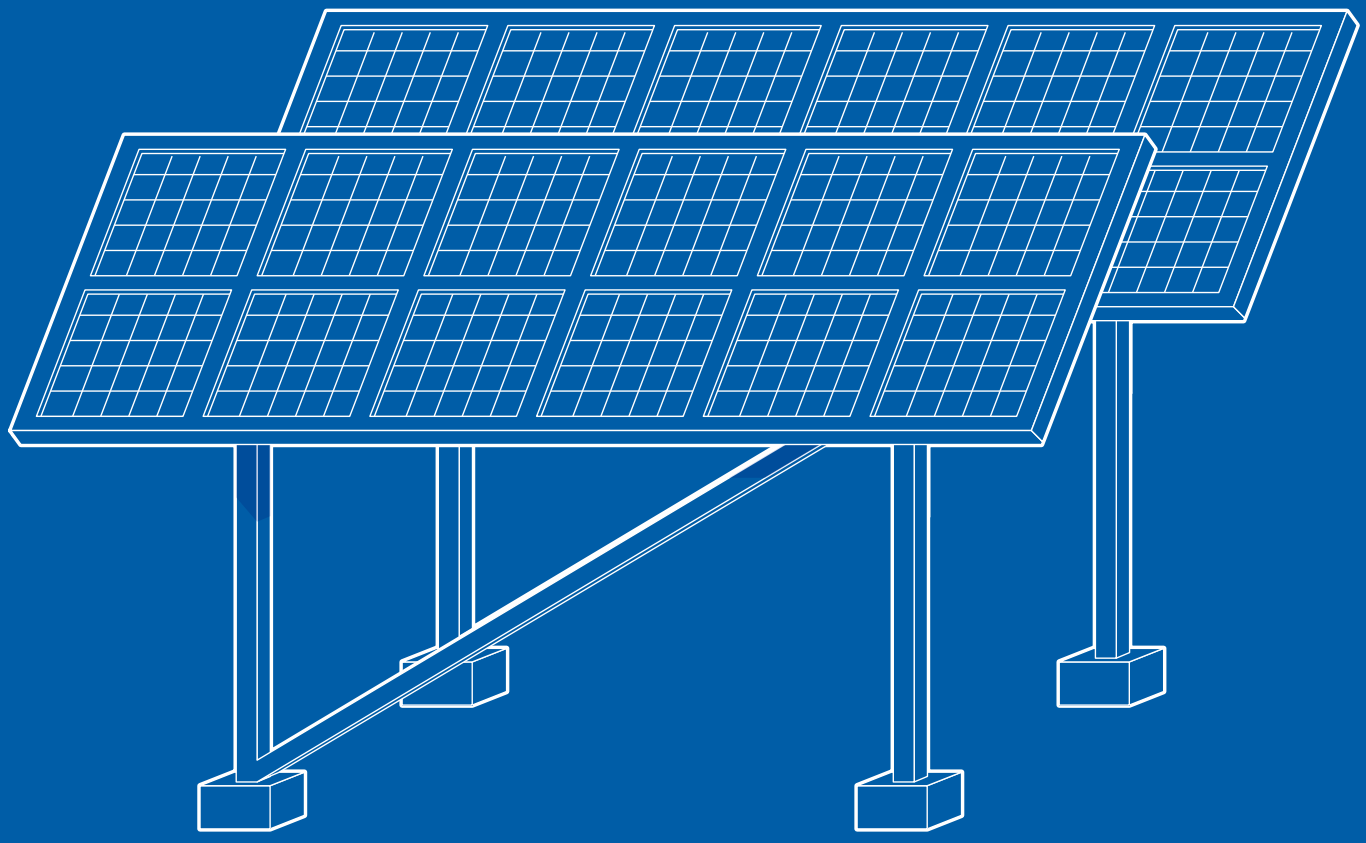
Global Water CENTER

unicef for every child

SPWS Design Specification Guide & Evaluation Checklist

A reference for Advanced SPWS Design Training participants

PART 1	PART 2	PART 3
Common SPWS Specification Gaps	Technical Reference	Tender Compliance



HOW TO USE THIS GUIDE

This guide is a take-away resource — not a replacement for specialist expertise. Use it to write better tender specifications, review your designs, and know when to seek expert help.

