Smart Energy Solutions for Africa

PRACTICAL OPERATION AND MAINTENANCE MANUAL FOR SOLAR IRRIGATION SYSTEMS

A Comprehensive Guide to Solar-Powered Irrigation Systems Management and Maintenance

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Contents

List of Figures

List of Tables

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Disclaimer

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The information provided in this guide is for general informational purposes only and **should not replace professional advice**. Always consult and hire qualified professionals to ensure your Solar-Powered irrigation system is installed and maintained safely and in compliance with local regulations.

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Introduction

This capacity-building manual was developed as part of the SESA project Smart Energy Solution for Africa, funded by Research & Innovation programme of the European Union. It is designed for technicians, small and medium-sized enterprises (SMEs) owners, and ordinary consumers. The following are the fundamental aims of the manual:

1. **To promote owners' understanding of solar-powered irrigation systems (SPIS)** by introducing basic system operations, monitoring performance, and the related energy and environmental benefits.
2. **To support owners in improving system efficiency,** sharing insights that enable them to optimize energy use, control costs, and extend the lifespan of SPIS.
3. **To provide basic knowledge and skills on routine maintenance**, recommended operational practices, troubleshooting common issues, and identifying situations that require professional intervention.
4. **To highlight the necessary safety precautions** to ensure the well-being of individuals who interact with the systems and to prevent incidents or malfunctions.

Additionally, the manual has the potential advantage of cost savings and eliminate superfluous expenditures (e.g. repairs, energy wastage) by educating users on optimal strategies for operating and maintaining solar-powered irrigation systems on their own. It supports the overarching objectives of promoting sustainable energy practices. This, in turn, aids in the reduction of pollution linked to traditional, fossil fuel powered irrigation systems, and in the mitigation of carbon footprints and the advancement of green energy solutions.

1. Overview of Solar-Powered Irrigation Systems

1.1. Fundamentals of Solar-Powered irrigation systems

A SPIS is a clean and sustainable irrigation technology that utilizes solar energy to pump and distribute water for agricultural use. As water scarcity and unreliable energy access continue to challenge agricultural productivity, SPIS offers a sustainable alternative to the most common irrigation systems by reducing dependence on fossil fuel sources, preventing from the consequences of their volatile prices. By replacing diesel- or gasoline-powered pumps, it lowers greenhouse gas emissions, reduces air pollution, and generates significant cost savings for farmers. Beyond lowering operating expenses, SPIS also supports more consistent and productive farming: it is one of the best-studied solutions for improving smallholder farmers' livelihoods, as access to modern irrigation can substantially increase yields, with case studies showing improvements of up to two- to three-fold (Efficiency for Access, 2019). This reliability enables year-round cultivation, leading to higher crop output, greater diversification, and improved farmer incomes (Schneider S., Raabe M. et al., n.d.).

SPIS is suitable for a wide range of irrigation scales, from small household gardens to large

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agricultural fields. It is particularly suitable for adoption in rural areas with limited access to electricity and abundant solar radiation, offering an affordable solution to increase agricultural productivity.

1.2. Components of Solar-Powered Irrigation Systems

The core components of SPIS are:

a. Solar panels organized in a **PV array**, which converts sunlight into electrical energy. Further information on PV can be found in the SESA Guide "Practical Operation and Maintenance Manual for Solar PV Systems" (Awopone et al., n.d.).
b. **Water pump/motor**, which may be surface-mounted or submersible. The pump extracts water from sources such as wells, lakes, rivers, boreholes and storage and delivers it to the fields through irrigation methods like drip, sprinkler, or flood irrigation.
c. A **pump controller** that plays a critical role in managing the pump's operation, ensuring voltage regulation and protecting it from electrical faults.

Figure 1: Solar Array (source: Erod Photos on Pexels)

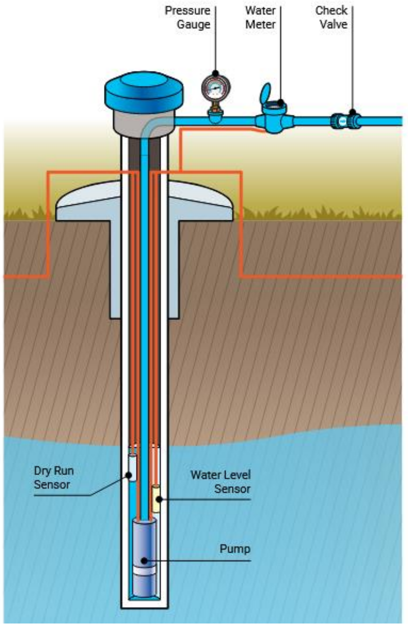

Figure 2: Submersible pump (source: Global Water Center, 2024).

