor 1.10

SELECTED

116.2 score

project criterion

RESERVE

10.6 score

available difference

GCC design note: Publish weights, thresholds and score interpretation. Preserve time synchronization, data quality, communications headroom and historian retention across the monitoring architecture. Integrate C&I; monitoring with the facility management system using adequate point count, bandwidth, retention, time sync and service availability. Integrate meters, inverter data, controllers, BMS, historian, communications and time synchronization into the facility operating platform.



1 CALCULATE C&I CONSTRUCTION DC CABLE ROUTE

FORMULA

$$L_{DC} = N_{string} L_{avg} / 1000$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$L_{DC} = 329 \times 42 \text{ m} / 1,000 = 13.82 \text{ km}$$

Calculated result = 13.82 km

C&I PV FIGURE 161



C&I CONSTRUCTION DC CABLE ROUTE

EXAMPLE VALUES

PV strings	329
Installed average route	42 m



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use approved shop drawings and measured installation routes for final material reconciliation. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 13.8 \text{ km} \times 1.10 = 15.2 \text{ km}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	13.8 km
K_design	1.10
X_design	15.2 km



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 16.7 \text{ km} - 15.2 \text{ km} = 1.52 \text{ km}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

13.8 km

worked result

REQUIRED

15.2 km

factor 1.10

SELECTED

16.7 km

project criterion

RESERVE

1.52 km

available difference

GCC design note: Use approved shop drawings and measured installation routes for final material reconciliation. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I CABLE DRUM REQUIREMENT

FORMULA

$$N_{\text{reel}} = \text{ceil}(L_{\text{total}}/L_{\text{reel}})$$

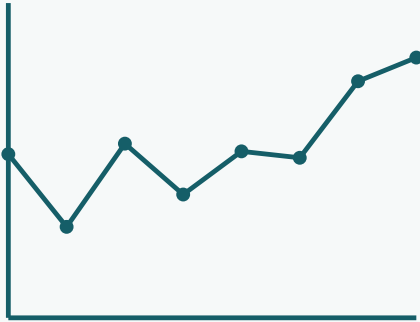
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$N_{\text{reel}} = \text{ceil}(13.82 \text{ km} / 0.75 \text{ km}) = 19 \text{ reels}$$

Calculated result = 19 reels

C&I PV FIGURE 162



C&I CABLE DRUM REQUIREMENT

EXAMPLE VALUES

Cable length	13.82 km
Reel length	0.75 km



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add route-specific waste, pulling sections and minimum tail lengths before ordering reels. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 19 \text{ reels} \times 1.10 = 21 \text{ reels}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	19 reels
K_design	1.10
X_design	21 reels



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 24 \text{ reels} - 21 \text{ reels} = 3 \text{ reels}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

19 reels

worked result

REQUIRED

21 reels

factor 1.10

SELECTED

24 reels

project criterion

RESERVE

3 reels

available difference

GCC design note: Add route-specific waste, pulling sections and minimum tail lengths before ordering reels. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I CABLE-PULLING TENSION

FORMULA

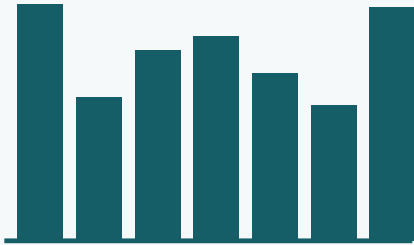
T_pull = mu W L

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

T_pull = 0.35x18 N/mx120 m = 756 N
Calculated result = 756 N

C&I PV FIGURE 163



C&I CABLE-PULLING TENSION

EXAMPLE VALUES

Friction coefficient	0.35
Cable weight	18 N/m
Pull length	120 m

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include bends, slope and sidewall-pressure limits. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 756 N x 1.10 = 831.6 N

GIVEN VALUES FOR EXAMPLE

X_calculated	756 N
K_design	1.10
X_design	831.6 N

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 914.8 N - 831.6 N = 83.2 N

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

756 N

worked result

REQUIRED

831.6 N

factor 1.10

SELECTED

914.8 N

project criterion

RESERVE

83.2 N

available difference

GCC design note: Include bends, slope and sidewall-pressure limits. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1

CALCULATE C&I TRANSFORMER INSTALLATION QUANTITY

FORMULA

$$N_{tx} = \text{ceil}(P_{AC}/P_{tx})$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$N_{tx} = \text{ceil}(180 \text{ MW} / 4.5 \text{ MW}) = 40 \text{ transformers}$$

Calculated result = 40 transformers

C&I PV FIGURE 164



C&I TRANSFORMER INSTALLATION QUANTITY

EXAMPLE VALUES

Plant power	180 MW
Transformer block	4.5 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Coordinate spare philosophy and feeder segmentation. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2

APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_{required} = X_{calculated} \times K_{design}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 40 \text{ transformers} \times 1.10 = 44 \text{ transformers}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	40 transformers
K_design	1.10
X_design	44 transformers



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3

SELECT RATING AND CONFIRM RESERVE

FORMULA

$$\text{Reserve} = X_{selected} - X_{required}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Reserve} = 48.4 \text{ transformers} - 44 \text{ transformers} = 4.4 \text{ transformers}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

40 transformers

worked result

REQUIRED

44 transformers

factor 1.10

SELECTED

48.4 transformers

project criterion

RESERVE

4.4 transformers

available difference

GCC design note: Coordinate spare philosophy and feeder segmentation. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I PV MODULE INSTALLATION RATE

FORMULA

$$\text{Prod_mod} = \text{N_installed} / \text{H_team}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

Prod_mod = 5,760 / 480 = 12.0 modules/person-h
Calculated result = 12 modules/person-h

C&I PV FIGURE 165



C&I PV MODULE INSTALLATION RATE

EXAMPLE VALUES

Modules installed	5,760
Team hours	480 h

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Track quality and rework alongside production rate. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$\text{X_design} = \text{X_calculated} \times \text{K_conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 12 modules/person-h x 0.95 = 11.4 modules/person-h

GIVEN VALUES FOR EXAMPLE

X_calculated	12 modules/person-h
K_design	0.95
X_design	11.4 modules/person-h

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = \text{X_design} - \text{X_min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 11.4 modules/person-h - 10.3 modules/person-h = 1.14 modules/person-h

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

12 modules/person-h

worked result

CONSERVATIVE

11.4 modules/person-h

factor 0.95

MINIMUM

10.3 modules/person-h

project criterion

MARGIN

1.14 modules/person-h

available difference

GCC design note: Track quality and rework alongside production rate. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I PV MECHANICAL COMPLETION

FORMULA

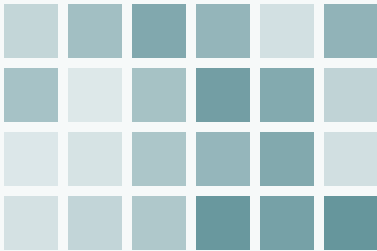
C_MC = N_MC / N_system

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

C_MC = 142 / 160 = 88.75%
Calculated result = 88.75 %

C&I PV FIGURE 166



C&I PV MECHANICAL COMPLETION

EXAMPLE VALUES

Systems complete	142
Total systems	160



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Completion requires signed inspection and cleared blocking defects. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 88.8 % x 0.95 = 84.3 %

GIVEN VALUES FOR EXAMPLE

X_calculated	88.8 %
K_design	0.95
X_design	84.3 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 84.3 % - 75.9 % = 8.43 %