★ = Critical — specify in tender

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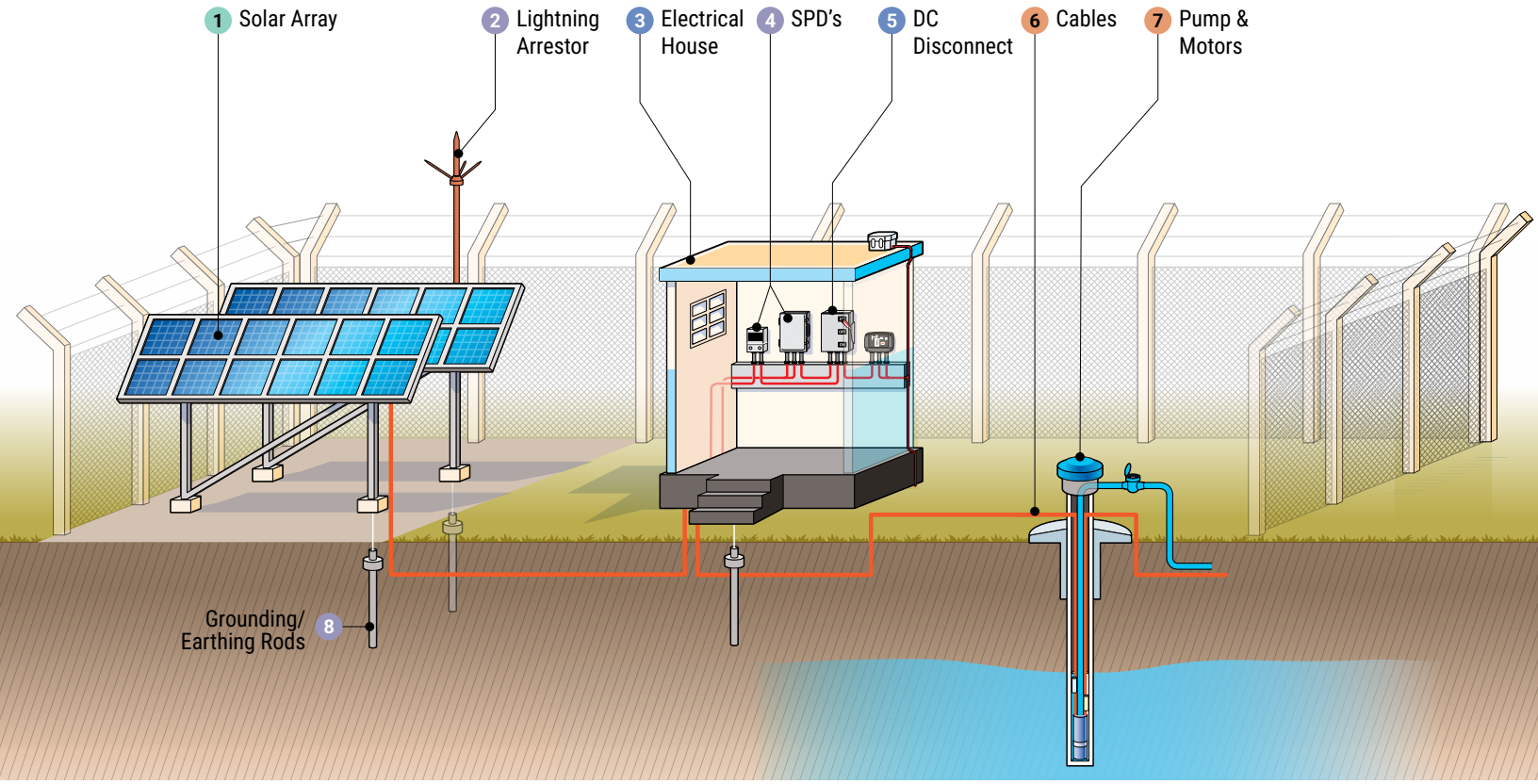
Part 1

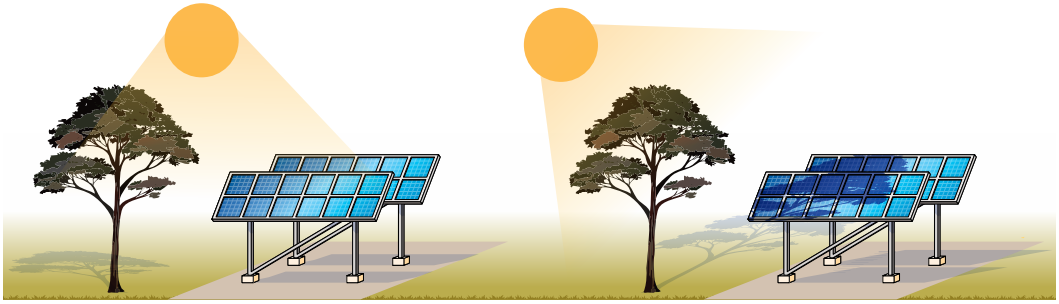
COMMON SPWS SPECIFICATION GAPS

14 common gaps in SPWS tender specifications, organised by system component — drawn from UNICEF field experience and technical review



SOLAR ARRAY

No.	✕ The Gap	✓ How to Address It
1. Shading Analysis	No seasonal shading analysis conducted. In temperate zones, a site that looks unobstructed in June may lose 15–20% of output in December due to lower sun angles and longer shadows from trees, buildings, or fences. Trees and shrubs will grow and need to be assessed for risk of shading in the future.	Conduct a four-season shading analysis before finalizing array position. Target <3% shading loss during peak production hours (9am–3pm). Use PVsyst, SunEye, or SolarPathfinder. Identify trees and shrubs that could cause shading in the future. Document and include results in the design package.

