Solar Installation Report

Project	Hybrid home, Biratnagar
Client	Example
Location	Biratnagar
Prepared by	ElectricalCalc
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Software	ElectricalCalc v0.8.0
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Reviewer	Not reviewed

This is a preliminary calculation report generated by software. It is not a certified, approved or stamped engineering design and must not be used for construction or procurement without review by a qualified engineer against site conditions, manufacturer data and the applicable local codes and regulations. Results are only as reliable as the inputs and assumptions listed.

Summary in plain words

- Hybrid home in Biratnagar: 4 panels, 2.20 kWp, with battery backup for power cuts.

Scope and notes

Worked example for the website - preliminary calculation, check with a qualified engineer.

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A. What to buy (shopping list)

Buy equipment that meets NEPQA-2025 (AEPC) and ask the seller for each datasheet. Ratings are the minimum - equal or higher is fine unless stated. The second column says whether the item is compulsory in Nepal or optional; section B explains every item.

Item	Compulsory or optional?	Specification	Qty	Why / rule	Why it is needed
Solar PV module	Compulsory (safety)	550 Wp mono/TOPCon, Voc 49.5 V, Vmp 41.6 V, Isc 14 A, efficiency ≥ 21 %, power warranty ≥ 80 % at 25 yr, IEC 61215/61730	4	Array 4 in series × 1 string(s) = 2.20 kWp; NEPQA-2025 module floors	IEC 61215/61730; NEPQA-2025 efficiency and warranty floors
Mounting structure	Compulsory (safety)	Hot-dip galvanised / aluminium tilt frame with anchor bolts, tilt as designed	1 row(s) of up to 4	Boxwell, Solar Electricity Handbook §123; roof must carry the weight - check structure	Must resist wind uplift and earthquakes
Mounting rails	Compulsory (safety)	Aluminium PV rail (2 per row of panels)	10 m	2 rails under each panel	Must resist wind uplift and earthquakes
End clamps / mid clamps	Compulsory (safety)	Matching panel frame thickness	4 end / 6 mid	4 end clamps per row, 2 mid clamps between neighbouring panels	Part of the mounting structure
Roof feet / anchors	Compulsory (safety)	Stainless fixings, sealed against leaks	10	One fixing about every 1.2 m of rail	Part of the mounting structure
PV cable (red and black)	Compulsory (safety)	4 mm² solar cable EN 50618 (H1Z2Z2-K), UV resistant, 1500 V DC	18 m red + same black	Cable schedule; book §87, §110	Solar-rated (EN 50618) or correctly sized copper
MC4 connector pairs	Compulsory (law / NEA)	Same brand as panel connectors (never mix brands)	4	Field-made string ends + spares	NEPQA-2025: connector of the panel maker's type, IEC 62852, IP67
DC isolator (PV)	Compulsory (safety)	600 V DC, ≥ 25 A, 2-pole, lockable	2	Rated above cold string Voc 211 V and 1.25 × Isc; book §79, §80, §109	Safe disconnection of panel power (IEC 60364-7-712)
DC surge protection device (Type 2, PV)	Strongly recommended	Ucpv ≥ 600 V DC, In ≥ 20 kA	1	Lightning-induced surges are common in Nepal; above cold string Voc	Nepal lightning risk (237 deaths 2021-2025); AEPC specs include SPDs
Hybrid inverter (low-voltage battery)	Compulsory (law / NEA)	2 kW continuous, surge ≥ 0.9 kW, battery 48 V, PV max 500 V, MPPT 125-425 V, pure sine 230 V 50 Hz, grid + backup outputs	1	Carries backup loads (×4/3, book §91) and the whole array	NEPQA-2025 certificates (IEC 61727/62116/62109); NEA anti-islanding

Item	Compulsory or optional?	Specification	Qty	Why / rule	Why it is needed
Battery	Compulsory (safety)	LiFePO4 48 V 100 Ah with BMS, ≥ 3000 cycles @ 80 % DoD, round-trip ≥ 85 %, warranty ≥ 5 yr, communication with inverter (CAN/RS485)	1	1 in series × 1 in parallel = 4.8 kWh; needs 58 Ah at 48 V (book §89)	Stores the backup energy; NEPQA-2025 cycle, capacity and warranty floors
Battery cable (red and black)	Compulsory (safety)	25 mm² flexible copper, crimped lugs	4 m each colour	Cable schedule; keep as short as possible (§125)	Must carry the fuse rating and inverter current
Battery fuse (DC, high breaking capacity)	Compulsory (safety)	63 A NH/ANL/class-T DC fuse	1	≥ 1.25 × max battery current 46 A; on the + terminal so all current passes (§109)	A lithium bank can push thousands of amps into a short
Battery isolator / DC breaker	Compulsory (safety)	63 A, 48 V DC rated	1	Lets you disconnect the battery safely (book §79)	Protects the cable it feeds
AC MCB (inverter output)	Compulsory (safety)	16 A, C-curve, 1-pole + N	1	≥ 1.25 × inverter AC current 8.7 A; cable sized to carry it	Protects the AC cable (IEC 60364)
RCD / RCBO	Compulsory (safety)	30 mA, Type A (Type B if the inverter manual requires)	1	Shock protection on AC circuits (§109)	Prevents electric shock (IEC 60364)
AC surge protection device (Type 2)	Strongly recommended	275 V AC, In ≥ 20 kA	1	Protects inverter and loads	Nepal lightning risk (237 deaths 2021-2025); AEPC specs include SPDs
AC cable	Compulsory (safety)	2.5 mm² copper (phase + neutral) + 2.5 mm² earth	10 m	Cable schedule	Solar-rated (EN 50618) or correctly sized copper
Backup distribution board	Compulsory (safety)	Separate small DB for the appliances needed in power cuts	1	Hybrid inverter backup output feeds only these circuits (book §29-§30, §160)	Separate board for power-cut circuits
Manual bypass / changeover switch	Compulsory (safety)	16 A, 2-pole, 3-position (inverter / off / grid)	1	Keeps the backup circuits powered from NEA if the inverter is serviced	Break-before-make: backup power must never feed the dead NEA line
Earth electrode	Compulsory (safety)	Copper-bonded rod ≥ 1.5 m (or copper plate earth pit per local practice), inspection pit	1	Earth the array frame, inverter and battery negative (§109, §121, §124)	AEPC spec: 2 electrodes, 10 ohm or less
Earth cable (green/yellow)	Compulsory (safety)	6 mm² frame bonding, 16 mm² to electrode, 2.5 mm² PE	23 m total	Cable schedule	AEPC spec: 2 electrodes, 10 ohm or less

Item	Compulsory or optional?	Specification	Qty	Why / rule	Why it is needed
Conduit / cable tray, glands, ties	Compulsory (safety)	UV-resistant conduit outdoors; glands sized to cables	as required	Protect cable runs (§110)	Solar-rated (EN 50618) or correctly sized copper
Warning labels	Compulsory (safety)	'Solar DC - live in daylight', isolator labels, dual-supply label at DB and meter	1	IEC 60364-7-712 practice	IEC 62548: warn that DC is live in daylight
NEA bidirectional (import/export) meter	Compulsory (law / NEA)	Supplied/approved by NEA after net-billing application	1	Needed to be credited for exported units; apply at your NEA distribution centre	NEA must approve and fit/seal the meter before you connect or export

B. Compulsory or optional in Nepal (your system type)

Compulsory (law / NEA) = NEPQA-2025 or NEA require it. Compulsory (safety) = IEC safety standards and AEPC specifications require it. Strongly recommended = a real Nepal risk. Optional = convenience.

Part	Hybrid (backup)
MC4 connectors of the panel maker's type	Compulsory (law / NEA)
Inverter with NEPQA/IEC certificates	Compulsory (law / NEA)
Battery with BMS (lithium)	Compulsory (law / NEA)
NEA approval + bidirectional meter	Compulsory (law / NEA)
Solar panels (IEC 61215 + 61730)	Compulsory (safety)
Mounting structure, anchored	Compulsory (safety)
Solar DC cable (EN 50618)	Compulsory (safety)
DC isolator	Compulsory (safety)
AC breaker (MCB)	Compulsory (safety)
RCD 30 mA	Compulsory (safety)
Earthing (2 electrodes, <= 10 ohm)	Compulsory (safety)
Warning labels	Compulsory (safety)
Multimeter for testing	Compulsory (safety)
Battery fuse (10-20 kA) + isolator	Compulsory (safety)
Changeover switch + backup board	Compulsory (safety)
DC surge protector	Strongly recommended
AC surge protector	Strongly recommended
Lightning air terminal	Optional
Monitoring app	Optional
Export limiter	Optional

C. Every part explained - what it is, which type is best, how to choose and connect it

One card per part, written for your system. Read the card before you buy that part.

Solar panels (PV modules)

Panels turn sunlight into DC electricity. Their power rating (Wp) is measured in a laboratory at 25 °C and full sun, so on a real roof they give less - that loss is already included in your design.

Types

Type	How it works	Good	Bad	Best for
Monocrystalline TOPCon / PERC [modern]	Single-crystal silicon cells, black look	Highest efficiency (21-23 %), small roof area, long life	Slightly dearer per watt	Almost every Nepali roof today
Bifacial	Glass on both sides collects reflected light too	A few % extra on a bright raised frame	Little gain flat on a tin roof; heavier	Ground or high open frames over light-coloured surfaces
Polycrystalline	Many-crystal cells, blue look (book §76)	Cheap	Lower efficiency (13-18 %), mostly discontinued; fails NEPQA ≥ 21 % above 350 Wp	Small old-stock DC lighting kits only
Thin-film / amorphous	Very thin layer on glass (book §76)	Copes better with partial shade and heat	Needs about 2.5× more roof area	Rarely sold in Nepal now

Best for your system

Monocrystalline (TOPCon/PERC) panels of about 550 W - you need 4 of them (about 10 m² of roof). Buy all panels of the SAME model and batch.

How to select (your numbers)

- Power about 550 Wp each, quantity 4 (your design).
- Datasheet values close to: Voc 49.5 V, Vmp 41.6 V, Isc 14.0 A, Imp 13.2 A - if your panel differs, re-enter its values in Engineer settings and recalculate.
- Voc temperature coefficient around -0.25 %/°C (smaller number = less voltage rise in cold).
- Maximum system voltage 1000 V or 1500 V (higher than your string's cold voltage).
- Efficiency at least 21 % for panels above 350 Wp (NEPQA-2025).

