Solar Farm Design & Construction Package

Project	Banke 10 MW solar (test)
Client	-
Location	Nepalgunj
Prepared by	-
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Reviewer	Not reviewed

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Summary in plain words

- A 10 MWp solar farm at Nepalgunj should produce about 16,014 MWh a year (about 14,987 MWh in a poor year, P90).
- Panels tilted 28.1° facing south, rows 7.7 m apart; land about 9.5 ha (14 bigha).
- 27 panels per string, 25 inverters of 330 kVA, transformer about 8.2 MVA.
- Build cost about Rs 65.0 crore; cost per unit Rs 5.06/kWh against a sale price of Rs 5.30/kWh; return 10.7% per year.
- Preliminary feasibility only - a bankable design needs a detailed simulation, site survey, grid study and NEA approval.

Scope and notes

Utility-scale solar farm - method: Neill, Stapleton & Martell, Solar Farms (Earthscan); data: PVGIS, NEA/ERC, NEPQA-2025, indicative Nepal prices.

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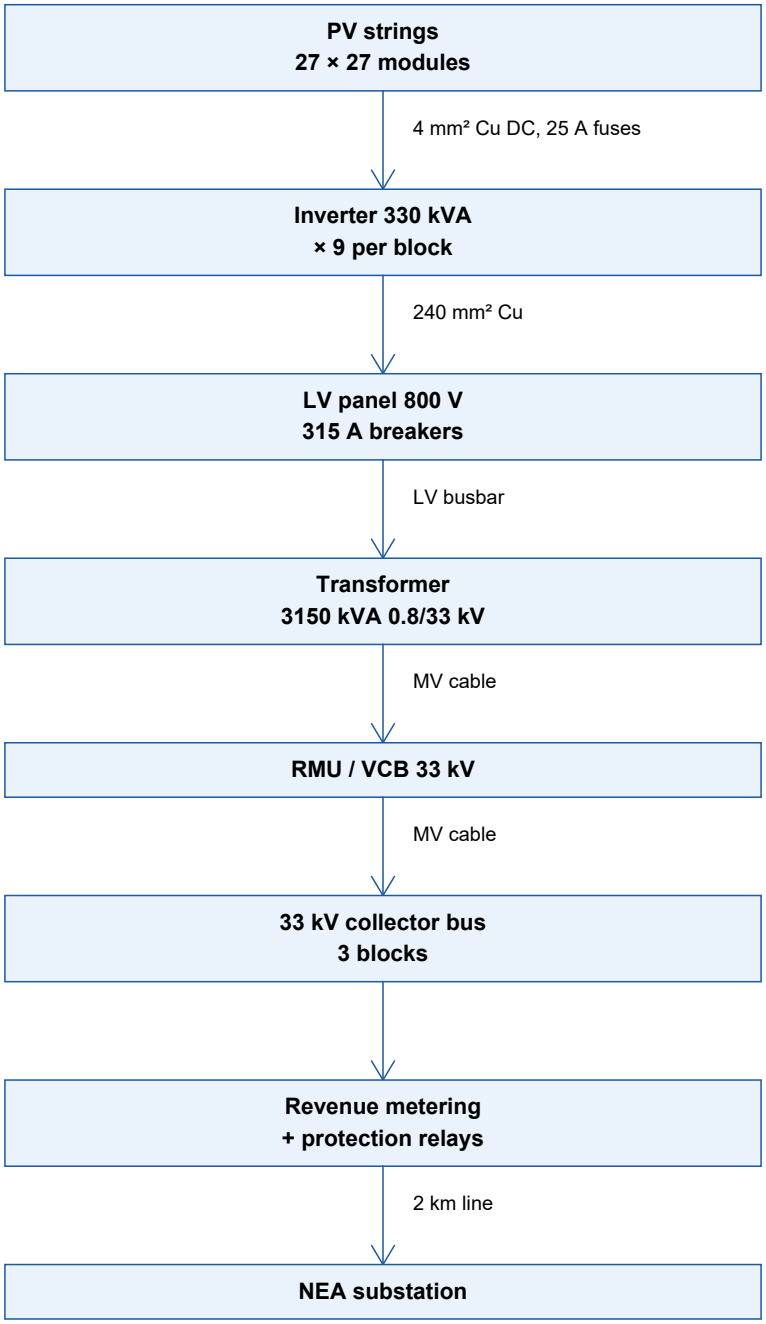
A. Plant at a glance

Utility-scale plants must be designed for construction, built and energised by a licensed EPC contractor under a registered engineer, with NEA approval of the grid connection. This package is a preliminary design basis and bill of quantities for that contractor - not construction drawings.