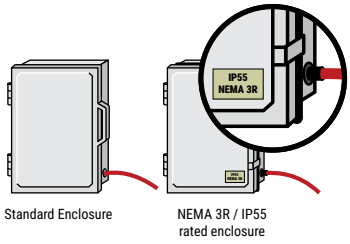


Summer angle of incidence

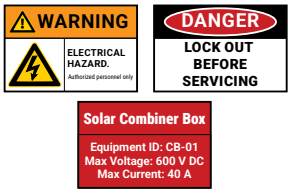
Winter angle of incidence

2. Structural Calculations	No structural or wind load calculations specified for the mounting system. Arrays may be installed on undersized frames that fail during the first storm season, causing panel damage and potential injury.	Require suppliers to submit structural calculations for wind load, anchoring method, and foundation design as part of their tender response. Specify corrosion-resistant materials: hot-dip galvanized steel or anodized aluminum as minimum.
3. Storm Drainage	No storm drainage plan included in the civil specification. Rainwater may accumulate around array foundations and control structures, causing erosion, waterlogging, and eventual flooding of electrical equipment.	Include a storm drainage plan as a civil works deliverable. Drainage channels, gravel aprons, or earthworks must be specified where surface runoff is a risk. Specify that all inverters and control equipment must be elevated above the site's maximum flood level.

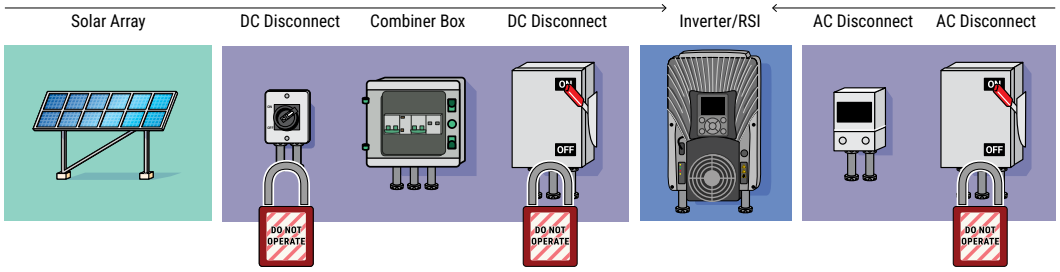
ELECTRIC CONTROL ROOM



Standard Enclosure NEMA 3R / IP55 rated enclosure



No.	✕ The Gap	✓ How to Address It
4. Enclosure Rating	No enclosure IP or NEMA rating specified. In solar pump installations, moisture ingress into combiner boxes and control panels is one of the most common long-term failure modes — especially in tropical climates where condensation is a persistent problem.	Write 'NEMA 3R / IP55 minimum for all enclosures, including indoor installations.' Water Mission 5.2.3 makes this a standard requirement. Specify conduit-sealing foam at all cable entry points to prevent condensation buildup.
5. Safety Signage & LOTO	No safety signage or LOTO (Lockout Tagout) information specified. A technician arriving years after installation — possibly with no handover from the original installer — cannot safely identify or isolate the system.	Specify as required deliverables: 'Warning — Electrical Hazard' on all enclosures; 'Lockout Before Servicing' on all isolators; voltage and current labels on every enclosure; and a LOTO directory diagram showing all isolation points, posted permanently at the site.



6. O&M Language	Operations and Maintenance (O&M) manual provided in English only. The community-level operator cannot read it, so it is filed away and maintenance does not happen. This is one of the most consistent findings from UNICEF field reviews.	Write 'O&M manual required in English AND [local language]' — name the language explicitly. If you do not specify it, it will not be provided. Include this as a contract deliverable with a withhold clause.
7. Stored Energy	Stored energy wait period not documented for VFDs or inverters. These devices store energy in capacitors and remain live and dangerous for 1–5 minutes after isolation. Without documentation, a maintenance technician may open the enclosure too soon.	Document the required wait period in the O&M manual AND on a label affixed to the equipment itself. Always consult the manufacturer's manual for the specific wait time. Include this as a commissioning check item.

PUMP, MOTOR & CABLES

No.	✕ The Gap	✓ How to Address It
8. Wrong Fuse Type	Writing 'DC fuses' instead of gPV fuses. Standard AC fuses cannot safely interrupt DC arcs. In a fault condition, an incorrectly rated fuse may fail to interrupt the circuit, allowing the arc to persist and cause a fire or equipment destruction.	Write 'gPV fuses on both positive and negative DC lines from each string.' gPV is the IEC designation for PV-rated fuses — name it explicitly. Standard AC fuses must never be substituted on a DC circuit.
9. VFD Filter Missing	No frequency filter or Output Reactor specified for long cable runs between the inverter/VFD and pump motor. The lowest bidder will not include one. VFDs produce harmonic disturbances that damage motor windings over time — without filtering the pump motor may fail years before it should.	Write 'dV/dT filter required for VFD-to-motor cable runs exceeding 50m and for VFD-motor runs less than 50m, 'Output reactor required'. (UNICEF guidance). Name the filter type, voltage rating, and current rating explicitly. Always verify against VFD manufacturer requirements
10. No AC Isolator	No AC isolator specified on the AC side. The AC breaker and AC isolator are different devices — the breaker protects the circuit from overcurrent; the isolator provides safe, lockable de-energization for maintenance. Specifying only the breaker leaves no safe maintenance isolation point.	Specify both: 'AC breaker sized to inverter output current' AND 'AC isolator (lockable, LOTO-capable) on AC side.' Both devices must be named in the tender. A breaker alone does not meet the LOTO safety requirement.