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

88.8 %

worked result

CONSERVATIVE

84.3 %

factor 0.95

MINIMUM

75.9 %

project criterion

MARGIN

8.43 %

available difference

GCC design note: Completion requires signed inspection and cleared blocking defects. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I PV PRE-ENERGIZATION READINESS

FORMULA

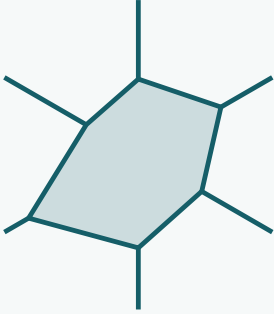
$R_{\text{energ}} = N_{\text{ready}} / N_{\text{required}}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{\text{energ}} = 186 / 200 = 93.0\%$
Calculated result = 93 %

C&I PV FIGURE 167



C&I PV PRE-ENERGIZATION READINESS

EXAMPLE VALUES

Ready items	186
Required items	200



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Every mandatory safety and protection prerequisite must be complete. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 93 \% \times 0.95 = 88.3 \%$

GIVEN VALUES FOR EXAMPLE

X_calculated	93 %
K_design	0.95
X_design	88.3 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$\text{Margin} = X_{\text{design}} - X_{\text{min}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Margin} = 88.3 \% - 79.5 \% = 8.83 \%$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

93 %

worked result

CONSERVATIVE

88.3 %

factor 0.95

MINIMUM

79.5 %

project criterion

MARGIN

8.83 %

available difference

GCC design note: Every mandatory safety and protection prerequisite must be complete. Use approved shop drawings, material records and installation measurements for turnover. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I INSPECTION FIRST-PASS ACCEPTANCE

FORMULA

$$FPY = N_{pass1} / N_{inspected}$$

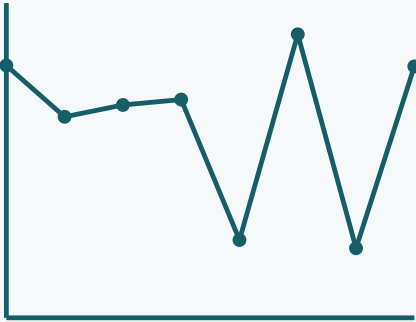
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$FPY = 4,620 / 4,900 = 94.29\%$$

Calculated result = 94.29 %

C&I PV FIGURE 168



C&I INSPECTION FIRST-PASS ACCEPTANCE

EXAMPLE VALUES

First-pass accepted	4,620
Inspected	4,900



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use consistent inspection lots and acceptance criteria. Trend the metric by contractor, system and reporting period and close adverse findings promptly. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 94.3\% \times 0.95 = 89.6\%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	94.3 %
K_design	0.95
X_design	89.6 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$Margin = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 89.6\% - 80.6\% = 8.96\%$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

94.3 %

worked result

CONSERVATIVE

89.6 %

factor 0.95

MINIMUM

80.6 %

project criterion

MARGIN

8.96 %

available difference

GCC design note: Use consistent inspection lots and acceptance criteria. Trend the metric by contractor, system and reporting period and close adverse findings promptly. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I LOST-TIME INJURY FREQUENCY

FORMULA

$$LTIFR = LTI \times 1e6 / H_work$$

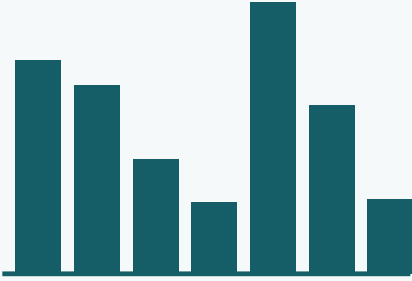
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$LTIFR = 2 \times 1,000,000 / 1,850,000 = 1.081$$

Calculated result = 1.081 per million h

C&I PV FIGURE 169



C&I LOST-TIME INJURY FREQUENCY

EXAMPLE VALUES

Lost-time injuries	2
Hours worked	1,850,000



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply the client and jurisdiction reporting definition. Trend the metric by contractor, system and reporting period and close adverse findings promptly. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_design = X_calculated \times K_upper$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 1.08 \text{ per million h} \times 1.05 = 1.14 \text{ per million h}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	1.08 per million h
K_design	1.05
X_design	1.14 per million h



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_limit - X_design$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 1.25 \text{ per million h} - 1.14 \text{ per million h} = 0.114 \text{ per million h}$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

1.08 per million h

worked result

DESIGN

1.14 per million h

factor 1.05

LIMIT

1.25 per million h

project criterion

MARGIN

0.114 per million h

available difference

GCC design note: Apply the client and jurisdiction reporting definition. Trend the metric by contractor, system and reporting period and close adverse findings promptly. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I CONTROLLED-DOCUMENT APPROVAL

FORMULA

C_doc = N_approved / N_submitted

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

C_doc = 1,284 / 1,400 = 91.71%
Calculated result = 91.71 %

C&I PV FIGURE 170



C&I CONTROLLED-DOCUMENT APPROVAL

EXAMPLE VALUES

Approved documents	1,284
Submitted documents	1,400



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Track overdue reviews and superseded revisions separately. Trend the metric by contractor, system and reporting period and close adverse findings promptly. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 91.7 % x 0.95 = 87.1 %

GIVEN VALUES FOR EXAMPLE

X_calculated	91.7 %
K_design	0.95
X_design	87.1 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 87.1 % - 78.4 % = 8.71 %



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

91.7 %

worked result

CONSERVATIVE

87.1 %

factor 0.95

MINIMUM

78.4 %

project criterion

MARGIN

8.71 %

available difference

GCC design note: Track overdue reviews and superseded revisions separately. Trend the metric by contractor, system and reporting period and close adverse findings promptly. Plan material quantities, installation productivity, mechanical completion, quality acceptance, safe work and controlled project documentation.



1 CALCULATE C&I PV COMMISSIONING CHECKLIST STATUS

FORMULA

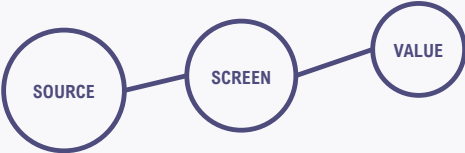
C_check = N_signed / N_total

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

C_check = 3,420 / 3,600 = 95.0%
Calculated result = 95 %

C&I PV FIGURE 171



C&I PV COMMISSIONING CHECKLIST STATUS

EXAMPLE VALUES

Signed checks	3,420
Total checks	3,600



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Blocking checks must be closed before energization. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 95 % x 0.95 = 90.2 %

GIVEN VALUES FOR EXAMPLE

X_calculated	95 %
K_design	0.95
X_design	90.2 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 90.2 % - 81.2 % = 9.02 %



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

95 %

worked result

CONSERVATIVE

90.2 %

factor 0.95

MINIMUM

81.2 %

project criterion

MARGIN

9.02 %

available difference

GCC design note: Blocking checks must be closed before energization. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I PV SYSTEMS TURNOVER COMPLETION

FORMULA

$$C_{\text{test}} = N_{\text{accepted}} / N_{\text{planned}}$$

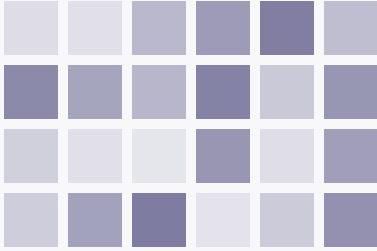
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$C_{\text{test}} = 186 / 200 = 93.0\%$$