Additional components include inverters (to convert DC electricity to AC), water storage units (elevated or surface tanks), and a mounting structure for supporting PV arrays. The system also incorporates wiring and electrical connections to safely transmit power between components, and an irrigation system (drip, sprinkler, or flood) to deliver water to crops. Optional components, such as a battery bank, can store excess energy for use during cloudy days or nighttime, and water meters can be installed to monitor water usage.

a. **Inverters** that convert electricity from direct current (DC) to alternating current (AC). It also regulates voltage, frequency and current.

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Figure 3: White inverter for solar cell system (© Ratchapon Supprasert | Dreamstime.com)

b. **Water storage units** that hold the pumped water (either surface or overhead storage types)

Figure 4a, 4b: Elevated and surface storage water tanks (source: Anonymous, field photos from Bugesera District, Rwanda).

c. **Mounting structure** that supports PV arrays.

d. **Wiring and Electrical Connections**: electrical connections, such as wires, fuses, circuit breakers, link all components safely and efficiently.

e. **Irrigation system** (drip, sprinkler and flood irrigation): Drip irrigation transports water directly to the plant roots, while sprinkler irrigation transports water through a system of pipes and sprinklers that spray water onto the land, and flood irrigation involves flooding an entire area with water.

Figure 5a,3b,3c: Drip irrigation (source: Anil Sharma on Pexels); Sprinkler irrigation (source: Q. Hưng Phạm on Pexels); Flood irrigation (source: Tom Fisk on Pexels)

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f. **Battery Bank (Optional)**: it can be used to Stores excess electricity for use during periods of low sunlight or at night, enhancing system reliability.

Figure 6: Battery for storage (© Alexey Arama | Dreamstime.com)

g. **Water meter**: Water metering is very important in water management by totalizing cumulative water volume displayed through meter. It reduces energy waste by supplying only required quantity of water (SESA D5.3 Policy roadmaps and policy briefs to remove barriers to specific technologies).

Figure 7: Water meter (source: Nothing Ahead on Pexels)

2. Layout and Configuration

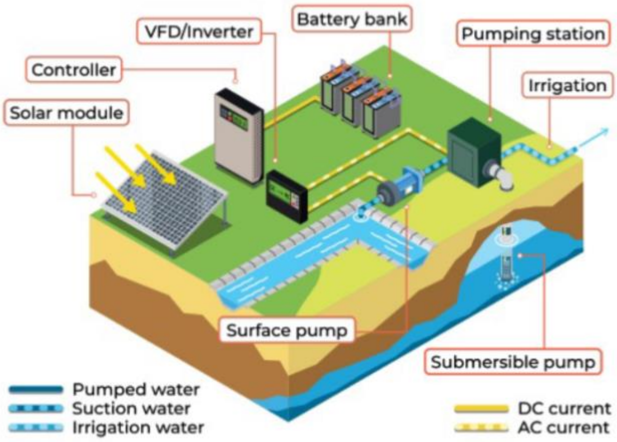

Figure 8: Solar pumping system with battery storage (source: FAO, n.d.).

The layout of the system, meaning how these elements are organized and connected, varies depending on the type of solar pumping system implemented (direct or via storage) and depends on factors such as the distance between the water source and the fields, the elevation

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gain, and the daily water requirements. A proper system layout is key to ensuring efficient energy use, minimizes water losses, and aligning with the specific needs of the crops and terrain. Panels should be oriented for maximum sun exposure, ideally close to the pump to reduce energy losses.
Below are presented the two main types of water pumping: direct pumping and pumped storage.

2.1. Direct pumping

It operates by pumping water from the source to irrigate the fields as needed. Direct pumping systems deliver water directly from the source while the sun is shining, making them simpler, cheaper to install, and easier to maintain. However, they depend entirely on sunlight availability and offer limited control over irrigation timing, unless the system is completed by a storage system. Direct pumping is generally more suitable for small-scale systems, low-lift irrigation, or crops with less stringent watering needs.

Figure 9 shows both direct pumping (submersible pump) and pumped storage (water tank).