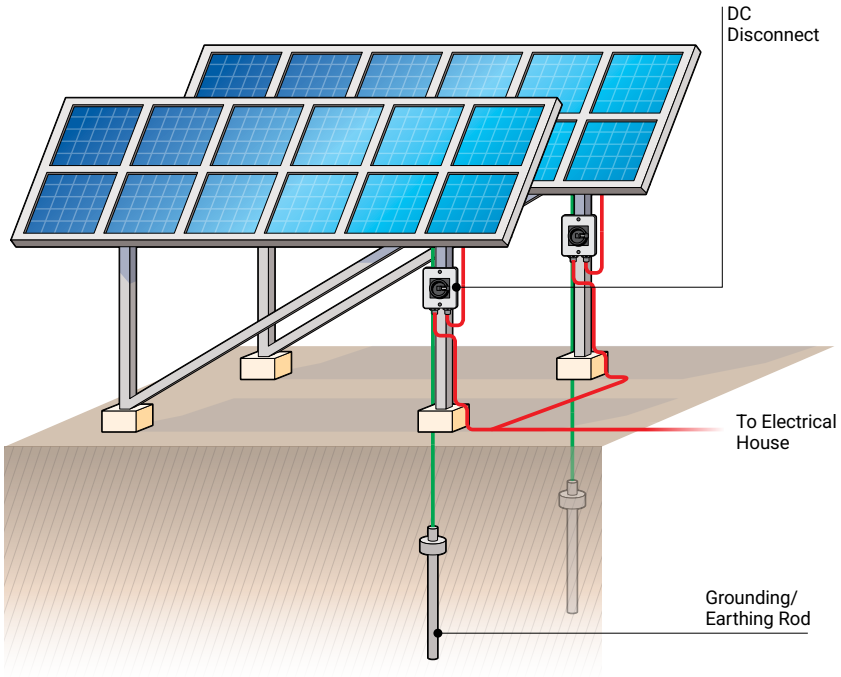
ELECTRICAL PROTECTION — SURGE PROTECTION (SPDS), LIGHTNING & GROUNDING

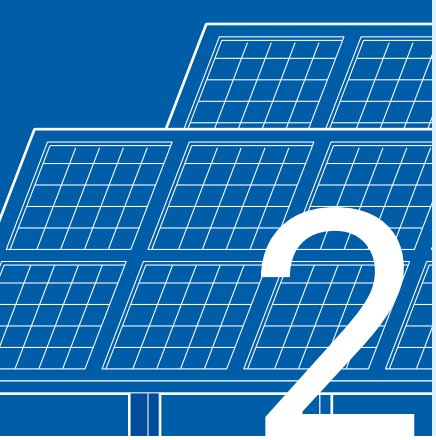
No.	✕ The Gap	✓ How to Address It
11. SPD Type Missing	Writing 'surge protection' or 'SPD' without specifying the type. This leaves the supplier free to install any device at any cost. Type I, Type II, and Type III SPDs provide very different levels of protection — the type must be named.	Write 'AC SPD Type II' and 'DC SPD Type II' in full. Reference IEC 61643-31. For installations in high lightning-risk areas (open plains, hilltops, high rainfall regions), specify Type I+II combination on the DC side.
12. Wrong Breaker Type	An AC-rated breaker specified or installed on the DC side. AC breakers are designed to interrupt AC current, which self-extinguishes at zero crossings. DC current does not have zero crossings — AC breakers cannot extinguish DC arcs, creating a serious and sustained fire and shock risk.	Write 'DC-rated circuit breaker, sized to array Isc × 1.25' explicitly. The DC rating must be stated. Never allow an AC breaker to be substituted on a DC circuit. Include this as a commissioning verification check.



SOURCE: eBay

No.	✕ The Gap	✓ How to Address It
13. Earth Resistance Test	No earth resistance test specified. The grounding system is installed but its effectiveness is never verified. In rocky soils or high-resistivity ground, resistance may be far above acceptable limits — meaning the system offers little real protection during a lightning event.	Specify 'Earth resistance test required at site prior to commissioning — target <10 ohms.' Engage the local power utility early — in many countries they have testing equipment and can advise. If resistance is too high, specify mitigation: chemical earth rods, deeper electrodes, or earth mats.
14. Grounding Plan Missing	Grounding plan not included in the design documentation. Individual components are bonded in isolation rather than connected to a single common earth point. In a fault or lightning event, current has no clear low-resistance path to ground, and dangerous voltage differences can develop between equipment parts.	Require a grounding plan as a mandatory design deliverable, showing all bonding connections and the common earth point. All metallic parts — array frames, mounting structures, inverter enclosures, pump housing — must be connected to the single common earth. Include grounding continuity as a commissioning check.





Part 2

TECHNICAL SPECIFICATION REFERENCE

A. Array & Site Design Requirements

These four areas are consistently missing from solar pump design specifications — and all four can cause serious problems after installation. They belong within design documentation and should be tender requirements.

A1. Module Mounting: Structural Calculations

Solar arrays fail during storms when mounting structures are undersized. This is preventable.