- 27 modules → 1 string; 27 strings → 1 inverter (400.95 kWp DC / 330 kVA); up to 9 inverters → 1 block transformer; 3 blocks → 33 kV collector → NEA connection

Item	Quantity	Unit
PV modules (550 Wp)	18225	modules
Installed DC capacity	10.024	MWp
Strings of 27 modules	675	strings
Mounting tables (2P × 27)	338	tables
Inverters (330 kVA)	25	inverters
Power blocks (one transformer each)	3	blocks
Total transformer capacity	8800	kVA
Total inverter AC capacity	8.25	MW
Collection / connection voltage	33.0	kV

B. Single-line diagram (one block)



Every connection (wire from this table)

From	To	Cable / protection
PV strings	Inverter 330 kVA	4 mm² Cu DC, 25 A fuses
Inverter 330 kVA	LV panel 800 V	240 mm² Cu
LV panel 800 V	Transformer	LV busbar
Transformer	RMU / VCB 33 kV	MV cable
RMU / VCB 33 kV	33 kV collector bus	MV cable
33 kV collector bus	Revenue metering	
Revenue metering	NEA substation	2 km line

Blocks and transformers

Block	Inverters	Inverter kVA (sum)	Transformer (kVA)	Ratio	DC kWp	MV current (A)
1	9	2970	3150	0.8/33 kV	3608.5	55.1
2	9	2970	3150	0.8/33 kV	3608.5	55.1
3	7	2310	2500	0.8/33 kV	2806.7	43.7

C. Bill of quantities

Item	Specification	Qty	Unit	Basis
PV module	550 Wp, ≥ 21 % efficiency (NEPQA-2025), 1500 V rated	18225	nos	strings × modules per string
Mounting table (fixed tilt)	2P × 27, tilt 28°, galvanised steel	338	nos	modules ÷ per table
Inverter	330 kVA, 1500 V DC, MPPT 500-1500 V, ≥ 97 % efficiency (NEPQA)	25	nos	MWp ÷ kWp per inverter
Step-up transformer	2500 kVA 0.8/33 kV; 3150 kVA 0.8/33 kV, ONAN, Dyn11	3	nos	one per block
MV switchgear (RMU/VCB)	33 kV	5	panels	per block + incomer + feeder
PV string cable	4 mm² Cu, H1Z2Z2-K	81.0	km	2 conductors × strings × average run
MC4-type connector pairs	1500 V, same make as module connectors	1350	pairs	2 field connections per string
String fuses gPV	25 A, 1500 V	1350	nos	both poles of each string
LV AC cable	240 mm² Cu, 0.6/1 kV	15.0	km	4 conductors × inverters × run
MV cable	33 kV XLPE (size by supplier)	4.5	km (single-core)	3 cores × blocks × run
DC SPD Type 2	Ucpv ≥ 1500 V	150	nos	per DC input / combiner
Weather station	POA + GHI pyranometers, temperature sensors	1	nos	1 per ~20 MWp [assumption]
Perimeter fence and gates	Chain-link, 2.1 m, with access gates	1232	m	square site of the fenced area [estimate]
Earthing and lightning	Earth mesh, rods, bonding conductors	1	lot	designer per soil test
SCADA, communications, revenue metering	Per NEA connection agreement	1	lot	verify current procedure

Quantities of cable are estimates from route assumptions - confirm with the detailed layout.

D. Cable schedule

Level	Circuits	Voltage (V)	Design current (A)	Protective device (A)	Size by current (mm²)	Size by voltage drop (mm²)	Selected	Voltage drop (%)	Limit (%)	Conductor length (km, est.)	Note
PV string (DC)	675	1123	13.2	25	4	1.5	4 mm² Cu	0.78	3.0	81.0	Solar cable (EN 50618 H1Z2Z2-K); CCC ≥ string fuse 25 A
Inverter AC (LV) → transformer	25	800	238.2	315	240	185	240 mm² Cu	0.7	1.0	15.0	Breaker 315 A per inverter; 3-phase + PE
MV 33 kV (block → switchyard)	3	33000	55.1	RMU / VCB	by supplier	by supplier	XLPE MV cable - size & screen by supplier for current and fault level	-	1.0	1.5	Radial from each block; consider a ring with RMUs for availability
Line to NEA substation (33 kV)	1	33000	144.3	Feeder VCB + relays	by NEA/designer	by NEA/designer	Overhead line or cable per NEA connection agreement	-	-	2.0	verify current procedure

Size = larger of current rating (Ib ≤ In ≤ Iz) and voltage drop (DC < 3 %, AC < 1 %).