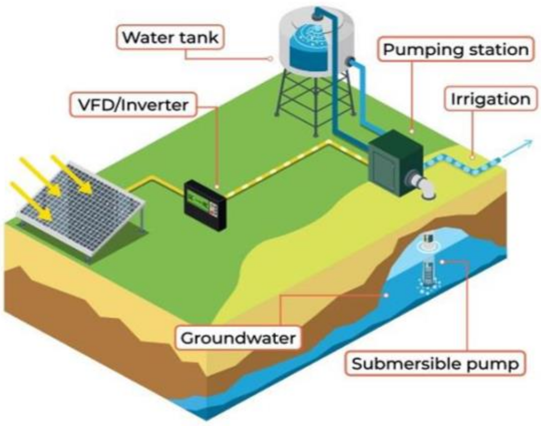

Figure 9: Irrigation system with direct pumping and pumped storage (source: FAO, n.d.).

2.2. Pumped storage

It operates by first pumping water from the source into the elevated storage tank or reservoir, as seen in Figure 9. The stored water is then used to irrigate the fields as needed. Being powered via PV, water is pumped during the day by its storage, allowing it to be distributed when needed, including at night or during cloudy periods. In this case, elevation must be considered to allow for gravity-fed distribution.

While more flexible and better suited to crops requiring precise watering schedules, pumped storage involves higher initial costs, more complex infrastructure, and reliance on favourable geological conditions for building storage. Pumped storage is better suited to larger farms, varied topography, or high-value crops that demand reliable irrigation.

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3. Safety Precautions

Safety precautions are essential to ensure the reliable and long-term operation of a solar irrigation system, while protecting users from potential hazards. Working with electrical components, water, and mechanical parts requires basic awareness and preventive measures.

3.1. Electrical Safety

The electrical safety of a solar pumping system includes grounding all metallic parts, such as solar panel frames, pump casings, and control boxes, to prevent electric shock. It is important to use insulated tools and wear rubber gloves when handling electrical connections to protect against electrical faults, install fuses, circuit breakers, and surge protectors. Additionally, always disconnect the solar panels and batteries before performing any maintenance work to ensure safety. These electrical use practices should always be followed:

(i) **Applying safe installation practices**: It is important to make sure that all components are placed according to the guidelines provided by the manufacturer and the electrical codes of the local area. Ensuring proper grounding and bonding is crucial for minimizing the likelihood of electric shock.

(ii) **Labelling and Signage**: It is important to mark electrical components with information such as power ratings and warning signs. This helps to alert and remind personnel about potential hazards.

(iii) **Maintenance of battery** (for systems with storage, when present): If the system incorporates energy storage components, it is crucial to handle and maintain batteries correctly, as they may pose extra risks such as chemical leakage or thermal runaway.

3.2. Water Safety

A sustainable water management plan is extremely important to protect both the system and the long-term viability of the cultivation. Water safety is a critical factor in the planning and operation of any solar irrigation system and includes both water availability and water quality.

- To maintain water **quality**, always prevent contamination by keeping water storage units properly covered and sealed.
- To ensure water **availability**, expand or increase the capacity of water storage facilities to meet demand during low-supply periods.

3.3. Solar Panel Safety

Always handle solar panels with clean, dry hands or wear gloves to prevent smudging and potential damage to the surface. Qualified technicians should install solar panels properly by mounting them at the correct tilt and orientation for maximum sunlight. For more detailed explanations of the safety of solar PV systems, refer to the SESA "Practical Operation and Maintenance Manual for Solar PV Systems" (Awopone et al., n.d.).

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3.4. Personal Protective Equipment (PPE)

The importance of personal protective equipment (PPE) is to guarantee the well-being of workers by reducing the risks of injury from electrical components, moving parts and getting in contact with chemicals (especially from batteries and cleaning tools).
To ensure their own well-being during installation, operation, and maintenance, workers are advised to follow these precautions:

(i) Put on safety footwear (with non-slip soles) to prevent slips and provide protection against heavy falling objects.

(ii) Use covers on rotating machinery to prevent hand or clothing entanglement.

(iii) Use chemical-resistant gloves, goggles, and aprons when handling or inspecting batteries.

4. Regular operation procedures

The routine operation of solar-powered irrigation systems generally entails activities such as monitoring water flow, conducting maintenance checks on the pumping and irrigation components, and assuring both energy and water delivery efficiency. Although these systems typically require minimal intervention, it is essential to follow regular operational practices to ensure consistent performance, water availability, and to promptly detect any potential problems. Always check daily start-up procedures, monitoring during operation and shutdown at the end of operation every day.