- Require suppliers to submit structural calculations for wind load, anchoring method, and foundation design as part of their tender response.
- Mounting systems must be rated to the local design wind speed — check the national building code for your region.
- Foundation anchoring (concrete footings or ground screws) must be sized to resist uplift, not just downward load.
- Specify corrosion-resistant materials: hot-dip galvanized steel, epoxy painted steel or anodized aluminum as minimum.

A2. Seasonal Shading Analysis

Trees, buildings, and walls cast longer shadows in winter. For example, in temperate weather conditions a site that looks unshaded in June may lose 20% of output in December. Check before you specify the array layout.

- Conduct a shading analysis for all four seasons before finalizing the array position.
- Target: less than 3% shading loss from fixed obstructions during peak production hours (9am to 3pm).
- Free tools include PVGIS (https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html), PVsyst, SunEye, and SolarPathfinder. Document the results in the design package.

A3. Storm Drainage Control Planning

Heavy rainfall can erode foundations, flood control panels, and damage pump infrastructure. Plan for it at the design stage, not after.

- Include a storm drainage plan in the civil works specification.
- Direct rainwater away from array foundations, control panels, and pump structures via drainage channels or earthworks.
- Inverter and all control equipment must be elevated above the site's maximum expected flood level.

A4. Security System

Solar pump systems are high-value targets in communities with limited security infrastructure. Design security mechanisms in from the start.

- Fencing: specify perimeter fencing with minimum height, material grade, and a lockable gate.
- CCTV: for higher-value or higher-risk installations, specify solar-powered cameras.
- Motion-activated lighting and alarm sensors are a cost-effective deterrent for the equipment area.
- Require a security schematic as part of the design documentation package.

Reference Tools

Resource / Tool	Description	Link / Source
PVGIS	Irradiance data and PV orientation	https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html
PVsyst Software	Shading analysis, yield simulation, and array layout	pvsyst.com
SolarPathfinder	Simple field-based site shading assessment tool	solarpathfinder.com
IEC 61215	PV module design qualification — includes wind load	https://webstore.iec.ch/en/publication/61345
Local building code	Minimum wind speed requirements for the region	National standards body

B. Cable Sizing: Ampacity & Voltage Drop

Every cable in your system needs to be sized for two things: (1) it must carry the current without overheating (ampacity), and (2) it must not lose too much voltage along its length (voltage drop). You do not need to be an electrical engineer to do this check — manufacturer reference charts do the calculation for you.

What to check

- Voltage drop: no more than 3% on DC runs, no more than 5% on AC runs. More drop = wasted energy and possible equipment faults.
- Ampacity: the cable's current rating must exceed your system's operating current. Check against the manufacturer's cable table.
- Specify cable type in the tender: PV-rated (for outdoor DC runs), UV-resistant outer sheath. Submersible drop cable must be rated for permanent water immersion.
- For VFD installations: shielded cable between VFD and motor if the run exceeds 20 m.



Tender tip: Don't write 'appropriately sized cables.' Write '4 mm² PV-rated DC cable with UV-resistant outer sheath' — the specifics protect you.

Reference Tools

Resource / Tool	Description	Link / Source
Voltage Drop Calculator	Free online tool — enter length, current, conductor size	https://www.jcalc.net/voltage-drop-calculator-as3008
Cable length selection chart	Ampacity and sizing tables for PV and pump applications — source to be verified	https://franklinwater.eu/media/394151/aid-2-2017-cable-selection-for-borehole-pumps.pdf
IEC 60364-5-52	DC Cable sixing tool	https://elek.com/calculators/cable-sizing-as/

C. Electrical Protection & Isolation Devices

Think of protection devices as your system's safety net. Each device does a specific job, and they must all be named explicitly in your tender. A contractor following a lowest-bid approach will not include a device that is not specified, even if it is standard practice elsewhere.

SOURCE: Tronic



DC SPD

SOURCE: Grundfos



AC Isolator

AC Side — Three Required Devices	DC Side — Four Required Devices
• AC Breaker — sized to inverter rated output current • AC Isolator — lockable switch for safe maintenance shutdown. NOT the same as the breaker — specify both. • AC SPD Type II — surge protection, installed between inverter and distribution board	• gPV Fuses — PV-rated fuses on BOTH +ve and –ve lines. Standard AC fuses will not do — gPV fuses are rated for DC interruption. • DC Breaker — DC-rated, sized to Isc × 1.25 • DC Disconnect — lockable isolator for the DC side • DC SPD Type II — in combiner box; consider Type I+II in high-lightning areas

Why this matters: AC and DC breakers are not interchangeable. DC arcs do not self-extinguish the way AC arcs do — using an AC breaker on a DC circuit is a fire risk.