When buying, check

- Label on the back: model, Wp, Voc, Isc, Vmp, Imp, max system voltage, max series fuse, certificates IEC 61215 and IEC 61730.
- Power tolerance 0/+3 % or 0/+5 W (never a minus tolerance) - NEPQA-2025.
- Warranty: product ≥ 10 years; power ≥ 80 % after 25 years (NEPQA floor).
- Buy from any brand listed/certified under NEPQA-2025 (AEPC); always ask the seller for the datasheet.
- Signs of a poor/fake panel: weight much lighter than the datasheet, no serial number, bubbles or brown spots in the cells, bent frame, a junction box that opens easily, 'Wp' far too high for its size.
- Ask the shop to measure Voc in the sun in front of you - it should be close to the label value.
- Certificates from an IECEE/IECRE-listed lab: IEC 61215:2021 and IEC 61730; above 350 W also PID (IEC 62804-1), salt-mist (IEC 61701) and ammonia (IEC 62716) - NEPQA-2025 (AEPC, Aug 2025) and Amendment-1 (Apr 2026).
- Serial number laminated INSIDE the glass (a sticker only is a warning sign); fill factor ≥ 75 % - NEPQA-2025 (AEPC, Aug 2025) and Amendment-1 (Apr 2026).
- Power warranty ≥ 97 % in year 1, ≥ 90 % at 10 years, ≥ 80 % at 25 years (≤ 0.8 %/yr) - NEPQA-2025.

Series or parallel?

Your 4 panels are wired as 4 in series × 1 string(s). In series the VOLTAGES add and the current stays the same: 4 × 41.6 V = about 166 V while working, 198 V open-circuit on a 25 °C test, and up to 211 V on the coldest morning (-1.0 °C). The current is that of one panel, about 13.2 A working / 14.0 A short-circuit.

How to connect

- 1. Keep panels face-down or covered with an opaque sheet until all wiring is finished - a panel in daylight is always live (book §117-§120).
- 2. Fix each panel to the rails with 4 clamps on the frame's clamping zone shown in the manual.
- 3. Join the panels in a chain: + of panel 1 to − of panel 2, and so on, for 4 panels. The free − of the first panel and the free + of the last panel are the string ends.
- 4. Measure the string's open-circuit voltage with a multimeter before connecting it anywhere (see Skills).
- 5. Bond every panel frame / rail to earth with 6 mm² green-yellow cable.
- 6. Leave about 10 mm between neighbouring panels and at least 10 cm between the panel frame and the roof for cooling (manufacturer manual, e.g. LONGi 2026).
- 7. Bond each frame to earth through the marked earthing hole with the proper star washer/lug - never drill new holes in the frame (manufacturer manual).

Common mistakes

- Mixing different panel models or wattages in one string (the weakest one limits all).
- Wiring in the shade of a water tank, railing or neighbour's building - even small shade cuts output a lot (book §57: 5 % shaded can lose 50-80 %).
- Walking or standing on panels; drilling the frame.
- Leaving the panel's own short leads hanging in water - tie them to the rail.

Reference: Book §56-§61, §76, §106, §117-§120; NEPQA-2025 §1.1

Mounting structure (frame, rails, clamps)

The frame holds the panels at the right angle and must survive Nepal's monsoon storms for 25 years. It also lifts the panels so air can cool them.

Types

Type	How it works	Good	Bad	Best for
Raised tilted frame on a flat RCC roof	Galvanised/aluminium legs bolted to the slab	Correct tilt and direction, cooler panels	Must be anchored for wind	Flat roofs
Rails on a tin / sloping roof	Rails fixed through the sheet into the purlins	Cheap, quick	Follows roof angle; leaks if badly sealed	Tin or tiled roofs
Ground frame / pole	Concrete footings in the yard (book §66)	Easy cleaning, any angle	Uses land; needs fencing from animals/children	Houses with yard space

Best for your system

A hot-dip galvanised or aluminium tilted frame bolted to your RCC slab with anchor bolts and sealed.

How to select (your numbers)

- Size: holds 4 panels (shopping list: Hot-dip galvanised / aluminium tilt frame with anchor bolts, tilt as designed).
- Rails: 10 m; clamps: 4 end / 6 mid; roof feet/anchors: 10.
- Leave at least 10 cm of air under the panels (book §59: hot panels make less power).
- Face the panels south; tilt as in your design (flat roofs: about equal to your latitude).

When buying, check

- Steel must be hot-dip GALVANISED (dull grey, thick zinc) - not painted mild steel which rusts in 2-3 monsoons.
- Stainless steel (A2) bolts and clamps; matching the panel frame thickness (e.g. 30-35 mm).
- Ask for the wind rating of the frame and follow its anchor spacing.

How to connect

- 1. Mark the frame positions on the slab; keep 30-50 cm from roof edges and away from the water tank's shadow.
- 2. Drill the slab, set anchor bolts with chemical/epoxy anchor or expansion bolts, and seal around each one.
- 3. Bolt the legs, check the tilt with a phone angle app, then fix the rails level.
- 4. Tighten all bolts to the torque in the manual; re-check after the first storm (book §135).

Common mistakes

- Fixing into the tin sheet only - it tears in wind.

- No sealing → roof leaks inside the house.
- Rusting black steel frames.
- Panels too close to the roof surface (overheating).

Reference: Book §59, §66, §123; local building rules for roof loads

PV cable and MC4 connectors

Special solar cable carries the DC power from the panels to the inverter/controller. MC4 connectors are the waterproof plugs used to join panels and cables.

Types

Type	How it works	Good	Bad	Best for
Solar cable EN 50618 (H1Z2Z2-K)	Double-insulated, UV- and heat-proof, rated 1500 V DC	Lasts 25 years outdoors	Dearer than house wire	All panel wiring
Ordinary PVC house wire	Single insulation, not UV proof	Cheap	Cracks in sun within a few years → fire/shock risk	Never for PV

Best for your system

4 mm² solar cable EN 50618 (H1Z2Z2-K), UV resistant, 1500 V DC, 4 mm², red for + and black for −, 18 m red + same black; 4 MC4 pairs of the same make as the panel plugs.

How to select (your numbers)

- Size 4 mm² (larger of: current rule 2.5 mm², voltage-drop rule 4 mm²); voltage drop about 1.31 % over 15.0 m.
- Voltage rating ≥ 211 V DC (your coldest-morning string voltage) - EN 50618 cable is 1500 V.
- Current: each string carries up to 17.5 A (1.25 × Isc).

When buying, check

- Print on the cable sheath: 'EN 50618' or 'H1Z2Z2-K', size in mm², 1500 V DC.
- Tinned copper strands; correct size (strip a sample - undersized copper is a common fake).
- MC4 connectors: IP67/IP68, rated ≥ 30 A and ≥ 1000 V, same make as your panels' connectors.
- Buy from any brand listed/certified under NEPQA-2025 (AEPC); always ask the seller for the datasheet.

Series or parallel?

Solar cable is not 'in series' or 'in parallel' itself - it simply carries the string. Keep + and − of the same string together (same route) so they do not form a large loop that picks up lightning surges.

How to connect

- 1. Route the + and − cables side by side in UV-proof conduit or tied to the rails; never lie them in water.
- 2. Crimp MC4 ends with an MC4 crimp tool (see Skills) - never squeeze with pliers.
- 3. Check polarity with a multimeter before plugging into the isolator.
- 4. Label both ends: 'PV string 1 +' / '−'.

Common mistakes

- Mixing MC4 brands (they look the same but can overheat and melt).
- Using house wire on the roof.
- Sharp bends over metal edges cutting the insulation.
- Cables dangling and rubbing in the wind.

Reference: Book §87, §110; EN 50618; IEC 62548

DC isolator / DC breaker (panel side)

A switch that safely disconnects the panels from the inverter or controller, so you can work on the system. DC is harder to switch off than AC - it makes a lasting spark - so the switch must be DC-rated.

Types

Type	How it works	Good	Bad	Best for
DC isolator (rotary switch)	Manual switch rated for DC voltage	Simple, lockable, cheap	No automatic overcurrent trip	Disconnect at the inverter

Type	How it works	Good	Bad	Best for
DC MCB (breaker)	Switch + automatic trip on overcurrent	Protects as well as isolates	Must be polarity-correct; dearer	Small PV/battery circuits
AC MCB used on DC	Wrong device	-	Can fail to break DC → fire	Never

Best for your system

600 V DC, ≥ 25 A, 2-pole, lockable - qty 2 (one near the inverter; a second at the array if the cable run is long or crosses the roof).

How to select (your numbers)

- Voltage rating ≥ 211 V DC (string voltage on the coldest morning).
- Current rating ≥ 17.5 A × number of strings (1).
- 2-pole (breaks + and −), lockable in the OFF position.

When buying, check

- 'DC' and the voltage (e.g. 600 V DC / 1000 V DC) printed on the device - not just '230/400 V'.
- Utilisation category DC-PV2 / DC-21B on the datasheet; IEC 60947-3.
- Buy from any brand listed/certified under NEPQA-2025 (AEPC); always ask the seller for the datasheet.

How to connect

- 1. Mount within reach of the inverter, before its PV input.
- 2. Panels + to the isolator's '+ IN', isolator '+ OUT' to the inverter PV +; same for −. Follow the terminal markings - many DC devices are polarity-sensitive.
- 3. Keep it OFF until commissioning tests are done.

Common mistakes

- Using an AC breaker on the PV side.
- Swapping + and − on a polarity-marked DC breaker.
- Opening a DC connector (MC4) under load instead of using the isolator (dangerous arc).

Reference: Book §79, §80, §109; IEC 60947-3

DC surge protector (SPD)

Nepal has frequent lightning in the pre-monsoon. A surge protector diverts lightning-induced voltage spikes on the panel cables to earth before they destroy the inverter.

Types

Type	How it works	Good	Bad	Best for
Type 2 PV SPD	Varistors that conduct to earth during a surge	Protects against induced surges	Wears out after big surges (indicator turns red)	All rooftop systems [modern practice]
Type 1+2 SPD	Handles part of a direct strike current	Needed with a lightning rod on the building	Dearer	Buildings with lightning protection

Best for your system

Ucpv ≥ 600 V DC, In ≥ 20 kA.

How to select (your numbers)

- Ucpv (max continuous PV voltage) ≥ 211 V DC.
- In ≥ 20 kA (8/20 µs), with a status window.
- Your panel-to-inverter cable is 15 m: because it is 10 m or more, fit a SECOND DC SPD in a box near the panels as well as the one at the inverter (IEC 61643-32 practice).
- Nepal recorded 237 lightning deaths in 2021-2025 (Koshi and Lumbini worst) - do not skip surge protection.