Calculated result = 93 %

C&I PV FIGURE 172



C&I PV SYSTEMS TURNOVER COMPLETION

EXAMPLE VALUES

Accepted packages	186
Planned packages	200



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Count only complete packages with records and approved exceptions. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 93 \% \times 0.95 = \mathbf{88.3 \%}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	93 %
K_design	0.95
X_design	88.3 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{\text{design}} - X_{\text{min}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 88.3 \% - 79.5 \% = \mathbf{8.83 \%}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

93 %

worked result

CONSERVATIVE

88.3 %

factor 0.95

MINIMUM

79.5 %

project criterion

MARGIN

8.83 %

available difference

GCC design note: Count only complete packages with records and approved exceptions. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I TRANSFORMER POLARIZATION INDEX

FORMULA

$$PI = R_{10min} / R_{1min}$$

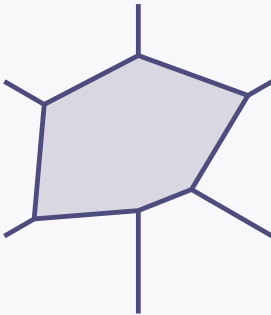
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$PI = 4,800 \text{ Mohm} / 2,100 \text{ Mohm} = 2.286$$

Calculated result = 2.286 ratio

C&I PV FIGURE 173



C&I TRANSFORMER POLARIZATION INDEX

EXAMPLE VALUES

10-minute resistance	4,800 Mohm
1-minute resistance	2,100 Mohm



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Interpret against equipment type, temperature and test standard. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 2.29 \text{ ratio} \times 0.95 = \mathbf{2.17 \text{ ratio}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	2.29 ratio
K_design	0.95
X_design	2.17 ratio



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 2.17 \text{ ratio} - 1.95 \text{ ratio} = \mathbf{0.217 \text{ ratio}}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

2.29 ratio

worked result

CONSERVATIVE

2.17 ratio

factor 0.95

MINIMUM

1.95 ratio

project criterion

MARGIN

0.217 ratio

available difference

GCC design note: Interpret against equipment type, temperature and test standard. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I PROTECTION COMMISSIONING PASS RATE

FORMULA

$$P_{\text{pass}} = N_{\text{pass}} / N_{\text{test}}$$

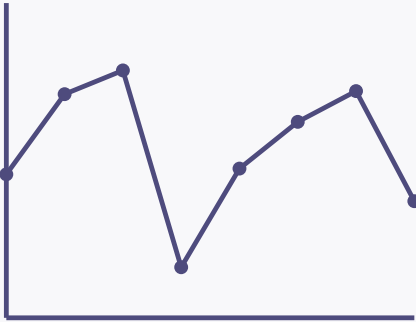
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{\text{pass}} = 478 / 486 = 98.35\%$$

Calculated result = 98.35 %

C&I PV FIGURE 174



C&I PROTECTION COMMISSIONING PASS RATE

EXAMPLE VALUES

Tests passed	478
Tests performed	486



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Retest after correcting settings, wiring or instrument issues. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 98.4 \% \times 0.95 = 93.4 \%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	98.4 %
K_design	0.95
X_design	93.4 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{\text{design}} - X_{\text{min}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 93.4 \% - 84.1 \% = 9.34 \%$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

98.4 %

worked result

CONSERVATIVE

93.4 %

factor 0.95

MINIMUM

84.1 %

project criterion

MARGIN

9.34 %

available difference

GCC design note: Retest after correcting settings, wiring or instrument issues. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I PV ENERGIZATION SEQUENCE

FORMULA

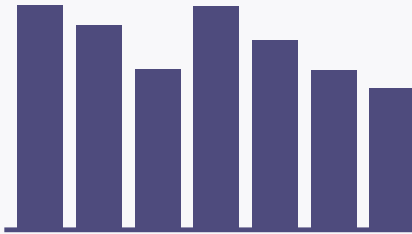
T_energ = sum(T_step)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

T_energ = 3+5+4+6+2 = 20 h
Calculated result = 20 h

C&I PV FIGURE 175



C&I PV ENERGIZATION SEQUENCE

EXAMPLE VALUES

Prechecks	3 h
HV system	5 h
MV blocks	4 h
Plant	6 h; hold 2 h



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include hold points, switching authority and contingency time. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 20 h x 1.10 = 22 h

GIVEN VALUES FOR EXAMPLE

X_calculated	20 h
K_design	1.10
X_design	22 h



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 24.2 h - 22 h = 2.2 h



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

20 h

worked result

REQUIRED

22 h

factor 1.10

SELECTED

24.2 h

project criterion

RESERVE

2.2 h

available difference

GCC design note: Include hold points, switching authority and contingency time. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I RELIABILITY DEMONSTRATION AVAILABILITY

FORMULA

$$A_{run} = (T_{run} - T_{trip}) / T_{run}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$A_{run} = (240 - 6) / 240 = 97.50\%$$

Calculated result = 97.5 %

C&I PV FIGURE 176



C&I RELIABILITY DEMONSTRATION AVAILABILITY

EXAMPLE VALUES

Run duration	240 h
Trip downtime	6 h



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Classify external grid events according to the test protocol. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 97.5\% \times 0.95 = 92.6\%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	97.5 %
K_design	0.95
X_design	92.6 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$Margin = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 92.6\% - 83.4\% = 9.26\%$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

97.5 %

worked result

CONSERVATIVE

92.6 %

factor 0.95

MINIMUM

83.4 %

project criterion

MARGIN

9.26 %

available difference

GCC design note: Classify external grid events according to the test protocol. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I CONTRACT CAPACITY TEST

FORMULA

$$P_{test,corr} = P_{meas} K_{corr}$$

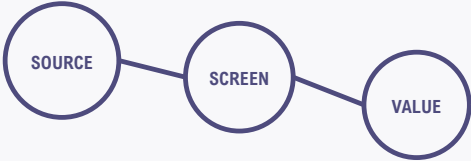
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$P_{test,corr} = 176.4 \text{ MW} \times 1.025 = 180.8 \text{ MW}$$

Calculated result = 180.8 MW

C&I PV FIGURE 177



C&I CONTRACT CAPACITY TEST

EXAMPLE VALUES

Measured power	176.4 MW
Condition correction	1.025

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use the contract-approved correction model and calibrated sensors. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{design} = X_{calculated} \times K_{conservative}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 180.8 \text{ MW} \times 0.95 = 171.8 \text{ MW}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	180.8 MW
K_design	0.95
X_design	171.8 MW

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{design} - X_{min}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 171.8 \text{ MW} - 154.6 \text{ MW} = 17.2 \text{ MW}$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

180.8 MW

worked result

CONSERVATIVE

171.8 MW

factor 0.95

MINIMUM

154.6 MW

project criterion

MARGIN

17.2 MW

available difference

GCC design note: Use the contract-approved correction model and calibrated sensors. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I PERFORMANCE RATIO GUARANTEE

FORMULA

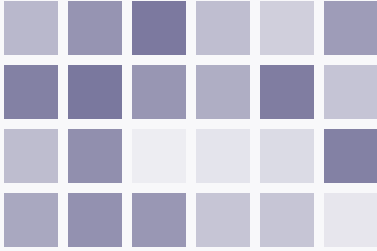
$$M_PR = PR_test - PR_guarantee$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