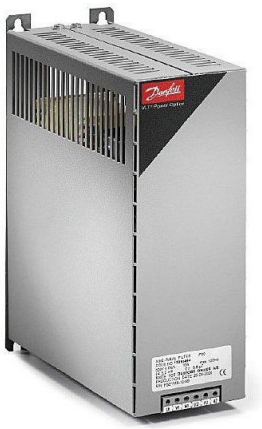
Reference Tools

Resource / Tool	Description	Link / Source
ABB Circuit Breaker Catalogue	Low voltage DC breakers selection charts by current rating	https://library.e.abb.com/public/676fe10fedcd484280466863ab50a791/1SDC200012D0202.pdf?x-sign=Uby7RJYrI6IFhxa2af%2bwbdRr1oKqCM4aKpHtoV7S4bzu2tkLEELs0VZ5CTrog9Lb
ABB Circuit Breaker Catalogue	Low Voltage AC breaker selection charts by current rating	https://new.abb.com/low-voltage/products/circuit-breakers?utm_source=mwoi_main_segmented_page&utm_medium=products
Schneider Electric PV Design Guide	Breaker, isolator, and fuse guidance for solar pumping	se.com (search: solar pumping design guide)
Phoenix Contact SPD Guide	AC and DC SPD Type II selection for PV systems	phoenixcontact.com (search: solar SPD)
IEC 61643-31	Requirements for surge protection devices in PV systems	https://webstore.iec.ch/en/publication/26931

D. AC Systems with VFDs: Frequency Filters

A Variable Frequency Drive (VFD) converts DC power from your solar array into AC power at the right frequency to drive a submersible pump motor. The problem: VFDs produce electrical noise (harmonics) that damages motor windings over time. Filters clean up that noise. Without them, your pump motor may fail years before it should.

UNICEF Minimum Standard: dV/dT filters are required when the cable distance between the VFD and the pump motor is greater than 50 m.



SOURCE: Danfoss

Output Filter

Which filter do you need?

Filter Type	Cable Length	Recommendation
Output Reactor	Cable runs <50m	Minimum level of protection.
dV/dT Filter	Cable run >50 m	UNICEF guidance for long runs. Provides stronger insulation protection.
Sine Wave Filter	Very long runs	Highest protection, but more costly. Use with large motors and long cable runs.
When to use filters	General practice	https://www.youtube.com/watch?v=eogNcrHouAA

Tender tip: dV/dT filters are required when the cable distance between the VFD and the pump motor is greater than 50 m.

Reference Tools

Resource / Tool	Description	Link / Source
Grundfos VFD Application Note	Grundfos Engineering Manual	https://product-selection.grundfos.com
Danfoss VLT Drive Design Guide	Filter selection charts by cable length and motor rating	https://www.danfoss.com/en/about-danfoss/our-businesses/drives/drives-expert-hub/knowledge-articles/

E. Lightning Protection & System Grounding

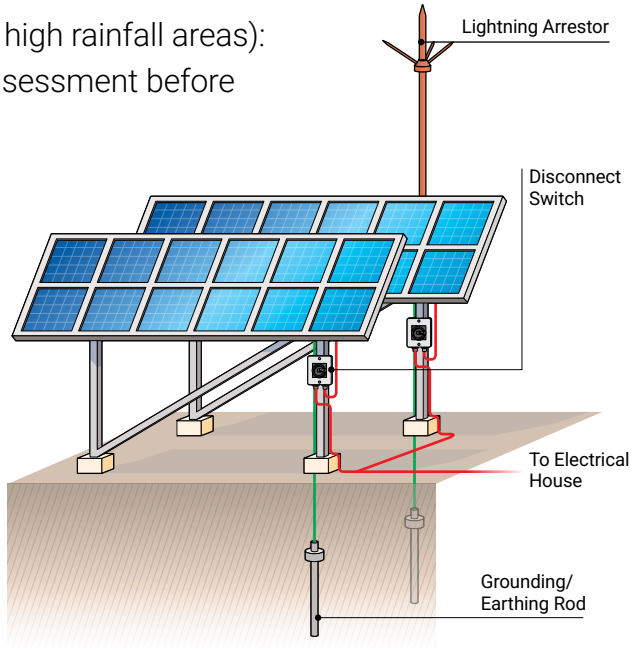
A lightning strike near a solar pump system can destroy the inverter, controller, and pump electronics in milliseconds. Proper earthing and surge protection limits this risk. The specifics depend on your site — this section tells you what to check and what to include in your specification.

Grounding — what to specify

- All metallic parts — array frames, mounting structures, inverter enclosures, pump housing — must be bonded and connected to a single common earth point.
- Before finalizing the grounding design, conduct an Earth Resistance Test at the site. Target: <10 ohms. If the soil resistance is too high (rocky or dry ground), additional measures are needed — chemical earth rods, deeper electrodes, or an earth mat.
- Ask your local power utility. In many countries, the national utility has earth resistance testing equipment and can advise. Engage them before construction.

Lightning protection — what to specify

- Lightning rod placement is calculated using IEC 62305 (or local equivalent). This requires a qualified electrical engineer — do not guess.
- For open sites (plains, hilltops, high rainfall areas): commission a lightning risk assessment before construction.
- Materials: copper earth rods and copper strip are standard. Sizing depends on site resistivity and system current.