When buying, check

- Marked 'PV' or 'DC' with Ucpv; IEC 61643-31.
- Replaceable cartridges with a visual indicator.

How to connect

- 1. Connect it after the DC isolator (between isolator and inverter), + and − to the SPD, its earth terminal to the earth bar with short (< 0.5 m), straight 6 mm² cable.
- 2. Check the window colour every month.

Common mistakes

- Long, looped earth lead (makes the SPD useless).
- Using an AC SPD on DC.

Reference: IEC 61643-31; IEC 60364-7-712 [modern]

Inverter

The inverter turns DC (from panels or battery) into normal 230 V, 50 Hz AC for your appliances. It is the most important electronic box in the system.

Types

Type	How it works	Good	Bad	Best for
On-grid / grid-tied	Panels → inverter → house and NEA grid; no battery	Cheapest per kW, most efficient	Switches OFF in power cuts (anti-islanding safety)	Lowering the bill where cuts are rare
Hybrid	Panels + battery + grid in one box; backup output for chosen loads	Saves bill AND gives backup in load-shedding [modern]	Dearer; needs a separate backup DB	Most Nepali homes with power cuts
Off-grid (stand-alone)	Battery → inverter → house; panels charge via controller	Works with no grid at all (book §91)	Battery must cover everything	Remote sites
Modified/square wave	Rough stepped AC (book §91)	Cheap	Fridges, fans and electronics overheat or hum	Avoid

Best for your system

A hybrid inverter with a low-voltage (48/24 V) battery input and a separate backup output: 2 kW continuous, surge ≥ 0.9 kW, battery 48 V, PV max 500 V, MPPT 125-425 V, pure sine 230 V 50 Hz, grid + backup outputs.

How to select (your numbers)

- Continuous power ≥ 1,833 W (your design: everything that runs at once × 4/3 rule, and/or the array size).
- Surge (peak) rating at least 2-3× the running power of your largest motor (fridge, pump) - check the appliance labels (book §91).
- PV input: max voltage above your cold string Voc 211 V and MPPT window containing 146-166 V.
- Pure sine wave, 230 V 50 Hz; efficiency ≥ 95 % peak (≤ 5 kVA) / ≥ 97 % (> 5 kVA) per NEPQA-2025.
- Battery voltage 48 V and lithium communication (CAN/RS485) matching your battery.
- NEA connection voltage: up to 5 kW single-phase 230 V; 5-40 kW three-phase 400 V; above 40 kW at 11 kV - NEA Board decision (776th meeting, 2018) - latest verifiable grid-connection rules.

When buying, check

- Datasheet: continuous W, surge W (and for how many seconds), PV max V, MPPT range, MPPT current, battery V, efficiency, IP rating (IP65 if outdoors), warranty ≥ 5 years (NEPQA).
- For grid-tied/hybrid: anti-islanding certificate (IEC 62116 / IEC 62109) - NEA requires it.
- Service centre in Nepal and spare parts; app/Wi-Fi monitoring.
- Buy from any brand listed/certified under NEPQA-2025 (AEPC); always ask the seller for the datasheet.
- Grid-tied: test certificates IEC 61727, IEC 62116 (anti-islanding), IEC 62109-1/-2 (+ IEC 61683, IEC 61000 EMC per Amendment-1); efficiency ≥ 95 % (≤ 5 kVA) / ≥ 97 % above; IP65; built-in meter and data logger; warranty ≥ 5 years - NEPQA-2025 (AEPC, Aug 2025) and Amendment-1 (Apr 2026).
- Battery/hybrid inverters: efficiency ≥ 90 % (transformerless), must survive 150 % load for 2 s, hybrid must charge from solar first; warranty ≥ 3 years up to 5 kVA - NEPQA-2025 (AEPC, Aug 2025) and Amendment-1 (Apr 2026).

How to connect

- 1. Mount on a solid wall, indoors and ventilated if possible, out of direct sun, with 30 cm free space around (book §124).
- 2. Connect in this order with everything OFF: earth (PE) first → battery cables (through fuse/isolator) → AC output to the backup/main DB → PV through the DC isolator.
- 3. Tighten terminals to the manual's torque; double-check polarity on DC.
- 4. Configure settings (battery type, grid code 230 V/50 Hz) before first start (see Skills).

Common mistakes

- Undersizing the surge rating (fridge/pump won't start).
- Mounting in a hot, closed room or in sun.
- Buying a 'modified sine' inverter.
- Grid-tied inverter expected to work in power cuts - it won't.

Reference: Book §81-§83, §91, §124; NEPQA-2025 §1.4-§1.5; IEC 62109/62116

Battery bank

The battery stores energy for the night and for power cuts. It is the most expensive part to replace, so choosing and treating it well matters most.

Types

Type	How it works	Good	Bad	Best for
LiFePO4 (lithium iron phosphate) [modern]	Lithium cells + built-in BMS	Use 80-95 % of capacity, 3,000-6,000+ cycles, light, no topping up	Higher first cost; must not be charged below 0 °C	Almost all new systems
Tubular lead-acid (flooded)	Liquid acid, tall tubular plates (book §89)	Cheap, widely repaired	Use only ~50 %; distilled water top-ups; acid fumes; 4-8 years	Tight budgets with a ventilated space
AGM / gel (sealed lead-acid)	Sealed, no topping up (book §89)	No maintenance	Short life when deeply cycled; ~50 % usable	Small loads

Best for your system

LiFePO4 with a built-in BMS, LiFePO4 48 V 100 Ah with BMS, ≥ 3000 cycles @ 80 % DoD, round-trip ≥ 85 %, warranty ≥ 5 yr, communication with inverter (CAN/RS485) - quantity 1.

How to select (your numbers)

- System voltage 48 V; capacity at least 58 Ah at 48 V (usable energy needed 2,508 Wh).
- Depth of discharge used in the design: 90 %.
- Same voltage as the inverter/controller battery input; communication cable (CAN/RS485) compatible with the inverter for lithium.
- Your site can reach -1 °C: keep a lithium battery INDOORS in a room that stays above 5 °C, or choose a battery with self-heating; otherwise it must not charge on cold mornings.
- Lithium (LiFePO4) must only be CHARGED between about 0 °C and 50 °C (some makers say 5 °C) - charging below freezing permanently damages it (Pylontech US5000 operation manual (2024); Victron).
- Never connect 48 V lithium modules in SERIES - only in parallel, and at most the number the maker allows per group (Pylontech US5000 operation manual (2024)).
- Before joining modules in parallel, bring them to the same voltage (charge each fully) and let them rest at least 15 minutes.

When buying, check

- NEPQA-2025 (lithium): ≥ 3,000 cycles at 80 % DoD, round-trip efficiency ≥ 85 %, BMS, warranty ≥ 5 years.
- Datasheet: nominal V, Ah, kWh, max charge/discharge current, cycle life at stated DoD, operating temperature.
- Signs of poor batteries: weight much lower than datasheet, no cell grade/BMS data, re-labelled cells, no local warranty service.
- Buy from any brand listed/certified under NEPQA-2025 (AEPC); always ask the seller for the datasheet.
- NEPQA-2025: lithium ≥ 3000 cycles at 80 % DoD (≥ 2000 below 2 kWh), BMS with cell protection, round-trip efficiency ≥ 85 %, warranty ≥ 5 years; 12 V lead-acid ≥ 1200 cycles, warranty ≥ 3 years; test reports IEC 62619 / IEC 61427 / IEC 60896 - NEPQA-2025 (AEPC, Aug 2025) and Amendment-1 (Apr 2026).

- Measured capacity must be 0 to +20 % of the label, never less (NEPQA-2025) - ask the seller to show a discharge test or check it yourself in the first weeks via the inverter's energy counter.

Series or parallel?

Your bank is 1 module(s) in series × 1 in parallel of 48 V 100 Ah = 48 V, about 4.8 kWh. In SERIES the voltages add (Ah stays the same): e.g. two 12 V batteries in series = 24 V. In PARALLEL the Ah add (voltage stays the same). Use identical batteries of the same age and charge level - a weak one drags the others down and can overheat (book §89, §107).

How to connect

- 1. Place batteries on a stand off the floor, in a cool, dry, ventilated place, away from children (book §125).
- 2. Make the series/parallel links with the short cables supplied or equal-length cables of the bank's size.
- 3. Connect the bank's + through the battery fuse and isolator to the inverter; − directly (or via isolator).
- 4. Cover terminals with insulated caps; keep metal tools away from the top of the battery.
- 5. Turn the battery's own switch/BMS on only after all cables are tight.

Common mistakes

- Mixing old and new or different-brand batteries.
- Shorting terminals with a spanner (huge current, burns, explosion risk).
- Thin battery cables (they heat up).
- Charging lithium below 0 °C (cold Himalayan sites).

Reference: Book §85-§89, §107, §125; NEPQA-2025 §1.2

Battery cables, lugs, fuse and isolator

Battery cables carry the largest currents in the system, so they are thick and short. A fuse right next to the battery protects them from a short circuit; an isolator lets you switch the battery off.

Types

Type	How it works	Good	Bad	Best for
Flexible copper welding/battery cable	Many fine strands	Bends easily, large current	-	Battery links
NH / ANL / class-T DC fuse	High breaking capacity DC fuse	Safely breaks a battery short circuit	Must be replaced after blowing	Battery +
Automotive blade fuse	Low breaking capacity	Cheap	Can explode on a battery short	Never on the main battery cable

Best for your system

25 mm² flexible copper, 63 A NH/ANL/class-T DC fuse, 63 A, 48 V DC rated.

How to select (your numbers)

- Cable 25 mm² (current rule 25 mm², voltage-drop rule 10 mm²), length 1.5 m (keep it short), design current 45.8 A.
- Fuse 63 A DC, high breaking capacity, as close to the battery + as possible.
- Isolator/DC breaker rated ≥ 63 A at 48 V DC.
- A 48 V lithium module can push about 2,500 A into a short circuit: the battery fuse/breaker must be DC-rated with a breaking capacity of at least 10 kA (1-4 modules) or 20 kA (5-8 modules) - Pylontech US5000 operation manual (2024). Class T fuses (20 kA) meet this; small automotive-style fuses do not.

When buying, check

- Copper (not copper-clad aluminium) - scrape a strand to check colour.
- Lugs sized to the cable AND the terminal bolt; tinned copper.
- Fuse marked with DC voltage and breaking capacity (kA).

How to connect

- 1. Cut cables to length; crimp lugs with a hydraulic crimper (see Skills); cover with heat-shrink (red +, black −).
- 2. Order: battery + → fuse → isolator → inverter/controller +. Battery − → inverter/controller −.
- 3. Tighten to the torque in the battery manual; re-check after one week.