E. Switchgear, protection, earthing and grid connection

Switchgear

Item	Qty	Function
Block RMU / VCB (33 kV)	3	Transformer protection and isolation
Main incomer / outgoing feeder VCB (33 kV)	2	Plant isolation and NEA feeder
LV distribution panel per block	3	Collects 9 inverter feeders
Auxiliary transformer and UPS	1	SCADA, security, lighting

Protection

Item	Requirement	Basis
String fuses (gPV)	25 A, 1500 V DC, both poles	5 strings per input: reverse current (Np−1)·1.25·Isc = 70 A vs module max fuse 30 A
DC switch-disconnector	≥ 1,421 V per pole (1500 V class), ≥ 88 A, DC-rated, lockable	Book Table 4.4: transformerless inverter with equipotential bonding only - rating per pole = array max voltage; functional earthing NOT permitted
DC surge protection	Type 2 PV SPD, Ucpv ≥ 1500 V at each inverter input	IEC 61643-31; string Voc on the coldest morning
AC protection per inverter	315 A breaker, AC SPD Type 2	Ib ≤ In ≤ Iz (IEC 60364-4-43)
MV surge arresters	3 per transformer, 33 kV class	Lightning on MV lines

Earthing and lightning

Item	Spec	Basis
Module frames and structures	Bonded to the earth grid, min 6 mm² Cu (10 mm² where lightning protection is installed) or equivalent	IEC 60364-7-712 equipotential bonding
Earth grid / mesh	Buried mesh (e.g. 50-70 mm² Cu or galvanised steel strip) linking all blocks, rods at inverters and transformers	Designer to verify step/touch voltages from soil resistivity tests
Transformer neutral and MV earthing	Per transformer vector group (e.g. Dyn11) and NEA rules	verify current procedure
Lightning protection	Risk assessment (IEC 62305); air terminals for control room/substation	Neill, Stapleton & Martell, Solar Farms (Earthscan) pp.117-120

NEA interconnection

Item	Spec	Note
Revenue metering (main + check meter, CTs/PTs)	Class 0.2S per NEA connection agreement	verify current procedure
Protection relays (ANSI/IEEE C37.2)	50/51, 50N/51N overcurrent/earth fault; 27/59 under/over voltage; 81U/81O frequency; anti-islanding (ROCOF / vector shift); 87T on large transformers	Settings by NEA - verify current procedure
Power factor / reactive control	Plant controller able to hold PF 0.95 lag-lead (book p.143)	NEA grid code requirement - verify current procedure
SCADA and communications	Inverter/string monitoring, weather station (POA pyranometer, module & ambient temperature), link to NEA Load Dispatch Centre	verify current procedure

F. Construction sequence

1. Site access, clearance and security

- 1. Survey and set out the boundary and blocks
- 2. Build access road and laydown area
- 3. Clear vegetation; manage drainage
- 4. Install fence, gates and site security

2. Foundations and trenches

- 1. Geotechnical pull-out tests on trial piles
- 2. Drive/screw piles or cast footings per the soil report
- 3. Excavate cable trenches; lay ducts with warning tape

3. Substation and MV works

- 1. Build transformer/RMU plinths and control room
- 2. Install transformers, RMUs and MV cables; terminate and test

4. Mounting structures

- 1. Erect 338 tables; check tilt 28° and row pitch 7.75 m
- 2. Torque fasteners to the manufacturer's values

5. Electrical site works

- 1. Mount modules (handle by frame; keep connectors dry)
- 2. Wire strings of 27 modules; label every string
- 3. Install inverters, SPDs, fuses and disconnectors
- 4. Pull and terminate LV cables
- 5. Bond all frames to the earth mesh

6. Communications

- 1. Install weather station, SCADA and network; configure monitoring

7. On-site grid works

- 1. Build the line to the NEA substation; install metering and relays per NEA

8. Testing and commissioning

- 1. Pre-connection tests (below)
- 2. NEA witness test and approval
- 3. Energise block by block
- 4. Post-connection, PR and availability tests

G. Testing and commissioning

Insulation test: system voltage 1,671 V -> test at 1000 V, minimum 1.0 MΩ (Solar Farms Table 5.1, IEC 62446).