Reference Tools

Resource / Tool	Description	Link / Source
IEC 62305	International standard for lightning protection of structures	https://webstore.iec.ch/en/publication/27136
Dehn Lightning Protection Handbook	Practical guide for PV system grounding (free download)	https://www.dehn-international.com/en/downloads#catalogues
Fluke Earth Ground Testing Guide	How to conduct earth resistance tests	https://www.fluke.com/en-us/products/electrical-testing/earth-ground?srsltid=AfmBOoq0LIpjC_bLG5x66CcpyKR1ilE7bZv5U5mYv7qG1z0Mds4asygL
Local power utility	Earth resistance testing and grounding recommendations	Country-specific — engage locally

F. Fire Protection

Electrical components in the control house like Inverter and combiner box faults can cause fires. The risk is low but the consequences are severe. These simple measures must be included in the design and specified in the tender.



SOURCE: Affrosonic

Fire Extinguisher

Equipment	Construction & Installation
• CO_2 or dry powder extinguisher within 5 m of inverter/panel, clearly labelled • Smoke or heat detector in enclosed equipment rooms, connected to audible alarm • 'No smoking / no open flame' signage at the equipment area	• Equipment room walls and roofing: non-combustible materials only (concrete, brick, metal cladding — not timber or thatch) • All cable entry points into equipment rooms sealed with fire-rated material (intumescent foam or fire putty)

Tender tip: Specify extinguisher type, size (minimum 2 kg), and mounting location. List smoke detectors and fire-rated cable sealing as required deliverables.

G. Spare Parts, Safety and System Labeling & O&M Documentation

Spare Parts

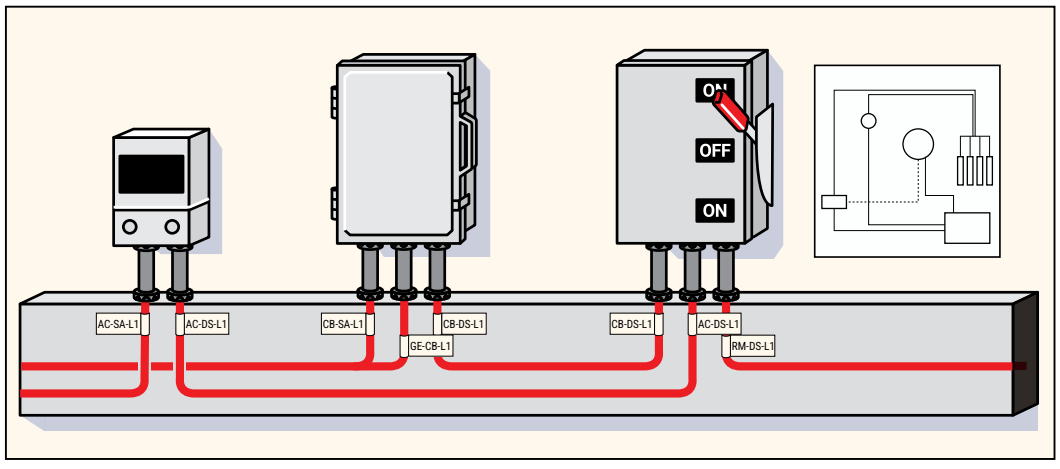
Replacement parts that are not stocked locally will sit on order for weeks or months, leaving a community without water. Include parts requirements in every tender.

- Write this in your tender: 'Contractor to supply manufacturer-recommended 2-year spare parts package (minimum). Remote sites: 3 to 5 years.'
- Critical spares: gPV fuses, control boards, pressure sensors, float switches, motor capacitors (AC systems).
- Decide whether spares sit on-site or with a local distributor — both are valid, but the decision should be made at design stage.

System Labeling

A technician arriving at a system they have never seen before — possibly years later — needs to be able to identify every wire and device without guessing.

- All wiring labeled at both ends with wire numbers that correspond to the as-built wiring diagram.
- Every breaker, fuse, and disconnect labeled with its function and current rating.
- A laminated single-line schematic posted inside the main control panel.
- DC positive and negative conductors: consistent colour coding throughout the entire installation.



O&M Manuals

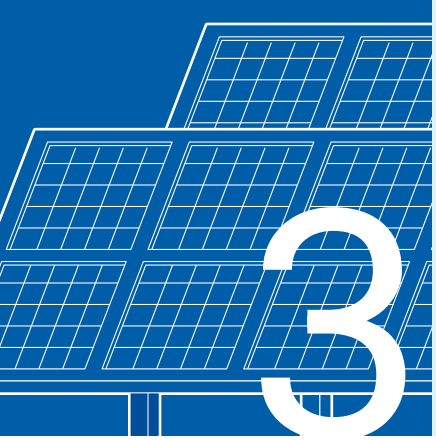
UNICEF Guidance: O&M manuals must be provided in the relevant local language(s). If the community-level operator cannot read the manual, it will not be used. Specify this in every tender.

- As-built wiring diagrams: mandatory handover deliverable. No diagrams = no final payment.
- Commissioning test report: mandatory deliverable. Must confirm all protection devices are functioning.
- Maintenance schedule (minimum annual) to be included in the O&M manual.

Note: Make these contract deliverables, not requests. Include them in the schedule of deliverables with a withhold clause.