M_PR = 80.6% - 79.0% = 1.600 percentage points
Calculated result = 1.6 percentage points

C&I PV FIGURE 178



C&I PERFORMANCE RATIO GUARANTEE

EXAMPLE VALUES

Test PR	80.6%
Guaranteed PR	79.0%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply uncertainty and test-period validity requirements. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_design = X_calculated \times K_conservative$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 1.6 percentage points x 0.95 = 1.52 percentage points

GIVEN VALUES FOR EXAMPLE

X_calculated	1.6 percentage points
K_design	0.95
X_design	1.52 percentage points



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$Margin = X_design - X_min$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 1.52 percentage points - 1.37 percentage points = 0.152 percentage points



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

1.6 percentage points

worked result

CONSERVATIVE

1.52 percentage points

factor 0.95

MINIMUM

1.37 percentage points

project criterion

MARGIN

0.152 percentage points

available difference

GCC design note: Apply uncertainty and test-period validity requirements. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I REVENUE METER ERROR

FORMULA

$$d_meter = (E_main - E_check) / E_check$$

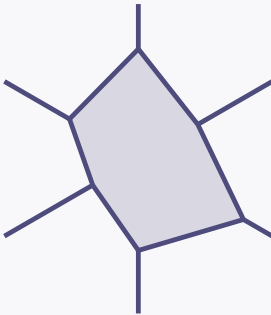
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$d_meter = (28,540 - 28,500) / 28,500 = 0.1404\%$$

Calculated result = 0.1404 %

C&I PV FIGURE 179



C&I REVENUE METER ERROR

EXAMPLE VALUES

Main meter	28,540 MWh
Check meter	28,500 MWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Investigate time synchronization, transformer ratios and calibration. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_design = X_calculated \times K_upper$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 0.14\% \times 1.05 = 0.147\%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.14 %
K_design	1.05
X_design	0.147 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_limit - X_design$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 0.162\% - 0.147\% = 0.015\%$$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

0.14 %

worked result

DESIGN

0.147 %

factor 1.05

LIMIT

0.162 %

project criterion

MARGIN

0.015 %

available difference

GCC design note: Investigate time synchronization, transformer ratios and calibration. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I COMMERCIAL OPERATION GATE

FORMULA

$$R_COD = \sum(w_i c_i)$$

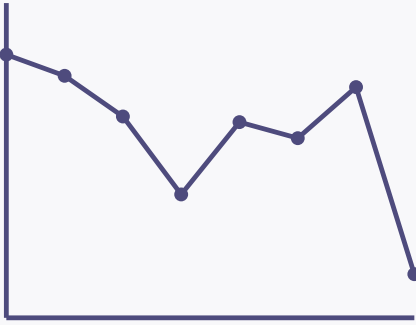
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$R_COD = 0.30 \times 100 + 0.25 \times 96 + 0.20 \times 94 + 0.15 \times 90 + 0.10 \times 88 = 95.1$$

Calculated result = 95.1 score

C&I PV FIGURE 180



C&I COMMERCIAL OPERATION GATE

EXAMPLE VALUES

Safety	30% at 100
Testing	25% at 96
Permits	20% at 94
Docs	15% at 90; training 10% at 88

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: All mandatory contractual conditions precedent must still be met. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_design = X_calculated \times K_conservative$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 95.1 \text{ score} \times 0.95 = \mathbf{90.3 \text{ score}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	95.1 score
K_design	0.95
X_design	90.3 score

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_design - X_min$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 90.3 \text{ score} - 81.3 \text{ score} = \mathbf{9.03 \text{ score}}$$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

95.1 score

worked result

CONSERVATIVE

90.3 score

factor 0.95

MINIMUM

81.3 score

project criterion

MARGIN

9.03 score

available difference

GCC design note: All mandatory contractual conditions precedent must still be met. Use calibrated instruments, approved procedures and contractual acceptance criteria. Control test packages, electrical verification, energization, capacity, performance-ratio, metering and commercial-operation acceptance.



1 CALCULATE C&I PV OPERATIONAL AVAILABILITY

FORMULA

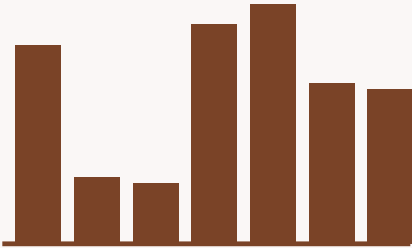
A = MTBF/(MTBF+MTTR)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

A = 2,400/(2,400+18) = 99.26%
Calculated result = 99.26 %

C&I PV FIGURE 181



C&I PV OPERATIONAL AVAILABILITY

EXAMPLE VALUES

MTBF	2,400 h
MTTR	18 h

i

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: This steady-state formula assumes repairable equipment. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 99.3 % x 0.95 = 94.3 %

GIVEN VALUES FOR EXAMPLE

X_calculated	99.3 %
K_design	0.95
X_design	94.3 %

i

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 94.3 % - 84.9 % = 9.43 %

i

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

i

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK

SUMMARY

CALCULATED

99.3 %

worked result

CONSERVATIVE

94.3 %

factor 0.95

MINIMUM

84.9 %

project criterion

MARGIN

9.43 %

available difference

GCC design note: This steady-state formula assumes repairable equipment. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE C&I PV MEAN TIME BETWEEN FAILURES

FORMULA

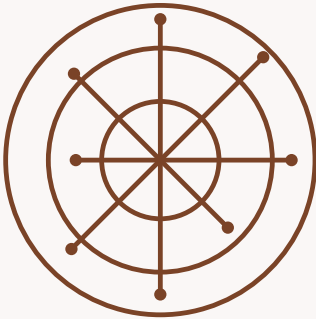
MTBF = T_operating/N_fail

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

MTBF = 48,000/16 = 3,000 h
Calculated result = 3,000 h

C&I PV FIGURE 182



C&I PV MEAN TIME BETWEEN FAILURES

EXAMPLE VALUES

Operating time	48,000 h
Failures	16



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use exposure hours across the defined equipment population. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 3,000 h x 0.95 = 2,850 h

GIVEN VALUES FOR EXAMPLE

X_calculated	3,000 h
K_design	0.95
X_design	2,850 h



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 2,850 h - 2,565 h = 285 h



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

3,000 h

worked result

CONSERVATIVE

2,850 h

factor 0.95

MINIMUM

2,565 h

project criterion

MARGIN

285 h

available difference

GCC design note: Use exposure hours across the defined equipment population. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE C&I PV MEAN TIME TO REPAIR

FORMULA

$$MTTR = T_repair / N_repair$$

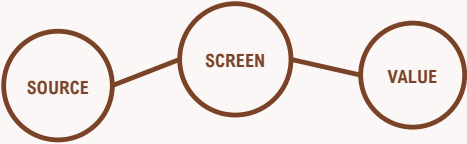
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$MTTR = 286 / 22 = 13.00 \text{ h}$$

Calculated result = 13 h

C&I PV FIGURE 183



C&I PV MEAN TIME TO REPAIR

EXAMPLE VALUES

Repair hours	286 h
Repairs	22



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Define whether logistics and waiting time are included. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_design = X_calculated \times K_conservative$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 13 \text{ h} \times 0.95 = 12.3 \text{ h}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	13 h
K_design	0.95
X_design	12.3 h