Test	Expected	Accept	Basis
Polarity and string open-circuit voltage	1,336 V per string at 25 °C cell	Within ±5 % of expected and equal between strings	book p.175 / IEC 62446-1
String short-circuit current	14.0 A at 1000 W/m² (scale with measured irradiance)	Within ±5-10 % of expected	book p.175
Insulation resistance (DC)	Test at 1000 V	≥ 1 MΩ	book Table 5.1 p.176 (system voltage 1,671 V)
Earth continuity and earth resistance	Continuous bonding; resistance per design	Designer's limit	IEC 62446-1
Substation tests	Cable voltage test, power-frequency test of switchgear, protection functions	Per IEC/TS 61936 and NEA	book p.175
Functional and loss-of-mains test	Inverters stop when the AC isolator opens; restart on reclosure	Immediate stop	book p.176
Performance ratio test	PR ≈ 0.78 (design)	≥ contract value	book p.176
Availability test	Plant generating whenever irradiance allows	Typically ≥ 99 % over ~5 days	book pp.176, 182

H. Operation and maintenance

Activity	Frequency	By
Visual and mechanical inspection	Quarterly	O&M technician
Module cleaning (dust; more in the dry season)	Monthly in Nov-May [assumption for Nepal]	Cleaning crew
Vegetation and grounds	As needed (monsoon growth)	Grounds staff
String I-V curve tests	Annually	Certified electrician
Cables, protection and isolation inspection	Annually	Certified electrician
Thermal (IR) scan of modules, combiners, switchgear	Annually	O&M technician
Transformer maintenance, relay calibration	Annually	HV-authorised electrician
Weather station cleaning / calibration	Fortnightly / annually	Technician
Inverter maintenance	Per manufacturer	Certified electrician
Revenue meter verification	Per PPA / NEA	Certified electrician

I. Permits and approvals in Nepal (verify current procedure)

Item	Authority	Status
DoED survey licence, then generation licence	Department of Electricity Development	verify current procedure
Power purchase agreement (competitive tender)	NEA	verify current procedure
Grid connection study and agreement	NEA (Grid Development / System Planning)	verify current procedure
IEE / EIA environmental approval	Ministry of Forests and Environment / local government	verify current procedure
Land purchase or lease; agricultural-land and ceiling rules	Land Revenue Office / local government	verify current procedure
Forest land clearance (if any)	Department of Forests	verify current procedure
Construction permits and local recommendation	Municipality / rural municipality	verify current procedure

1. Solar farm - energy, layout and land

Input parameters

Plant DC capacity	10 MWp
Latitude	28.05 °
Sun on the tilted panels (PVGIS)	5.625 kWh/m²/day
Table slant length	4.6 m
Module efficiency	21.3 %

Calculation method and equations

- Tilt = latitude, minimum 10° (Box 4.1)
- Row pitch d = l·cosβ + l·sinβ·cosλ / tan α (p.102); α, λ = sun height and direction on 21 Dec at the edge of the shade-free window: sin α = sin φ sin δ + cos φ cos δ cos ω, δ = −23.45°
- GCR = l / d
- PR = Π (1 − loss_i) (p.148)
- Energy = MWp × sun hours × 365 × PR (p.81)
- Capacity factor = Energy / (capacity × 8760 h)
- Land = module area ÷ GCR × (1 + extra for roads/substation) [modern assumption]

Results (calculated by deterministic code)

Panel tilt (facing south)	28.1 °
Row pitch (front edge to front edge)	7.747 m
Clear gap between rows	3.69 m
Ground coverage ratio	0.5937
Performance ratio	0.78
First-year energy (P50)	16,013.64 MWh/yr
Specific yield	1,601.36 kWh/kWp/yr
Capacity factor (DC basis)	18.28 %
Capacity factor (AC basis)	22.16 %
Inverter / export capacity (AC)	8.25 MW
Step-up transformer rating (≥ total inverter kVA)	8.25 MVA
Land needed	9.489 ha
Land needed (Terai units)	14.01 bigha
Land needed (hill units)	186.52 ropani
Land per MWp	0.9489 ha/MWp

Losses

Loss	Loss (%)	Factor
Temperature	11.12	0.8888
Reflection (angle of incidence)	2.43	0.9757
Soiling / dust	3.0	0.97
Mismatch and module tolerance	1.5	0.985
DC cable	1.5	0.985
Inverter	2.0	0.98
AC cable	0.5	0.995
Transformer	1.0	0.99
Availability / downtime	1.0	0.99

Monthly energy

Month	Sun hours	Energy (MWh)
Jan	5.69	1376.0

Month	Sun hours	Energy (MWh)
Feb	6.32	1380.0
Mar	6.94	1678.0
Apr	7.0	1638.0
May	6.37	1540.0
Jun	5.18	1212.0
Jul	3.71	897.0
Aug	4.04	977.0
Sep	4.77	1116.0
Oct	5.9	1427.0
Nov	5.99	1402.0
Dec	5.67	1371.0

Assumptions

- Rows are shade-free from 9:00 to 15:00 solar time on 21 December (book target: < 1 % shading loss a year).
- Extra land 20% for roads, setbacks and substation (assumption).
- Transformer rated at least the total inverter AC kVA (book: match the inverter rating, pp.116-117).
- Energy is the P50 (median) estimate; bankable studies also report P90.