H. Design for Maintainability

Design for Maintainability
Every specification decision in this guide has a maintenance consequence. The systems that fail communities are rarely those that were badly built — they are the ones that could not be safely maintained when something went wrong. Keep these principles in mind throughout the design stage:
✳ Accessibility first: Isolators and disconnects must be physically reachable by one person without entering a confined space or climbing. If a technician cannot reach the isolator, the system cannot be safely de-energized.
✳ Spare parts where they are needed: A 2-year spare parts package stored in a capital city warehouse does not help a remote community. Specify where spares are held and ensure the local supply chain can replace a critical component within a reasonable timeframe.
✳ Labelling maintenance infrastructure: Wire numbers, enclosure labels, and the wiring schematic in the panel are not compliance extras — they are the information a technician needs to work safely on a system they have never seen before, possibly years after installation.
✳ SPDs and filters need inspection: Surge protection devices have failure indicators and must be checked periodically. VFD output reactors and dV/dT filters should be on the annual maintenance schedule. If they are not listed, they will not be checked.
✳ Commissioning is the baseline: The commissioning test report is not just a contract deliverable — it is the reference point against which all future maintenance checks are measured. Without it, there is no way to identify gradual degradation.
✳ Stored energy is a maintenance hazard: VFDs and inverters store energy in capacitors and remain live for 1–5 minutes after isolation. This must be documented in the O&M manual and on the equipment itself, not just noted at commissioning.



Part 3

TENDER COMPLIANCE: KEY PRINCIPLES

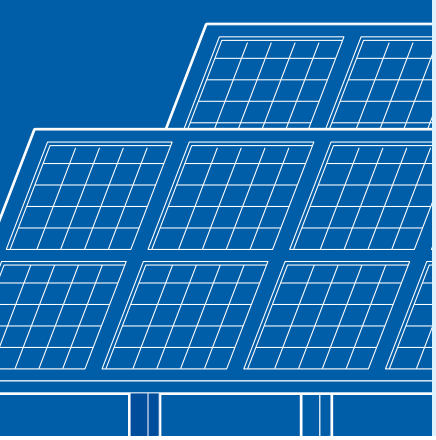
Getting Specifications Into Tenders

The biggest lesson from UNICEF's experience with SPWS procurement: items not written into the tender specification will not be provided. This is not negligence on the part of contractors — it is how competitive tendering works. The specification is the contract. If an item is not there, it is not required.

Five Principles for Better Specifications

1. Be specific	Don't write 'surge protection.' Write 'AC SPD Type II, 40 kA, 230V single-phase, to IEC 61643-31.' A contractor cannot substitute a cheaper device if the specification is clear.
2. Name the standard	Reference the standard: 'dV/dT filter in accordance with VFD manufacturer's installation requirements' is much harder to ignore than 'appropriate filtering.'
3. Require a compliance schedule	Ask each tenderer to submit a compliance declaration: item by item, confirm compliance or explain the deviation. This surfaces substitutions before the contract is signed.
4. Make documentation a deliverable	Include O&M manuals (English + local language), as-built drawings, and commissioning test reports in the schedule of deliverables. Withhold final payment until delivered.
5. Include a Bill of Materials	For any SPWS installation, require the contractor to submit a full Bill of Materials with their tender. This makes it easy to spot missing items before award.

Remember: Better specifications protect the community, not just the project. A system that fails in year 3 because the right fuses were not specified costs far more to fix than specifying them correctly in the first place.



APPENDIX

FURTHER SUPPORT & RESOURCES

Where to Get Further Help

Technical Backstopping

- Design review support is available through the WASH COE.
- Country-specific design support can be arranged independently through country programme budgets.

Local Supply Chain

- Pump distributors (Grundfos, Lorentz, Franklin, Shakti and others) have application engineers who can assist with sizing, filter selection, and local spare parts stocking.
- Electrical equipment distributors (ABB, Schneider, Eaton) can advise on breaker and isolator selection and provide sizing charts.
- National power utilities can often conduct earth resistance testing and advise on grounding systems — engage them early, it is usually free.

Water Mission Technical References (provided with this course)

The following Water Mission documents are distributed alongside this guide and are the primary verified references for electrical safety and principles content:

Resource / Tool	Description	Link / Source
Water Mission 5.1 Electrical Principles	Electricity fundamentals, AC/DC power, solar PV, batteries, power sources. Background reading for understanding why protection devices are specified the way they are.	Provided with course materials
Water Mission 5.2 Electrical Safety	Electrical hazards, safety codes (IEC/NEC), arc flash, LOTO procedure, bonding/grounding, electricity and water, PPE, enclosure ratings, safety signage.	Provided with course materials

Key Standards Referenced in This Guide

Resource / Tool	Description	Link / Source
IEC 62305	Lightning protection for structures and electrical systems	iec.ch
IEC 61643-31	Surge protection devices for PV systems	iec.ch
IEC 60364-5-52	Selection and installation of wiring systems	iec.ch
IEC 61215	PV module design qualification — includes wind load	iec.ch
ISO 9633	Pumping systems — acceptance testing	iso.org
NEC / NFPA 70	US National Electrical Code — referenced in Water Mission standards	nfpa.org
Local Elec. Code	Always verify against national wiring regulations	National standards body



SOURCE: Global Water Center