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$Margin = X_design - X_min$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Margin = 12.3 \text{ h} - 11.1 \text{ h} = 1.23 \text{ h}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

13 h

worked result

CONSERVATIVE

12.3 h

factor 0.95

MINIMUM

11.1 h

project criterion

MARGIN

1.23 h

available difference

GCC design note: Define whether logistics and waiting time are included. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE C&I SERIES-PATH RELIABILITY

FORMULA

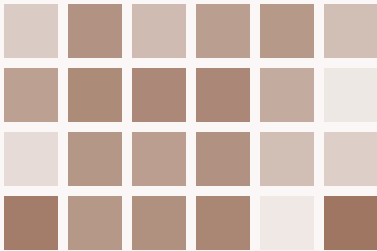
$R_s = \text{prod}(R_i)$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_s = 0.992 \times 0.985 \times 0.996 = 97.32\%$
Calculated result = 97.32 %

C&I PV FIGURE 184



C&I SERIES-PATH RELIABILITY

EXAMPLE VALUES

Subsystem A	99.2%
Subsystem B	98.5%
Subsystem C	99.6%

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: A series system succeeds only when every required element succeeds. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 97.3\% \times 0.95 = 92.5\%$

GIVEN VALUES FOR EXAMPLE

X_calculated	97.3 %
K_design	0.95
X_design	92.5 %

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$\text{Margin} = X_{\text{design}} - X_{\text{min}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Margin} = 92.5\% - 83.2\% = 9.25\%$

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

97.3 %

worked result

CONSERVATIVE

92.5 %

factor 0.95

MINIMUM

83.2 %

project criterion

MARGIN

9.25 %

available difference

GCC design note: A series system succeeds only when every required element succeeds. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE C&I PARALLEL REDUNDANCY RELIABILITY

FORMULA

$$R_p = 1 - \text{prod}(1 - R_i)$$

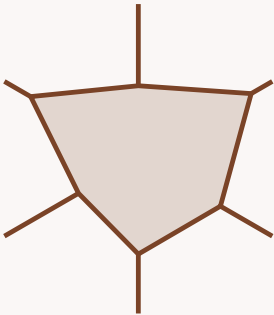
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$R_p = 1 - (1 - 0.92)(1 - 0.92) = 99.36\%$$

Calculated result = 99.36 %

C&I PV FIGURE 185



C&I PARALLEL REDUNDANCY RELIABILITY

EXAMPLE VALUES

Branch A	92%
Branch B	92%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: This result assumes independent branches and successful switching. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 99.4\% \times 0.95 = \mathbf{94.4\%}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	99.4 %
K_design	0.95
X_design	94.4 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{\text{design}} - X_{\text{min}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 94.4\% - 85\% = \mathbf{9.44\%}$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

99.4 %

worked result

CONSERVATIVE

94.4 %

factor 0.95

MINIMUM

85 %

project criterion

MARGIN

9.44 %

available difference

GCC design note: This result assumes independent branches and successful switching. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE C&I MISSION-TIME RELIABILITY

FORMULA

$$R(t) = \exp(-\lambda t)$$

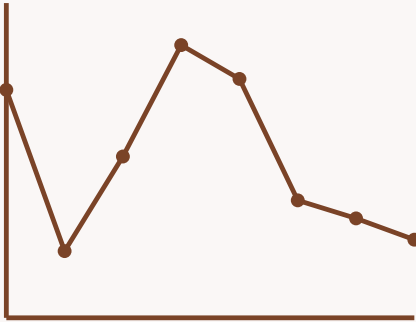
Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$R = \exp(-1.8e-5 \times 8,760) = 85.40\%$$

Calculated result = 85.41 %

C&I PV FIGURE 186



C&I MISSION-TIME RELIABILITY

EXAMPLE VALUES

Failure rate	1.8e-5 per h
Mission time	8,760 h



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: A constant failure rate is not valid across every life stage. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

$$X_{\text{design}} = X_{\text{calculated}} \times K_{\text{conservative}}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{\text{design}} = 85.4 \% \times 0.95 = 81.1 \%$$

GIVEN VALUES FOR EXAMPLE

X_calculated	85.4 %
K_design	0.95
X_design	81.1 %



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

$$\text{Margin} = X_{\text{design}} - X_{\text{min}}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 81.1 \% - 73 \% = 8.11 \%$$



WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.



IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

85.4 %

worked result

CONSERVATIVE

81.1 %

factor 0.95

MINIMUM

73 %

project criterion

MARGIN

8.11 %

available difference

GCC design note: A constant failure rate is not valid across every life stage. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE C&I PV COMPONENT FAILURE RATE

FORMULA

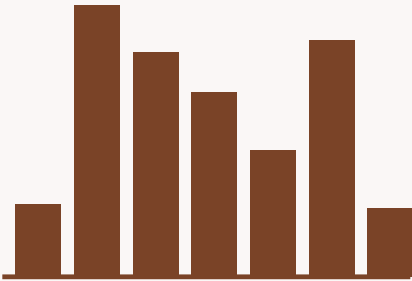
$\lambda = N_{fail} / T_{exposure}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$\lambda = 14 / 180,000 = 0.07778 \text{ failures/1000h}$
Calculated result = 0.0778 failures/1000h

C&I PV FIGURE 187



C&I PV COMPONENT FAILURE RATE

EXAMPLE VALUES

Failures	14
Exposure	180,000 h



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use consistent equipment populations and observation periods. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$X_{design} = X_{calculated} \times K_{upper}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 0.078 \text{ failures/1000h} \times 1.05 = 0.082 \text{ failures/1000h}$

GIVEN VALUES FOR EXAMPLE

X_calculated	0.078 failures/1000h
K_design	1.05
X_design	0.082 failures/1000h



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$Margin = X_{limit} - X_{design}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Margin = 0.09 \text{ failures/1000h} - 0.082 \text{ failures/1000h} = 0.008 \text{ failures/1000h}$



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

0.078 failures/1000h

worked result

DESIGN

0.082 failures/1000h

factor 1.05

LIMIT

0.09 failures/1000h

project criterion

MARGIN

0.008 failures/1000h

available difference

GCC design note: Use consistent equipment populations and observation periods. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE EXPECTED ANNUAL C&I PV FAILURES

FORMULA

$$N_{exp} = \lambda N_{unit} t$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$N_{exp} = 2.2e-5 \times 120 \times 8,760 = 23.13 \text{ failures}$$

Calculated result = 23.13 failures

C&I PV FIGURE 188



EXPECTED ANNUAL C&I PV FAILURES

EXAMPLE VALUES

Failure rate	2.2e-5 per h
Units	120
Time	8,760 h

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Account for age and common-cause effects where material. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_{design} = X_{calculated} \times K_{upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_{design} = 23.1 \text{ failures} \times 1.05 = \mathbf{24.3 \text{ failures}}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	23.1 failures
K_design	1.05
X_design	24.3 failures

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = X_{limit} - X_{design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$\text{Margin} = 26.7 \text{ failures} - 24.3 \text{ failures} = \mathbf{2.43 \text{ failures}}$$

WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.

IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

23.1 failures

worked result

DESIGN

24.3 failures

factor 1.05

LIMIT

26.7 failures

project criterion

MARGIN

2.43 failures

available difference

GCC design note: Account for age and common-cause effects where material. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE C&I CRITICAL SPARE HOLDING QUANTITY

FORMULA

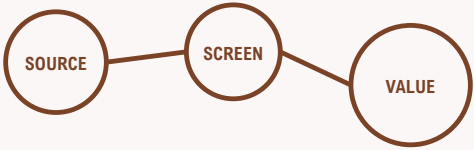
N_spare = ceil(N_installed x r_spare)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

N_spare = ceil(240 x 0.03) = 8 units
Calculated result = 8 units

C&I PV FIGURE 189



C&I CRITICAL SPARE HOLDING QUANTITY

EXAMPLE VALUES

Installed	240
Spare rate	3%



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Criticality and procurement lead time matter more than a universal percentage. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 8 units x 1.10 = **9 units**

GIVEN VALUES FOR EXAMPLE

X_calculated	8 units
K_design	1.10
X_design	9 units



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 10 units - 9 units = **1 unit**



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

8 units

worked result

REQUIRED

9 units

factor 1.10

SELECTED

10 units

project criterion

RESERVE

1 unit

available difference

GCC design note: Criticality and procurement lead time matter more than a universal percentage. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE ANNUAL C&I PV PREVENTIVE LABOR

FORMULA

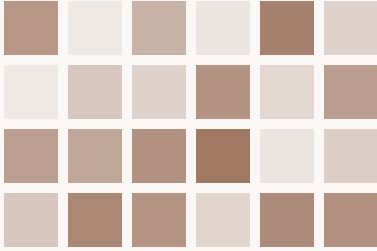
$H_{PM} = N_{assets} \times tasks \times hours$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$H_{PM} = 60 \times 4 \times 2 = 480 \text{ labor-hours/year}$
Calculated result = 480 labor-h/year

C&I PV FIGURE 190



ANNUAL C&I PV PREVENTIVE LABOR

EXAMPLE VALUES

Assets	60
Tasks	4/year
Duration	2 h

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add travel, permit, isolation and restoration time. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{required} = X_{calculated} \times K_{design}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 480 \text{ labor-h/year} \times 1.10 = 528 \text{ labor-h/year}$

GIVEN VALUES FOR EXAMPLE

X_calculated	480 labor-h/year
K_design	1.10
X_design	528 labor-h/year

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$Reserve = X_{selected} - X_{required}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 580.8 \text{ labor-h/year} - 528 \text{ labor-h/year} = 52.8 \text{ labor-h/year}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

480 labor-h/year

worked result

REQUIRED

528 labor-h/year

factor 1.10

SELECTED

580.8 labor-h/year

project criterion

RESERVE

52.8 labor-h/year

available difference

GCC design note: Add travel, permit, isolation and restoration time. Use component failure data, repair logistics and common-cause analysis for final RAM studies. Set reliability, maintenance, spares and failure-response targets that fit facility access, production schedules and service agreements.



1 CALCULATE C&I DIRECT INSTALLED PV COST

FORMULA

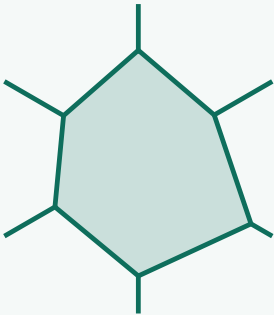
C_direct = sum(C_i)

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

C_direct = 310+42+38+24+16 = 430 MSAR
Calculated result = 430 MSAR

C&I PV FIGURE 191



C&I DIRECT INSTALLED PV COST

EXAMPLE VALUES

Generation	310 MSAR
Electrical	42 MSAR
Civil	38 MSAR
Grid	24; controls 16 MSAR



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use a consistent estimate date, currency and scope boundary. Base the project budget on the approved scope, estimate class, quotations and escalation date. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

X_required = X_calculated x K_design

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 430 MSAR x 1.10 = 473 MSAR

GIVEN VALUES FOR EXAMPLE

X_calculated	430 MSAR
K_design	1.10
X_design	473 MSAR



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

Reserve = X_selected - X_required

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Reserve = 520.3 MSAR - 473 MSAR = 47.3 MSAR



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

430 MSAR

worked result

REQUIRED

473 MSAR

factor 1.10

SELECTED

520.3 MSAR

project criterion

RESERVE

47.3 MSAR

available difference

GCC design note: Use a consistent estimate date, currency and scope boundary. Base the project budget on the approved scope, estimate class, quotations and escalation date. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE C&I TOTAL PV INVESTMENT

FORMULA

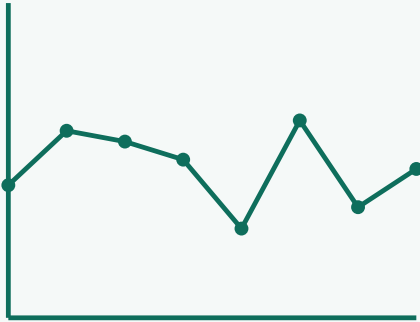
$C_{total} = C_{EPC} + C_{dev} + C_{cont}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$C_{total} = 466.6 + 18.0 + 35.0 = 519.6$ MSAR
Calculated result = 519.5 MSAR

C&I PV FIGURE 192



C&I TOTAL PV INVESTMENT

EXAMPLE VALUES

EPC	466.6 MSAR
Development	18.0 MSAR
Contingency	35.0 MSAR

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Add financing, land and taxes only when inside the stated boundary. Base the project budget on the approved scope, estimate class, quotations and escalation date. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{required} = X_{calculated} \times K_{design}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{design} = 519.5 \text{ MSAR} \times 1.10 = 571.5$ MSAR

GIVEN VALUES FOR EXAMPLE

$X_{calculated}$	519.5 MSAR
K_{design}	1.10
X_{design}	571.5 MSAR

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$Reserve = X_{selected} - X_{required}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 628.6 \text{ MSAR} - 571.5 \text{ MSAR} = 57.1$ MSAR

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

519.5 MSAR

worked result

REQUIRED

571.5 MSAR

factor 1.10

SELECTED

628.6 MSAR

project criterion

RESERVE

57.1 MSAR

available difference

GCC design note: Add financing, land and taxes only when inside the stated boundary. Base the project budget on the approved scope, estimate class, quotations and escalation date. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE C&I INSTALLED PV COST PER KILOWATT

FORMULA

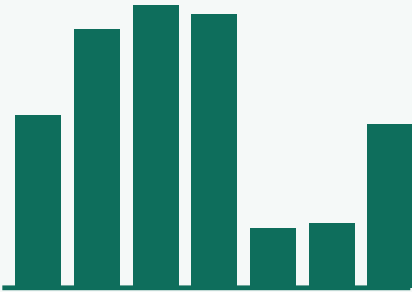
C_kW = C_total / P_AC

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

C_kW = 519.6 MSAR / 180 MW = 2,886 SAR/kW
Calculated result = 2,886.3 SAR/kW

C&I PV FIGURE 193



C&I INSTALLED PV COST PER KILOWATT

EXAMPLE VALUES

Total CAPEX	519.6 MSAR
AC capacity	180 MW



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Compare projects on the same capacity and cost basis. Base the project budget on the approved scope, estimate class, quotations and escalation date. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

X_design = X_calculated x K_upper

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 2,886 SAR/kW x 1.05 = 3,031 SAR/kW