Warnings and limitations

- Preliminary feasibility only: a bankable design needs an hourly simulation (e.g. PVsyst), a geotechnical survey, grid-impact study and NEA connection approval.

Data sources and references

- Neill, Stapleton & Martell, Solar Farms (Earthscan)
- PVGIS v5.3 (EC JRC)
- LBNL utility-scale land-use study (2022) for land-use cross-check

2. String and inverter matching (5-step method)

Input parameters

Module	550 Wp, Voc 49.5 V, Vmp 41.6 V, Isc 14 A
Inverter	330 kVA, 1500 V max, MPPT 500-1500 V, 390 A
Coldest cell temperature (dawn)	-0.3 °C
Hottest cell temperature	70 °C
Book margins	DC drop 2%, min −10%, max +5%

Calculation method and equations

- V(T) = V_STC + γ·(T − 25), γ in V/°C = %/100 × V_STC (pp.106-107)
- N_min = ceil(V_MPPT,min / (Vmp(70 °C) × (1 − DC drop) × 0.9)) (Step 1)
- N_max = floor(V_DC,max / (Voc(T_min) × 1.05)) (Step 2; book prints the inequality reversed)
- Strings = floor(I_DC,max / Isc) (Step 3)
- N × strings × Wp ≤ inverter max DC power (Step 4)

Results (calculated by deterministic code)

Module Vmp at 70 °C cell	36.17 V
Module Voc at -0.3 °C cell	52.63 V
Minimum per string (with margins)	16 modules
Maximum per string (with margins)	27 modules
Minimum per string (no margin)	15 modules
Maximum per string (no margin)	28 modules
Maximum for the MPPT upper limit (secondary check)	31 modules
Maximum parallel strings per inverter (current)	27 strings
Chosen modules per string	27 modules
Strings per inverter (after power check)	27 strings
DC power per inverter	400.95 kWp
DC/AC ratio	1.215
String Voc on the coldest morning	1,421.03 V
Strings per DC input	3 × 4 + 3 × 5 strings
Number of inverters	25 inverters
Total inverter AC rating	8.25 MW

Assumptions

- Coldest cell temperature equals the record minimum ambient at dawn.
- The book applies the Pmax temperature coefficient to Vmp; the same approximation is used here.

Data sources and references

- Neill, Stapleton & Martell, Solar Farms (Earthscan), Ch.4 pp.105-116

3. Solar farm - money (indicative)

Input parameters

Sale price to NEA	5.3 Rs/kWh
Build cost	65000 Rs/kW
O&M (% of build cost)	1 %/yr
Discount rate	10 %
Panel ageing	0.5 %/yr
Contract length	25 years

Calculation method and equations

- LCOE = (capex + Σ O&M_t/(1+r)^t) / Σ E_t/(1+r)^t
- E_t = E_1 × (1 − ageing)^(t−1)

Results (calculated by deterministic code)

Build cost	650,000,000.00 Rs
Cost per unit (LCOE)	5.061 Rs/kWh
IRR	10.68 %
Net present value	33,489,853.90 Rs
Simple payback	8.464 years

Assumptions

- Prices are indicative Nepal values (see sources); no tax, loan, VAT or land cost included.

Data sources and references

- ERC, NEA Electricity Consumer Tariff Determination 2078 (decided 2078/07/08 BS), p.74 [V] - https://www.erc.gov.np/charge-order
- NEPQA-2025 and Amendment-1 (AEPC, Aug 2025 / Apr 2026) [V]
- Net billing export Rs 5.94/kWh - Kathmandu Post 2022; Urja Khabar Jul 2026 [S]
- Utility solar PPA Rs 4.99-5.54/kWh (2024 NEA tender) - Urja Khabar 28 May 2025 [S]
- Equipment prices - pricenepal.com (Jul 2026), sandippaudel.com (Aug 2026) [S, indicative]
- Temperatures - DHM/WMO normals via Wikipedia climate tables [S]

Review record

To be completed by the reviewing engineer. Signing below records review only; it does not by itself constitute certification under any jurisdiction's professional engineering rules.

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