Common mistakes

- Fuse at the inverter end instead of the battery end.
- Loose lugs (they heat and melt).
- Crimping with a hammer.

Reference: Book §87, §109, §110, §125

AC breaker (MCB), RCD and AC surge protector

On the 230 V side the MCB protects the cable from overload, the RCD protects people from electric shock, and the AC surge protector protects appliances from grid and lightning spikes.

Types

Type	How it works	Good	Bad	Best for
MCB (C-curve)	Trips on overload/short	Standard	No shock protection	Every circuit
RCD 30 mA Type A	Trips if current leaks to earth (through a person)	Saves lives; works with inverter DC leakage	-	Solar systems [modern]
RCD Type AC	Older type	Cheap	Can be blinded by DC leakage from inverters	Not recommended with inverters
RCBO	MCB + RCD in one	Saves space	Dearer	Backup DB

Best for your system

16 A, C-curve, 1-pole + N; 30 mA, Type A (Type B if the inverter manual requires); 275 V AC, In ≥ 20 kA.

How to select (your numbers)

- MCB 16 A for the inverter output (inverter current 8.7 A × 1.25, next standard size).
- AC cable 2.5 mm² copper over 8.0 m.
- RCD 30 mA, Type A (Type B only if the inverter manual says so).

When buying, check

- IEC 60898 (MCB), IEC 61008/61009 (RCD/RCBO) printed on the device.
- Breaking capacity ≥ 6 kA.

How to connect

- 1. Mount in a small DB box next to the inverter or in the backup DB.
- 2. Inverter AC output L → MCB → RCD → loads; N through the RCD; PE to the earth bar - never through a breaker.
- 3. Press the RCD 'T' test button after switching on: it must trip.

Common mistakes

- Putting the RCD before the inverter instead of on its output loads.
- Using Type AC RCDs.
- Swapping L and N.

Reference: Book §109; IEC 60364-4-41

Backup distribution board and changeover switch

A hybrid inverter's backup output feeds only the circuits you chose for power cuts. These circuits move into a small separate board. A manual bypass/changeover switch lets you feed them from the grid if the inverter is being serviced.

Types

Type	How it works	Good	Bad	Best for
Separate backup DB	Only the backup circuits are fed by the inverter backup output	Battery never drains on heavy loads	Some rewiring	Hybrid systems (book §29-§30, §160)
3-position changeover (inverter / off / grid)	Break-before-make switch	Can never connect two sources together	-	Bypass for maintenance

Best for your system

Separate small DB for the appliances needed in power cuts; 16 A, 2-pole, 3-position (inverter / off / grid).

How to select (your numbers)

- Move lights, fridge, Wi-Fi, fans (your 'needed in power cut' appliances) to the backup DB.

- Changeover rated ≥ the inverter output MCB (16 A), 2-pole.

When buying, check

- Break-before-make 3-position switch; 2-pole (L and N).

How to connect

- 1. This is house-wiring work: switch the main switch OFF first; if you are not confident with 230 V, have a CTEVT-certified electrician move the circuits.

Common mistakes

- Connecting the inverter output and the grid together (destroys the inverter, dangerous for NEA line workers).

Reference: Book §29-§30, §160

Earthing (grounding)

Earthing gives fault and lightning currents a safe path into the ground so metal parts never become dangerous to touch. Every solar system needs it (book §109).

Types

Type	How it works	Good	Bad	Best for
Copper-bonded steel rod	Rod driven 1.5-3 m into moist soil	Long life, easy to test	Needs depth	Most sites
Plate earth pit (copper/GI plate + charcoal/salt)	Traditional Nepali practice	Low resistance in dry soil	Salt corrodes; needs watering	Rocky/dry soil
GI pipe	Galvanised pipe in a pit	Cheap	Rusts in 5-10 years	Temporary

Best for your system

Copper-bonded rod ≥ 1.5 m (or copper plate earth pit per local practice), inspection pit; cables: 6 mm² frame bonding, 16 mm² to electrode, 2.5 mm² PE.

How to select (your numbers)

- PV frames/rails bonded with 6 mm² green-yellow copper; main earth to the electrode 16 mm²; inverter/DB PE as in the cable schedule.
- Bond the PV earth to the house's existing earth (one earthing system for the building).
- AEPC's own specification: at least TWO earth electrodes (pipe-in-pipe or copper-bonded rod) each ≥ 2.5 m long, 2.5 m apart, each with ~30 kg earth-enhancing compound and a concrete inspection pit; bonding conductors 6 mm² (frames) / 16 mm² copper; electrodes linked with 50 mm² bare copper buried 0.5 m deep - AEPC 2 kWp institutional PV bidding specification (earthing clause).
- Target earth resistance 10 Ω or less (AEPC PV spec); lightning-protection earths are often required ≤ 5 Ω - AEPC 2 kWp institutional PV bidding specification (earthing clause).
- Hill sites in Nepal measured 39-226 Ω before improvement (AEPC Dhading tender): always measure, and add electrodes or compound until the target is met.

When buying, check

- Green-yellow copper cable, bronze/brass clamps, an inspection pit with a removable cover.

How to connect

- 1. Choose moist ground near the building, away from the septic tank.
- 2. Drive the rod, fit the clamp, build a small inspection chamber.
- 3. Run the 16 mm² cable to the main earth bar; connect PV frame bonding, inverter PE, SPD earths to the bar.
- 4. Test the earth resistance (see Skills) and write the value in the commissioning record.

Common mistakes

- No earth at all ('the inverter has one inside').
- Earth through a water pipe.
- Painted surfaces under earth clamps (no contact).

Reference: Book §109; IEC 60364-5-54; IEC 62305 (lightning)

Lightning protection

A lightning rod system is only needed when the building is tall or exposed (hilltop, the tallest roof around) or already has one. Surge protectors are needed in every case.

Types

Type	How it works	Good	Bad	Best for
Surge protectors only	DC + AC SPDs	Cheap, protects electronics	Does not protect against a direct strike	Most houses
Lightning rod (air terminal) + down conductor	Intercepts a direct strike	Protects the building	Must be designed (IEC 62305)	Exposed buildings

Best for your system

Surge protectors on DC and AC (already in your list). Add a lightning rod only if your building is exposed - keep panels at least 0.5-1 m from the rod's down conductor or bond them as its designer specifies.

How to select (your numbers)

- If your house has a lightning rod, use Type 1+2 SPDs instead of Type 2.

When buying, check

- IEC 62305 rated components.

How to connect

- 1. Never run PV cables alongside the lightning down conductor.

Common mistakes

- Assuming SPDs stop direct strikes.

Reference: IEC 62305; IEC 61643 [modern]

NEA bidirectional meter and net billing

To export solar power to the NEA grid and get credit, NEA must approve the connection and fit (or approve) an import/export (bidirectional) meter. This is a legal process, not a purchase.

Types

Type	How it works	Good	Bad	Best for
NEA bidirectional (import/export) meter	Counts units bought and sold separately	Exports credited (net billing about Rs 5.94/unit, secondary source)	Paperwork and waiting	Grid-tied and hybrid systems

Best for your system

Apply to your NEA distribution centre before connecting; do not export until approved.

How to select (your numbers)

- Ask NEA for the current net-metering/net-billing application form, list of documents, approved inverter certificates and meter requirements (rules have changed several times - verify current procedure).
- Minimum system for NEA grid connection was 500 W; households 0.5-10 kW (2018 rules) - NEA Board decision (776th meeting, 2018) - latest verifiable grid-connection rules.
- Export is credited at about Rs 5.94/kWh (net billing since July 2022) while you pay up to Rs 11/unit for imports - so size the system to USE most of your solar yourself.

When buying, check

- Inverter anti-islanding certificate (IEC 62116) and datasheet copies ready for NEA.
- Single-line diagram from this report.

How to connect

- 1. Submit the application with the inverter certificates and the wiring diagram.
- 2. NEA inspects and fits/seals the bidirectional meter; you (or a CTEVT-certified electrician) make the final AC connection only after NEA approval.
- 3. Keep the export setting OFF (or zero-export) until approval.

Common mistakes

- Exporting before approval (illegal; can be disconnected/fined).
- Assuming the old Rs 7.30 rate.

Reference: NEA / ERC procedures (verify current); book §46, §81-§83

Monitoring (Wi-Fi dongle / app)

Most modern inverters send their data to a phone app. You see daily energy, battery charge and any fault codes, so you catch problems early.

Types

Type	How it works	Good	Bad	Best for
Wi-Fi/LAN data logger	Plugs into the inverter's COM port	Phone app, alerts	Needs Wi-Fi at the inverter	Every system [modern]
Inverter display only	LCD on the unit	Free	No history	Off-grid sites

Best for your system

Buy the inverter maker's own logger (Wi-Fi) and register the system in its app on day one.

How to select (your numbers)

- Make sure Wi-Fi reaches the inverter location.

When buying, check

- Logger model listed for your inverter model.

How to connect

- 1. Plug the logger in, connect it to home Wi-Fi from the app, check readings match the inverter display.

Common mistakes

- Never checking the app - most failures show there first.

Reference: [modern]

Tools and safety gear

Having the right tools makes the job safe and the connections reliable.

Types

Type	How it works	Good	Bad	Best for
Essential	-	-	-	-

Best for your system

Buy or borrow these before you start.

How to select (your numbers)

- Digital multimeter rated CAT III 1000 V DC (to measure your string voltage safely).
- MC4 crimp tool + MC4 spanners; cable cutter and stripper for 2.5-6 mm².
- Hydraulic lug crimper for 25 mm² cable (if you have a battery).
- Insulated screwdrivers and spanners (1000 V), torque wrench.
- Drill with masonry bits, spirit level, phone angle app, measuring tape, marker and cable labels.
- Safety: insulated gloves, safety glasses, non-slip shoes, harness/rope for roof work, opaque sheet to cover panels.

When buying, check

- Multimeter must show the CAT rating and 1000 V DC on the case.

How to connect

- 1. Check every tool before climbing the roof; never work alone on a roof.

Common mistakes

- Cheap multimeters without CAT rating on PV strings.