GIVEN VALUES FOR EXAMPLE

X_calculated	2,886 SAR/kW
K_design	1.05
X_design	3,031 SAR/kW



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

Margin = X_limit - X_design

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 3,334 SAR/kW - 3,031 SAR/kW = 303.1 SAR/kW



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

2,886 SAR/kW

worked result

DESIGN

3,031 SAR/kW

factor 1.05

LIMIT

3,334 SAR/kW

project criterion

MARGIN

303.1 SAR/kW

available difference

GCC design note: Compare projects on the same capacity and cost basis. Base the project budget on the approved scope, estimate class, quotations and escalation date. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE ANNUAL C&I PV FIXED O&M COST

FORMULA

$C_OPEX = \text{sum}(C_fixed)$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$C_OPEX = 6.2 + 2.1 + 1.4 + 0.8 = 10.5 \text{ MSAR/year}$
Calculated result = 10.5 MSAR/year

C&I PV FIGURE 194



ANNUAL C&I PV FIXED O&M COST

EXAMPLE VALUES

O&M contract	6.2 MSAR
Land	2.1 MSAR
Insurance	1.4 MSAR
Other	0.8 MSAR

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Separate fixed and energy-dependent operating costs. Base the project budget on the approved scope, estimate class, quotations and escalation date. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_required = X_calculated \times K_design$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_design = 10.5 \text{ MSAR/year} \times 1.10 = 11.6 \text{ MSAR/year}$

GIVEN VALUES FOR EXAMPLE

X_calculated	10.5 MSAR/year
K_design	1.10
X_design	11.6 MSAR/year

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$Reserve = X_selected - X_required$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$Reserve = 12.7 \text{ MSAR/year} - 11.6 \text{ MSAR/year} = 1.16 \text{ MSAR/year}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

10.5 MSAR/year

worked result

REQUIRED

11.6 MSAR/year

factor 1.10

SELECTED

12.7 MSAR/year

project criterion

RESERVE

1.16 MSAR/year

available difference

GCC design note: Separate fixed and energy-dependent operating costs. Base the project budget on the approved scope, estimate class, quotations and escalation date. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE ANNUAL C&I PV ENERGY VALUE

FORMULA

$R_{\text{energy}} = E_{\text{del}} \text{ Tariff}$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$R_{\text{energy}} = 332,900 \text{ MWh} \times 112 \text{ SAR/MWh} = 37.28 \text{ MSAR}$
Calculated result = 37.28 MSAR/year

C&I PV FIGURE 195



ANNUAL C&I PV ENERGY VALUE

EXAMPLE VALUES

Delivered energy	332,900 MWh
Tariff	112 SAR/MWh

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Apply contractual indexation, deemed energy and settlement rules. Use one controlled energy case, currency date, financing basis and degradation convention across the investment model. Use one consistent C&I; capacity, installed-cost, OPEX, self-consumption, tariff, finance and degradation basis through the project life. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$X_{\text{required}} = X_{\text{calculated}} \times K_{\text{design}}$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$X_{\text{design}} = 37.3 \text{ MSAR/year} \times 1.10 = 41 \text{ MSAR/year}$

GIVEN VALUES FOR EXAMPLE

$X_{\text{calculated}}$	37.3 MSAR/year
K_{design}	1.10
X_{design}	41 MSAR/year

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$\text{Reserve} = X_{\text{selected}} - X_{\text{required}}$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$\text{Reserve} = 45.1 \text{ MSAR/year} - 41 \text{ MSAR/year} = 4.1 \text{ MSAR/year}$

WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.

IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

37.3 MSAR/year

worked result

REQUIRED

41 MSAR/year

factor 1.10

SELECTED

45.1 MSAR/year

project criterion

RESERVE

4.1 MSAR/year

available difference

GCC design note: Apply contractual indexation, deemed energy and settlement rules. Use one controlled energy case, currency date, financing basis and degradation convention across the investment model. Use one consistent C&I; capacity, installed-cost, OPEX, self-consumption, tariff, finance and degradation basis through the project life. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE C&I PV FREE OPERATING CASH FLOW

FORMULA

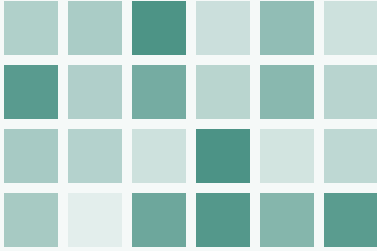
CF_oper = Revenue - OPEX

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

CF_oper = 37.28 - 10.50 = 26.78 MSAR/year
Calculated result = 26.78 MSAR/year

C&I PV FIGURE 196



C&I PV FREE OPERATING CASH FLOW

EXAMPLE VALUES

Revenue	37.28 MSAR
OPEX	10.50 MSAR

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include taxes, working capital and reserve movements where relevant. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 26.8 MSAR/year x 0.95 = **25.4 MSAR/year**

GIVEN VALUES FOR EXAMPLE

X_calculated	26.8 MSAR/year
K_design	0.95
X_design	25.4 MSAR/year

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 25.4 MSAR/year - 22.9 MSAR/year = **2.54 MSAR/year**

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

26.8 MSAR/year

worked result

CONSERVATIVE

25.4 MSAR/year

factor 0.95

MINIMUM

22.9 MSAR/year

project criterion

MARGIN

2.54 MSAR/year

available difference

GCC design note: Include taxes, working capital and reserve movements where relevant. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE C&I PV SIMPLE PAYBACK

FORMULA

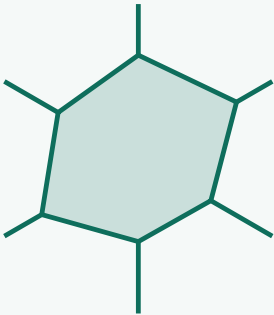
$$PB = C_total / CF_oper$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

PB = 519.6 MSAR / 26.78 MSAR/year = 19.40 years
Calculated result = 19.4 years

C&I PV FIGURE 197



C&I PV SIMPLE PAYBACK

EXAMPLE VALUES

Investment	519.6 MSAR
Annual cash flow	26.78 MSAR



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Simple payback ignores discounting and post-payback cash flow. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$X_design = X_calculated \times K_upper$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 19.4 years x 1.05 = 20.4 years

GIVEN VALUES FOR EXAMPLE

X_calculated	19.4 years
K_design	1.05
X_design	20.4 years



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$Margin = X_limit - X_design$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 22.4 years - 20.4 years = 2.04 years



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

19.4 years

worked result

DESIGN

20.4 years

factor 1.05

LIMIT

22.4 years

project criterion

MARGIN

2.04 years

available difference

GCC design note: Simple payback ignores discounting and post-payback cash flow. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE C&I PV NET PRESENT VALUE

FORMULA

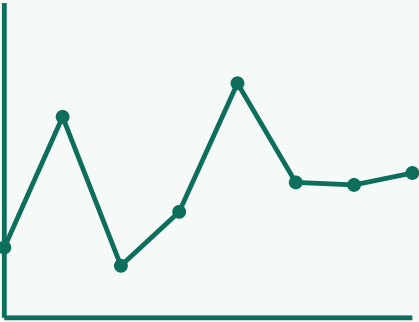
NPV = PV_inflows-PV_outflows

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

NPV = 565 MSAR - 519.6 MSAR = 45.46 MSAR
Calculated result = 45.46 MSAR

C&I PV FIGURE 198



C&I PV NET PRESENT VALUE

EXAMPLE VALUES

PV inflows	565 MSAR
PV outflows	519.6 MSAR

WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Use complete financing, tax and terminal-value assumptions. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY CONSERVATIVE PERFORMANCE FACTOR

FORMULA

X_design = X_calculated x K_conservative

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 45.5 MSAR x 0.95 = **43.2 MSAR**

GIVEN VALUES FOR EXAMPLE

X_calculated	45.5 MSAR
K_design	0.95
X_design	43.2 MSAR

KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MINIMUM PROJECT CRITERION

FORMULA

Margin = X_design - X_min

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 43.2 MSAR - 38.9 MSAR = **4.32 MSAR**

WHERE IS THIS VALUE USED?