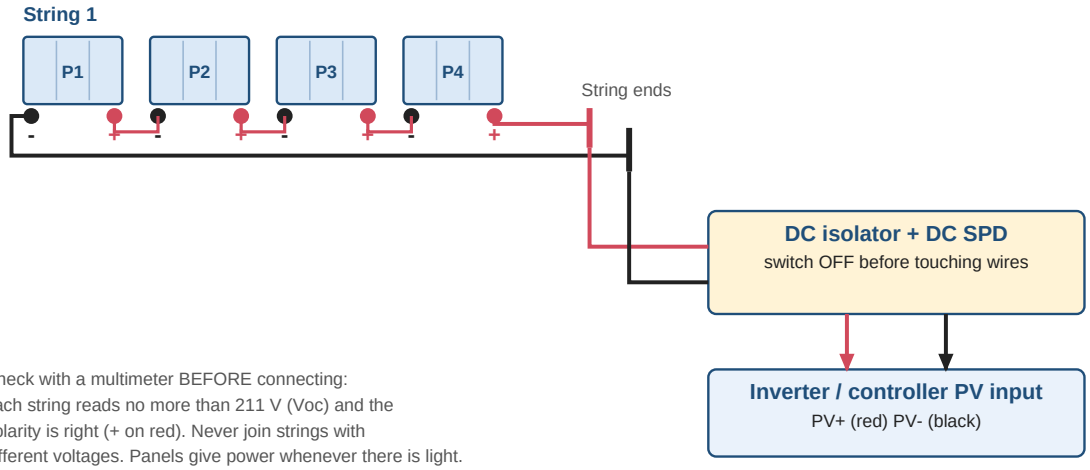
Reference: Book §117-§118

D. Series and parallel - your panels and batteries

Your panels: how to connect them

How to connect your panels

Each string: 4 panel(s) in SERIES (+ of one panel to - of the next): voltages add, 4 x 41.6 V = 166 V working (up to 211 V on a cold morning).
Current stays the same through a string: about 14.0 A maximum (Isc).
Panel: 550 W panel. Cable: 4 mm2 solar cable, red for +, black for -.

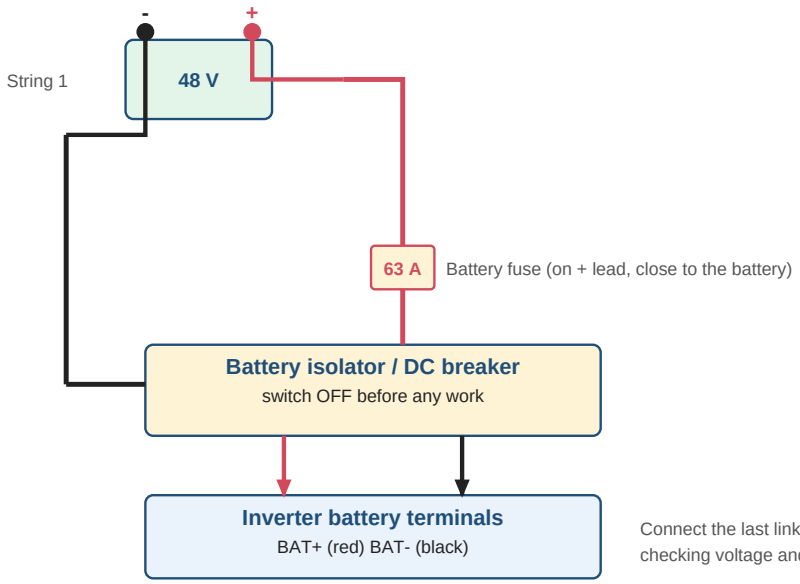


Check with a multimeter BEFORE connecting: each string reads no more than 211 V (Voc) and the polarity is right (+ on red). Never join strings with different voltages. Panels give power whenever there is light.

Your battery bank: how to connect it

How to connect your batteries

1 module(s) in SERIES per string (+ of one to - of the next): 1 x 48 V = 48 V.
Bank: 48 V, 4.8 kWh. Module: 48 V 100 Ah. Cable: 25 mm2, crimped lugs.
Use the same model and age for every module; make all links the same length; tighten to the datasheet torque.



Connect the last link only after checking voltage and polarity.

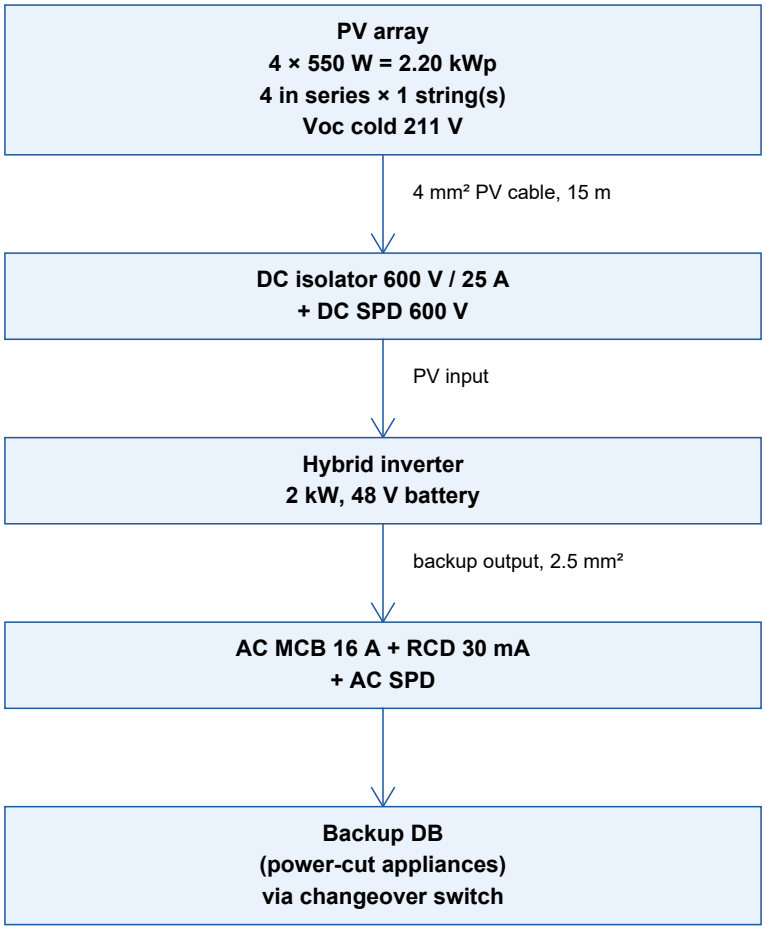
- SERIES (+ of one to − of the next): voltages add, current stays the same. PARALLEL (+ to +, − to −): currents add, voltage stays the same. Power = volts × amps either way.
- 4 panels in series per string × 1 string(s). String voltage: about 166 V working, 198 V open-circuit at 25 °C, up to 211 V on the coldest morning (-1.0 °C) and down to 146 V working on a hot afternoon. Your hybrid inverter accepts: max 500 V, MPPT 125-425 V. Allowed string length for your equipment: 4 to 9 panels.
- Too many panels in series → cold-morning voltage above the inverter limit → the inverter is destroyed (not covered by warranty). Too few → voltage below the MPPT window on hot days → the inverter stops or harvests little.
- Every string joined in parallel must have the same number of the same panels facing the same way; otherwise the strings

fight each other and the system loses power.

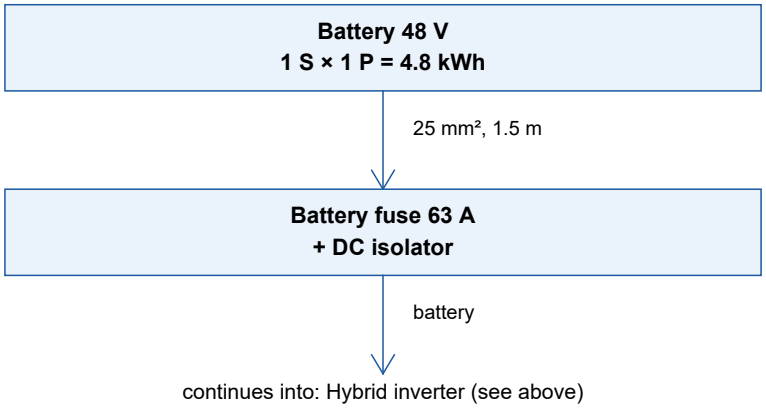
- 1 in series × 1 in parallel = 4.8 kWh. Series raises voltage to match the inverter; parallel adds Ah (hours of backup). Use identical batteries; for parallel strings take + from the first battery and − from the last (diagonal), with equal-length links (book §107).

E. Your whole system, drawn

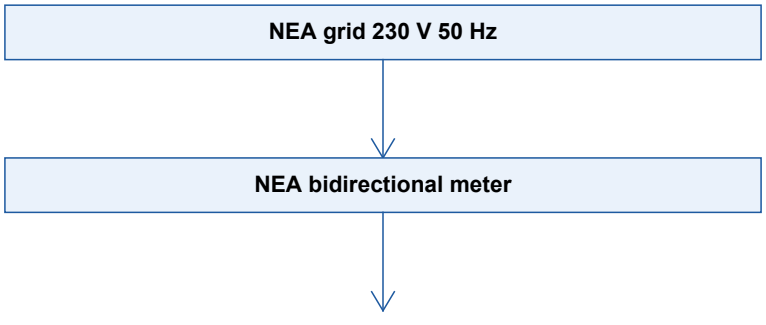
Path 1

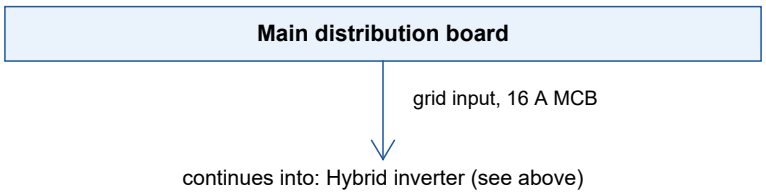


Path 2

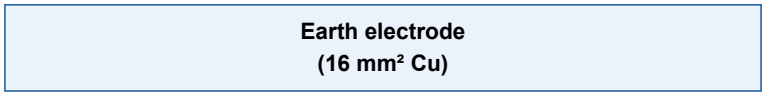


Path 3





Path 4

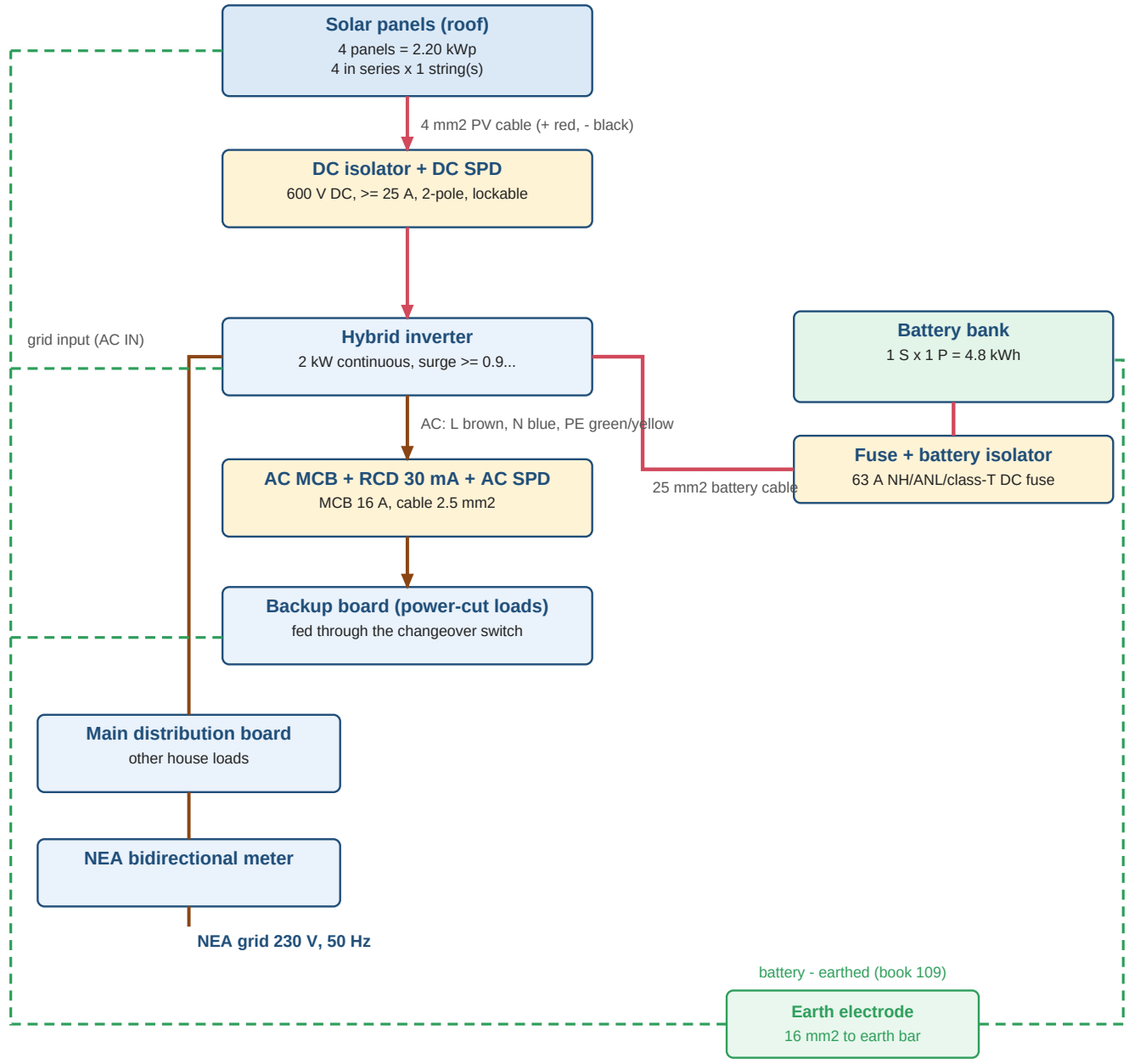


Every connection (wire from this table)

From	To	Cable / protection
PV array	DC isolator 600 V / 25 A	4 mm² PV cable, 15 m
PV array	Earth electrode	6 mm² frame bonding
Battery 48 V	Battery fuse 63 A	25 mm², 1.5 m
Battery 48 V	Earth electrode	battery − earthed (§109)
DC isolator 600 V / 25 A	Hybrid inverter	PV input
Battery fuse 63 A	Hybrid inverter	battery
Hybrid inverter	AC MCB 16 A + RCD 30 mA	backup output, 2.5 mm²
AC MCB 16 A + RCD 30 mA	Backup DB	
NEA grid 230 V 50 Hz	NEA bidirectional meter	
NEA bidirectional meter	Main distribution board	
Main distribution board	Hybrid inverter	grid input, 16 A MCB
Hybrid inverter	Earth electrode	2.5 mm² PE

Complete system

Your whole system - Hybrid system with battery backup

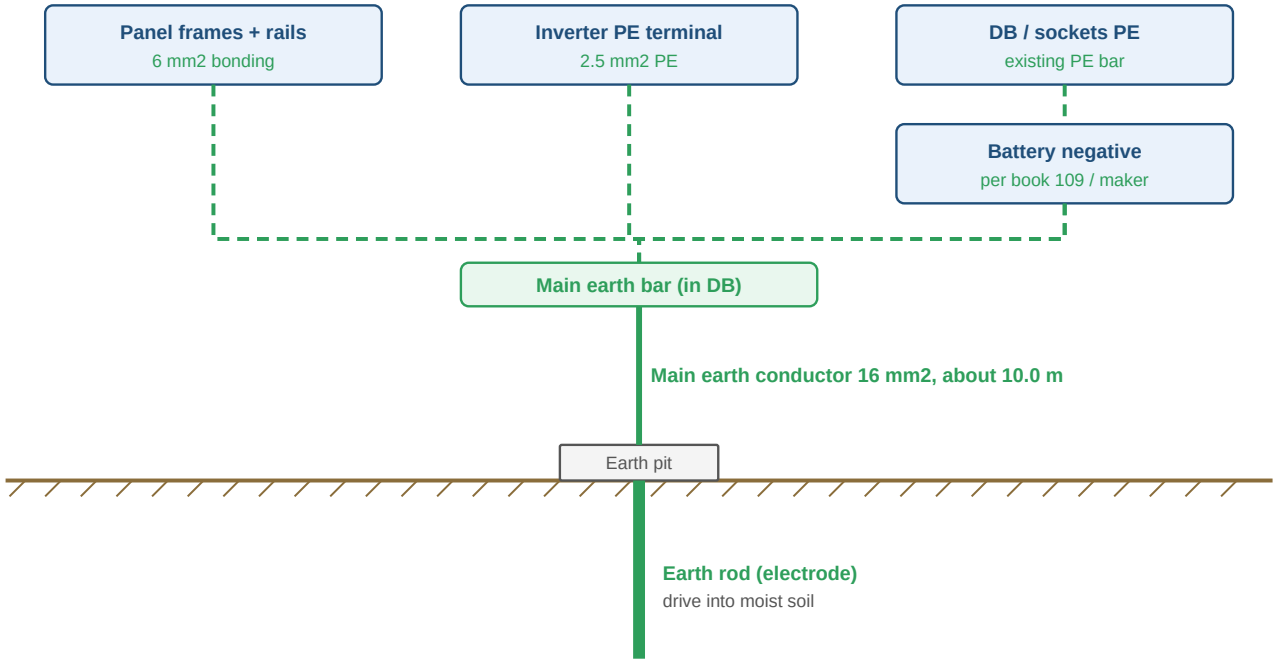


Dashed green = earth wires (green/yellow insulation).

Earthing

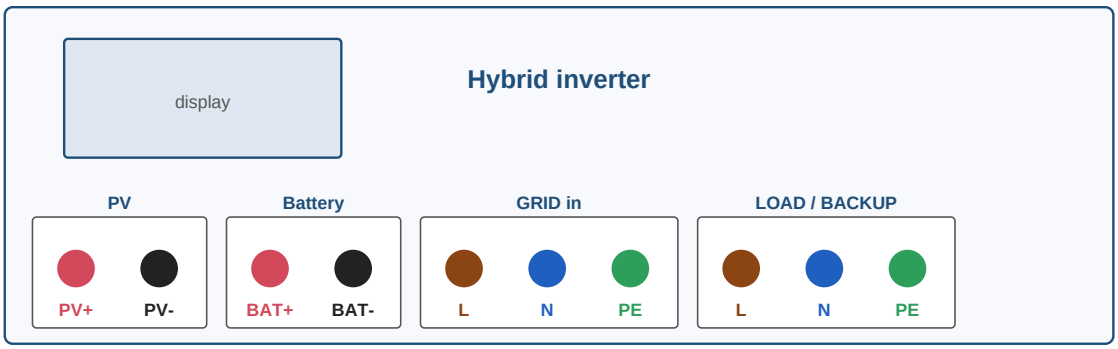
How to earth your system

All metal parts and the earth bar connect to ONE earth electrode. Use green/yellow cable only.
Measure the earth resistance after installation and write it in the test record.



Inverter terminals - what goes where

Inverter terminals - what goes where



Colours: DC + red, DC - black. AC: L (line) brown, N (neutral) blue, PE (earth) green/yellow.
Check YOUR model's manual: terminal positions and labels vary between makes.
Connect in this order: earth (PE) first, then battery, then AC, then PV last; switch on battery -> inverter -> PV.

Wire colours: AC live brown, neutral blue, earth green-yellow; DC + red, - black.

F. Cables, fuses and breakers

Circuit	From → To	Length (m)	Design current (A)	Protective device (A)	Size for current (mm²)	Size for voltage drop (mm²)	Chosen (mm²)	Voltage drop (%)
PV string cable (each string, + and −)	Array → hybrid inverter	15.0	17.5	17.5	2.5	4	4	1.31
Battery cable (+ and −)	Battery bank → fuse/isolator → inverter	1.5	45.8	63	25	10	25	0.25
Inverter AC output	Inverter → distribution board	8.0	8.7	16	2.5	1.0	2.5	0.54
PV frame bonding (earth)	Each panel frame / rail → earth bar	-	-	-	-	-	6	-
Main earthing conductor	Main earth bar → earth electrode	10.0	-	-	-	-	16	-
Inverter / DB protective earth (PE)	Inverter → DB earth bar	8.0	-	-	-	-	2.5	-

Chosen size = the larger of the current-rating size and the voltage-drop size.