Performance guarantees, minimum acceptance values and conservative project forecasts.

IMPORTANT

Use a project-specific factor supported by measured data, manufacturer guarantees or the applicable standard.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

45.5 MSAR

worked result

CONSERVATIVE

43.2 MSAR

factor 0.95

MINIMUM

38.9 MSAR

project criterion

MARGIN

4.32 MSAR

available difference

GCC design note: Use complete financing, tax and terminal-value assumptions. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE C&I PV LEVELIZED ENERGY COST

FORMULA

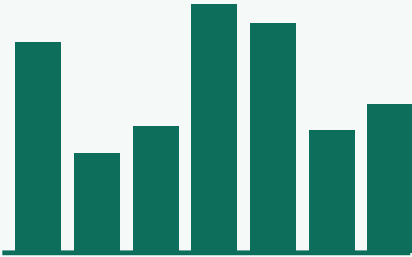
$$\text{LCOE} = \text{PV_cost} / \text{PV_energy}$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

LCOE = 650 MSAR / 6.10 TWh = 106.6 SAR/MWh
Calculated result = 106.6 SAR/MWh

C&I PV FIGURE 199



C&I PV LEVELIZED ENERGY COST

EXAMPLE VALUES

Present-value cost	650 MSAR
Present-value energy	6.10 TWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Discount costs and energy consistently over the same life. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY CONSERVATIVE UPPER ALLOWANCE

FORMULA

$$\text{X_design} = \text{X_calculated} \times \text{K_upper}$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

X_design = 106.6 SAR/MWh x 1.05 = 111.9 SAR/MWh

GIVEN VALUES FOR EXAMPLE

X_calculated	106.6 SAR/MWh
K_design	1.05
X_design	111.9 SAR/MWh



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 CHECK MAXIMUM ALLOWABLE LIMIT

FORMULA

$$\text{Margin} = \text{X_limit} - \text{X_design}$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

Margin = 123.1 SAR/MWh - 111.9 SAR/MWh = 11.2 SAR/MWh



WHERE IS THIS VALUE USED?

Equipment limits, loss budgets, protection settings and compliance checks.



IMPORTANT

The allowable limit must come from the adopted code, grid rule, contract or manufacturer data.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.

OK SUMMARY

CALCULATED

106.6 SAR/MWh

worked result

DESIGN

111.9 SAR/MWh

factor 1.05

LIMIT

123.1 SAR/MWh

project criterion

MARGIN

11.2 SAR/MWh

available difference

GCC design note: Discount costs and energy consistently over the same life. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



1 CALCULATE C&I PV MINIMUM BANKABLE TARIFF

FORMULA

$$T_BE = (OPEX+Debt+Tax)/E_del$$

Use one consistent unit system and define the calculation boundary before substitution.

WORKED EXAMPLE

$$T_BE = (10.5+22.5+2.0) \text{ MSAR} / 332,900 \text{ MWh} = 105.1 \text{ SAR/MWh}$$

Calculated result = 105.1 SAR/MWh

C&I PV FIGURE 200



C&I PV MINIMUM BANKABLE TARIFF

EXAMPLE VALUES

Annual obligations	35.0 MSAR
Delivered energy	332,900 MWh



WHERE

The symbols and values shown are the inputs used in this worked example.

Basis: Include reserve funding and contractual revenue adjustments. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.

2 APPLY PROJECT DESIGN ALLOWANCE

FORMULA

$$X_required = X_calculated \times K_design$$

The factor illustrates a preliminary conservative design adjustment.

WORKED EXAMPLE

$$X_design = 105.1 \text{ SAR/MWh} \times 1.10 = 115.7 \text{ SAR/MWh}$$

GIVEN VALUES FOR EXAMPLE

X_calculated	105.1 SAR/MWh
K_design	1.10
X_design	115.7 SAR/MWh



KEY POINT

Replace the illustrative factor with the approved project value during detailed design.

Design check: Retain traceable inputs, units, assumptions and source references in the design calculation.

3 SELECT RATING AND CONFIRM RESERVE

FORMULA

$$Reserve = X_selected - X_required$$

A positive margin indicates that the illustrative project criterion is satisfied.

WORKED EXAMPLE

$$Reserve = 127.2 \text{ SAR/MWh} - 115.7 \text{ SAR/MWh} = 11.6 \text{ SAR/MWh}$$



WHERE IS THIS VALUE USED?

Preliminary equipment selection, procurement schedules and design-basis documentation.



IMPORTANT

Select the next compliant standard rating after checking environmental derating and operating duty.

Basis: Final acceptance remains subject to current local authority requirements and detailed engineering review.



SUMMARY

CALCULATED

105.1 SAR/MWh

worked result

REQUIRED

115.7 SAR/MWh

factor 1.10

SELECTED

127.2 SAR/MWh

project criterion

RESERVE

11.6 SAR/MWh

available difference

GCC design note: Include reserve funding and contractual revenue adjustments. Use the same energy, cost, tax, financing and timing assumptions throughout the investment model. Use one controlled energy case, tariff basis, installed cost, O&M; forecast, financing convention and discount rate throughout the C&I; investment model.



References

COMMERCIAL AND INDUSTRIAL SOLAR PV ENGINEERING SOURCES

IEC 61215 series	Terrestrial PV module design qualification and type approval.
IEC 61730 series	PV module safety qualification.
IEC 62548 series	Photovoltaic array design requirements.
IEC 62446 series	PV documentation, commissioning tests and inspection.
IEC 61724-1	Photovoltaic system performance monitoring.
IEC 60364-7-712	Requirements for photovoltaic power-supply systems.
IEC 60364-5-52	Selection and erection of wiring systems.
IEC 60364-4-41	Protection against electric shock.
IEC 61643-32	Surge protective devices for photovoltaic installations.
IEC 62305 series	Protection against lightning.
IEC 60947-2	Low-voltage circuit-breaker requirements and performance.

IEC 61439 series	Low-voltage switchgear and controlgear assemblies.
IEC 61000 series	Electromagnetic compatibility and power-quality assessment.
IEEE 1547	Interconnection and interoperability of distributed energy resources.
IEEE 519	Harmonic control in electric-power systems.
NFPA 70 / 70E	Electrical installation and workplace safety requirements where adopted.
NFPA 855	Stationary energy-storage fire-safety requirements where applicable.
IEA PVPS Task 13	PV reliability, performance and field-assessment guidance.
IFC	International Fire Code provisions adopted for the facility.
ASCE/SEI 7	Minimum design loads and associated building criteria.
GCC utility codes	Current national grid and interconnection requirements.
C&I facility design basis	Approved load, tariff, structural, fire, electrical and operating data.

Verify edition, equipment scope, boundary conditions, units, environmental derating and project requirements before using any source.



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