G. Safety first, and the legal stop-points

- Panels produce dangerous DC voltage whenever there is daylight - there is no off switch on a panel (§119, §132).
- Never unplug MC4 connectors or open a DC fuse holder while current flows - switch off the isolator first.
- A battery short circuit releases huge current: fire, burns, explosion. Fuse it, insulate tools, remove jewellery.
- Work at height only with a ladder footed by a helper, a harness on steep roofs, and never in rain or wind.
- Lead-acid batteries contain acid and release hydrogen - ventilate, no flames, wear goggles and gloves.
- Connecting to the NEA grid needs NEA approval and NEA's bidirectional meter; never back-feed the grid without approval (danger to line workers). House wiring at 230 V can kill: switch the main switch OFF, or use a CTEVT-certified electrician if you are not confident.
- Use NEPQA-2025 compliant equipment (AEPC) so warranties and any subsidy remain valid.
- House wiring (230 V AC): no Nepali law requiring a licensed electrician for house or solar wiring was found (only CTEVT/NSTB skill certificates exist). You may do it yourself if you follow this report exactly and test the RCD and earth afterwards - but 230 V AC can kill: if you are not confident, have a CTEVT-certified electrician do the AC connection while you watch, and check their work against this report.
- Everything on the DC side (panels, mounting, DC cables, isolator, SPD, battery) can be done by a careful owner following this report, but panels are live whenever light falls on them - cover them while wiring.
- COMPULSORY: apply to your NEA distribution centre before connecting to or exporting to the grid. NEA approves the system and fits/seals the bidirectional meter. Export without approval is not allowed and endangers line workers during outages. Keep export switched OFF until approved. The procedure's validity after mid-2025 was unclear - confirm the current steps at your NEA office.
- Never connect the inverter's backup output and the NEA supply together - the changeover must be break-before-make.
- If anything gets hot, smells of burning, or the display shows an earth/insulation fault: switch off in the shutdown order and do not restart until the cause is found.

H. Skills you will need (learn these before starting)

Using a multimeter safely

- 1. Why: You will check voltage and polarity before every connection - it is the installer's most important tool.
- 2. Set the dial to DC volts (V with a straight line), range above 1000 V if manual-ranging.
- 3. Black probe in COM, red probe in V/Ω. Never use the 10 A / mA socket for voltage.
- 4. Panel test: in sun, touch red to the panel + and black to −. Expect about 49.5 V (the panel's Voc). A minus sign means the probes are reversed.
- 5. String test: with the DC isolator OFF, measure the whole string's + and −. Expect roughly 198 V at 25 °C (higher on a cold morning, up to 211 V). Write it in the commissioning record.
- 6. Continuity test (beep mode) only on cables that are disconnected at both ends.
- 7. Never measure current by putting the probes across a battery or a string - that is a short circuit.
- 8. Safety: Use a CAT III 1000 V DC meter with good probes.
- 9. Safety: Keep fingers behind the probe guards.

Assembling and crimping MC4 connectors

- 1. Why: Badly made MC4 joints are the most common cause of solar fires (book §120 stresses good connections).
- 2. Strip about 7 mm of insulation without nicking the copper strands.
- 3. Insert into the metal pin; crimp with an MC4 crimping tool in the matching die (4 or 6 mm²).
- 4. Pull hard on the pin - it must not move.
- 5. Push the pin into the housing until it clicks; tighten the back nut with MC4 spanners.
- 6. Male pin goes in the female housing for one polarity - follow the panel's own plugs: + lead gets the connector that mates with the panel's − lead plug, and vice versa.
- 7. Check polarity with the multimeter before plugging in.
- 8. Safety: Never plug/unplug MC4 connectors while current flows - open the DC isolator first.
- 9. Safety: Never mix connector brands.

Fixing the frame to the roof and waterproofing

- 1. Why: The frame must survive monsoon storms and the roof must not leak (book §123).
- 2. RCC flat roof: mark positions, drill with a masonry bit, clean the dust, set anchor bolts (chemical or expansion), apply waterproof sealant around each one and over the base plate edges.
- 3. Tin / sloping roof: locate the purlins, use roof hooks or feet screwed into the purlins with EPDM washers and roofing sealant; never fix to the sheet alone.
- 4. Check the tilt with a phone angle app and that rails are straight before fixing panels.
- 5. Pour water around fixings after installation and check inside for leaks.
- 6. Safety: Use a harness on sloping roofs and keep away from roof edges.
- 7. Safety: Never work on a wet roof.

Cable routing, conduit and labelling

- 1. Why: Neat, protected cables last 25 years; labels keep the next person safe.
- 2. Run + and − of each circuit together in UV-proof conduit or tied to the rails.
- 3. Use cable glands where cables enter boxes; leave drip loops so water runs off.
- 4. Label: 'SOLAR DC - LIVE IN DAYLIGHT' at the isolator, inverter and DB; 'Two power sources' at the DB and meter; circuit names on every breaker.
- 5. Safety: Keep DC and AC cables apart where possible.
- 6. Safety: No joints inside walls.

Measuring earth resistance

- 1. Why: A good earth makes fault and lightning protection work.
- 2. Best: an earth resistance tester (3-pole method) - hire one or ask the electrician; record the value.
- 3. Target: as low as practical and within your local electrical rules (ask the electrician/NEA what value they require) - add a second rod if it is high.
- 4. Simple check without a tester: the RCD must trip when its test button is pressed, and the multimeter should show near 0

Ω continuity between each panel frame and the earth bar (system OFF).

- 5. Safety: Disconnect the earth conductor only with the whole system OFF.

Crimping battery lugs and tightening terminals

- 1. Why: Battery currents are large; a loose or badly crimped lug gets hot enough to melt (book §125).
- 2. Cut the 25 mm² cable square; strip exactly the lug barrel depth.
- 3. Insert fully, crimp with a hydraulic crimper using the die for that cable size (two crimps for big lugs).
- 4. Slide on heat-shrink (red +, black −) and shrink it with a hot-air gun.
- 5. Tighten terminal bolts with a torque wrench to the battery manual's value; re-check after one week.
- 6. Safety: Remove rings and watches; use insulated spanners.
- 7. Safety: Connect the − cable last, disconnect it first.
- 8. Safety: Never lay tools on top of batteries.

Setting up the inverter / charger for your battery

- 1. Why: Wrong charge settings shorten battery life or damage it.
- 2. Select the battery type in the menu: 'LiFePO4/Lithium' (use the battery's communication mode CAN/RS485 if both support it) or 'Flooded/AGM' for lead-acid.
- 3. If you must enter voltages manually, copy them from the BATTERY datasheet: charge (absorption) voltage, float voltage, low-voltage cut-off, max charge current.
- 4. Typical values for a 48 V (16-cell) LiFePO4 battery, ONLY if the datasheet gives none: charge about 54-56 V, cut-off about 46-48 V; never above 57.6 V = 3.6 V per cell (NEPQA-2025 high-voltage disconnect). For 24 V divide by 2.
- 5. Set the maximum charge current at or below the battery's recommended value.
- 6. Hybrid: set the backup reserve (e.g. keep 30-50 % for power cuts) and the grid charging on/off.
- 7. Safety: Typical values are a fallback only - the battery datasheet always wins.

First switch-on and safe shutdown

- 1. Why: The order protects the electronics (book §107, §126-§128).
- 2. Switch ON: battery isolator → inverter → (wait for battery detection) → PV DC isolator → AC output breaker → loads one by one.
- 3. Check the display: PV voltage close to your string voltage, battery voltage, no fault codes.
- 4. Shutdown: loads/AC breaker OFF → PV DC isolator OFF → inverter OFF → battery isolator OFF.
- 5. Safety: Never open the battery isolator while the inverter is running heavy loads.

Monthly self-check (10 minutes)

- 1. Why: Catches problems before they become expensive (book §131-§139).
- 2. Compare this month's energy in the app with the expected monthly figure in your report.
- 3. Look at panels for dirt, bird droppings, cracks; clean with water and a soft brush early morning.
- 4. Check SPD windows (green = OK), smell/heat at terminals, loose cables, rust on the frame.
- 5. Press the RCD test button.
- 6. Battery: no swelling, terminals clean and tight.
- 7. Safety: Do not hose panels in hot afternoon sun (thermal shock); never use detergent or pressure washers.

I. Step-by-step installation

1. Before you start - safety and tools (§118-§120)

- 1. Read every manual (inverter/controller, battery) first - the settings matter as much as the wiring.
- 2. Tools: digital multimeter (DC up to 1000 V), DC clamp meter, insulated screwdrivers, crimping tool for MC4 and battery lugs, torque wrench, drill, spirit level, compass (phone app), ladder or scaffold.
- 3. Protection: insulated gloves (Class 0 for arrays above 500 V, Class 00 below), safety glasses, safety shoes, harness for roof work. Keep a first-aid kit; for lead-acid add eye wash and acid spill kit.
- 4. Never work alone on a roof. Keep children and animals away and tell people nearby you are working with high voltage.
- 5. Remove rings, watches and bracelets before touching batteries - a short circuit can weld metal.
- 6. This array reaches about 211 V DC - lethal. Wear insulated gloves when handling PV connectors (§126).

2. Site check (§63-§73, §121)

- 1. Confirm the roof spot is free of shade from about 9 am to 3 pm all year (trees, water tanks, neighbouring floors - Nepali rooftops grow!).
- 2. Check the roof can carry the panels and frame; on tin roofs fix into the purlins, never only the sheet.
- 3. Choose the inverter/battery place: dry, shaded, ventilated, close to the battery (within ~1-2 m, §125) and near the distribution board. Batteries off a cold concrete floor on a shelf (§124).
- 4. Mark the cable route and the earth-pit location.

3. Mount the structure and panels (§123)

- 1. Fix the tilt frame facing due south at the designed tilt; tighten all bolts.
- 2. Unpack each panel and look for cracked glass; measure each panel's open-circuit voltage in sun - expect about 49.5 V (cooler days higher).
- 3. Clamp the panels to the rails (end clamps at row ends, mid clamps between panels).
- 4. Keep panels covered with an opaque sheet, or leave the strings unconnected, while you wire - panels make electricity whenever light falls on them.

4. Wire the PV strings and check polarity (§106, §123)

- 1. Connect 4 panels in series per string (+ of one to − of the next) using the panel leads.
- 2. Make 1 string(s). Use only matching MC4 connectors, crimped with the proper tool.
- 3. Measure each string's open-circuit voltage before going further: expect about 198 V at 25 °C (up to 211 V on a cold morning). All strings should read within ~2 % of each other.
- 4. Check polarity with the meter (red + / black −). A reversed string can destroy the inverter.
- 5. Run the PV cables (4 mm² red and black) in UV-resistant conduit to the DC isolator; keep + and − close together to limit loops (lightning).
- 6. Leave the DC isolator OFF.

5. Earthing (§109, §121, §124)

- 1. Make the earth pit/rod and connect a 16 mm² green/yellow cable to the main earth bar.
- 2. Bond every panel frame and rail with 6 mm² green/yellow cable (or approved bonding clips).
- 3. Connect the inverter and distribution-board earth terminals to the earth bar.
- 4. For battery systems, earth the battery negative as the inverter manual allows (many LiFePO4 hybrid inverters require it to stay floating - follow the manual).
- 5. Measure and record the earth resistance; improve the pit (deeper rod, second rod) if it is high.

6. Install the battery (§124)

- 1. Place the battery upright on a sturdy shelf, ventilated, away from sparks, sun and children; label it with the installation date.
- 2. Connect 1 module(s) in series and 1 string(s) in parallel with the maker's interconnect cables; use equal cable lengths for parallel strings.
- 3. Tighten every terminal to the torque on the datasheet; protect terminals from short circuits.
- 4. Fit the 63 A battery fuse on the + cable close to the battery, then the battery isolator - leave it OFF.
- 5. Measure the bank voltage: LiFePO4 48 V-class banks rest at about 51-53 V; lead-acid about 51-53 V when charged.

7. Mount the inverter / controller (§125)

- 1. Mount vertically on a non-flammable wall with the clearances in its manual (it gets hot).
- 2. Connect the battery cables (25 mm²) to the inverter: negative first, check polarity twice, then positive.
- 3. Connect the PV DC isolator output to the PV input terminals - still with the isolator OFF.
- 4. Set the battery type and voltages in the inverter/controller menu before switching on (§127).

8. AC connection - careful: 230 V can kill (§119, §126)

- 1. The inverter AC output goes through a 16 A MCB, a 30 mA RCD and an AC surge protector to the backup distribution board via the changeover switch.
- 2. Switch OFF the house main switch first. No Nepali licence law for house wiring was found, so you may make this connection yourself following these steps exactly, then press the RCD test button; if you are not confident with 230 V, have a CTEVT-certified electrician do it while you check it against this report.
- 3. For net billing: apply at your NEA distribution centre BEFORE connecting to the grid; NEA approves the inverter (anti-islanding) and fits a bidirectional meter. Exports are not credited before approval.

9. Switch on (§125, §127-§128)

- 1. Turn ON the battery isolator - the inverter/controller should wake up and show battery voltage.
- 2. Turn ON the PV DC isolator in daylight - check the PV voltage and charging/feeding power on the display.
- 3. Turn ON the AC MCB and test with a small load such as a lamp.
- 4. Shutdown order is the reverse: AC MCB off → PV isolator off → battery isolator off. Never open DC connectors under load.

10. Commissioning tests and first week (§127-§128, IEC 62446)

- 1. Fill in the commissioning record table in this report (expected values are given).
- 2. Insulation test of each string to earth at 500 V: minimum 1 MΩ.
- 3. Simulate a power cut (switch off the NEA main) and check the backup circuits keep running.
- 4. For battery systems, let the battery charge fully for a day before heavy use (§128).
- 5. Watch the daily kWh for a week; compare with the monthly estimate in this report.

J. Testing before switching on (write the measured values)

Test	Expected	Measured	OK?
String 1 open-circuit voltage (Voc)	≈ 198 V at 25 °C (max 211 V cold)		
String 1 short-circuit current (clamp meter, sunny)	≤ 14 A (≈ Isc × sunlight/1000 W/m²)		
Polarity of every string and the battery	Correct (+ to +)		
Insulation resistance, string + and − to earth	≥ 1 MΩ		
Earth electrode resistance	As low as practical - record value		
Battery bank voltage at rest	48-55 V		
Inverter AC output voltage / frequency	230 V ±10 %, 50 Hz (NEPQA)		
RCD trip test button	Trips		

K. Looking after the system

When	Task
Weekly	Glance at the inverter/controller display: daily kWh, battery state, any fault codes; keep a simple logbook (§139).
Monthly (dry season: Oct-May)	Clean panels early morning with soft brush and plain water - Nepal dust and brick-kiln soot cut output; no detergent abrasives.
Monthly	Check battery area: ventilation, no leaks, dust off battery tops; LiFePO4: check BMS alarms. Lead-acid: water level (§139).
Before monsoon	Check roof fixings, conduit seals and junction boxes for water ingress; clear drains around the earth pit.
Every 6 months	Re-torque battery and DC terminals (power off); look for hot or discoloured connectors; test the RCD button.
Yearly	Measure string voltages and compare with the commissioning record; test earth resistance; check SPD status windows; balance lead-acid batteries (§139).
After lightning / storm	Check SPD indicators and replace tripped cartridges; inspect panels for damage.

L. If something goes wrong

Symptom	Likely cause	What to check
Battery runs flat / power cuts off early	Using more energy than designed (§134)	Logbook or inverter daily use vs the design figure; reduce load or add panels/battery.
Lower solar output than expected	Dirt, new shade, wrong angle (§135)	Clean panels; look for new shade (tree, tank, new floor next door); compare string voltages.
Strange or intermittent faults, worse in heat/cold	Loose or damaged connection (§136)	With power off: tighten terminals, inspect MC4s for burn marks, measure voltage drop along cables.
Power fails when a big appliance starts	Inverter surge too small or weak battery (§137-§138)	Compare motor starting current with inverter surge rating; check battery voltage under load.
One battery hotter or lower voltage than others	Failing cell (§137)	Voltage difference > 0.7 V needs balancing; ≥ 2 V means a failed battery - replace it.
Inverter trips on hot afternoons	Overheating / poor ventilation (§138)	Clear space around the inverter, keep it out of direct sun, check its fan.
Inverter trips in rain	Earth leakage / insulation fault (§138)	Insulation-test strings; look for water in junction boxes and damaged cable.
Grid-tied inverter shows 'grid over-voltage' at midday	High NEA voltage plus cable rise	Measure grid voltage; a larger AC cable reduces voltage rise; ask NEA about transformer tap.

References: Boxwell, Solar Electricity Handbook §104-§112 (design, protection), §117-§130 (installation), §131-§139 (troubleshooting, maintenance); IEC 62548-1 (PV array design), IEC 62446-1 (testing), IEC 60364-5-52 (cable current ratings), IEC 60364-7-712 (PV installations); NEPQA-2025 and Amendment-1 (AEPC); Copper/PVC in conduit, IEC 60364-5-52 method B1, 2 loaded conductors (conservative)

1. Home solar - hybrid with power-cut backup

Input parameters

System type	hybrid backup
Charge controller / MPPT	MPPT
Panel rating	550.00 W
Inverter efficiency	94 %
Temperature loss	10.87 %
Shading loss	0 %
Battery type	LiFePO4 (lithium)
Depth of discharge	90 %

Calculation method and equations

- Daily Wh = Σ (W × qty × hours) (§48)
- Design Wh = DC Wh + AC Wh ÷ η_inverter (§50)
- Array W = Design Wh ÷ sun hours (annual average) ÷ (η_controller × (1 − temperature loss) × (1 − shading)) (§56-§59)
- Panels = ceil(Array W ÷ panel Wp)
- Battery Wh = backup appliances W (÷ η_inverter for AC) × power-cut hours ÷ η_battery [modern/derived]
- Battery Ah = Battery Wh ÷ system V ÷ depth of discharge (§89)
- Current = W ÷ system V (§86); Cable mm² = L × I × 0.04 ÷ (V ÷ 20) (§87)
- System V: lowest of 12/24/48 V keeping that cable ≤ 6 mm² (§85); 12 V only up to ~3 kW (§91)
- Controller A = array W ÷ system V × 1.25 [modern margin - the book gives none, §90]
- Inverter W ≥ max(4/3 × backup appliances (§91), installed array ÷ 1.2) [modern]

Results (calculated by deterministic code)

Appliance energy per day	8,070.00 Wh/day
Energy the solar must supply per day (after losses)	8,585.11 Wh/day
Everything switched on at once	1,190.00 W
Sun hours used (annual average)	5.198 kWh/m²/day
Solar array needed	2,059.11 W
Panels of 550 W	4 panels
Installed solar array	2,200.00 W
Roof area for panels	10.32 m²
Battery / system voltage	48 V
Energy the battery must deliver	2,508.40 Wh
Battery capacity at 48 V	58.06 Ah
Battery nominal capacity	2.787 kWh
Charge controller rating (array current × 1.25)	57.29 A
Battery/array cable by the book's formula (5 % drop)	2.292 mm²
Estimated battery life (one cycle per day, capped)	12 years
Inverter continuous rating	1,833.33 W
Estimated solar generation per year	3,347.97 kWh/yr
Appliance use per year	2,945.55 kWh/yr

Appliance list (power analysis)

Appliance	W	Qty	Hours/day	Wh/day	Supply	Backup	Motor
LED bulb	10.0	10.0	6.0	600.0	AC 230 V	Yes	
Ceiling fan	75.0	4.0	8.0	2400.0	AC 230 V	Yes	Yes
Refrigerator	150.0	1.0	24.0	3600.0	AC 230 V	Yes	Yes

Appliance	W	Qty	Hours/day	Wh/day	Supply	Backup	Motor
LED TV (32-43 inch)	60.0	1.0	5.0	300.0	AC 230 V		
Wi-Fi router	10.0	1.0	24.0	240.0	AC 230 V	Yes	
Water pump 0.5 HP	450.0	1.0	1.0	450.0	AC 230 V		Yes
Laptop	60.0	2.0	4.0	480.0	AC 230 V		

Monthly generation vs use

Month	Sun hours	Solar (kWh)	Use (kWh)	Surplus (kWh)
Jan	5.69	311.3	250.2	61.1
Feb	6.28	310.3	226.0	84.4
Mar	6.7	366.5	250.2	116.4
Apr	6.21	328.8	242.1	86.7
May	5.17	282.8	250.2	32.7
Jun	4.1	217.1	242.1	-25.0
Jul	3.58	195.9	250.2	-54.3
Aug	3.89	212.8	250.2	-37.4
Sep	4.24	224.5	242.1	-17.6
Oct	5.28	288.9	250.2	38.7
Nov	5.76	305.0	242.1	62.9
Dec	5.56	304.2	250.2	54.0

Assumptions

- Method and step order from Boxwell, Solar Electricity Handbook (2012); sunshine is site data (PVGIS), not the book's UK/US tables.
- Controller factor 0.9 (MPPT) as in the book (§58).
- Temperature loss 10.9% from the site's PVGIS model (replaces the book's ×1.4 roof rule).
- Battery: LiFePO4 (lithium), depth of discharge 90%, efficiency 95%.
- Book cable formula assumes copper and a 5 % voltage drop; final cables must also meet current-rating rules.
- Grid is available most of the time; the battery only covers the chosen power-cut hours.

Warnings and limitations

- Motor loads (Ceiling fan, Refrigerator, Water pump 0.5 HP) need a high start-up surge rating - check the inverter's surge (peak) rating against the appliance datasheets (§91).

Data sources and references

- Boxwell, Solar Electricity Handbook (2012)
- PVGIS v5.3 (EC JRC) monthly in-plane irradiation for the site

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.

Reviewed by	
Registration / licence no.	
Signature	
Date	
Comments	