Below is a summary of the standard operating procedures for solar-powered irrigation systems:

1. **Visual Examination**: Inspect solar panels for visible damage, dirt accumulation, or obstructions. Check the mounting structures and surface pump housing for looseness or wear. Ensure irrigation pipes and sprinklers are free from cracks or leaks.

2. **Performance Monitoring**: Track the energy production and compare it with expected output. Monitor the water flow and irrigation coverage against crop requirements. Pay attention to unusual fluctuations in either electricity generation or water output.

3. **Controller Check**: Verify the controller's operational status, ensuring it regulates power distribution effectively between the solar generator and the pump. Look out for error codes, unusual alerts, or irregular readings.

4. **Pump Inspection**: Ensure the pump operates smoothly without abnormal noise or vibration. Confirm that water is being drawn efficiently from the source and delivered at consistent pressure.

5. **Battery system inspection** (if present): Regularly inspect and clean battery terminals carefully. Check electrolyte levels frequently (if applicable) and maintain batteries in a high state of charge to extend lifespan and ensure reliability.

6. **Connections Inspection**: Check all electrical and water connections for tightness and integrity. Look for overheating, corrosion, or leaks in joints and fittings. If necessary, seek

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professional assistance for electrical components.

7. **Irrigation Line Inspection**: Examine pipes, drip lines, and sprinkler heads for blockages, sediment buildup, or wear. Regularly flush the irrigation system to maintain water flow efficiency.

8. **Environmental Factors**: After heavy rain, storms, or drought conditions, inspect both the solar and irrigation systems. Check for debris clogging the pump inlet or damage to irrigation lines caused by animals or environmental stress.

9. **Documentation**: Maintain records of energy generation, water flow rates, irrigation schedules, and maintenance tasks. Documentation helps identify performance trends, crop water usage, and system efficiency over time.

10. **Professional Maintenance Services**: Schedule periodic inspections by trained technicians for both the solar and irrigation components, as some issues (e.g., electrical safety checks or pump servicing) require specialized expertise.

5. Routine Maintenance Practice

The routine maintenance of a SPIS is essential to ensure optimal energy generation, system liability and prolong system lifespan. The classification of these maintenance duties is described in more detail below.

5.1. Solar Panels

Conduct routine cleaning, shade management, and visual inspection of solar panels to ensure optimal energy generation and prolong system lifespan.

Cleaning:

- **Method**: Use soft brushes or sponges and mild soapy water. Use only solar panel cleaning agents that are safe and non-corrosive. Avoid abrasive materials and high-pressure water sprays.
- **Focus Areas**: Remove debris, dirt, and bird droppings from solar panels.
- **Frequency:** at least twice a month.

Inspection:

- **Visual Checks**: Look for cracks, discoloration, or delamination in panels.
- **Mounting and Racking Systems**: Ensure all bolts and supports are secure.
- **Shading**: Check for new shading issues due to tree growth or new constructions.
- **Grounding and Bonding**: Ensure these are intact for safety and system performance.

5.2. Battery Management and Maintenance

Proper battery maintenance is critical to ensure safety, prolong battery life, and maintain the overall performance of a solar pumping system. Key practices include inspecting terminals for

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corrosion, managing charge levels to prevent overcharging or deep discharging, and ensuring adequate ventilation to prevent overheating. Consistent monitoring and preventive care help optimize battery efficiency and reduce the risk of system failure.

- **Inspect Battery Terminals**: Always check for corrosion (white or blue powder), and clean with a baking soda solution if needed.
- **Avoid battery over-charging and under-charging** following these tips:
    i. Setting low-voltage disconnects in your solar system.
    ii. Use a charge controller or inverter with configurable low-voltage cutoffs.
    iii. Monitor the battery state of charge (SOC) regularly.
- **Ventilation**: Ensure battery enclosures are well-ventilated to avoid overheating.

5.3. Inverter and Controller Maintenance

Maintaining the inverter and charge controller is essential for the reliable operation of a solar pumping system.

- **Status Monitoring**: Learn the meaning of indicator lights (green = good, red = fault, etc.)
- **Cleaning**: Keep inverter and charge controllers clean by wiping away accumulated dust with a dry cloth, in a cool and dry place. Minimizing dust buildup helps maintain proper ventilation and performance.

5.4. Wiring and connections

Proper maintenance of wiring and cables is vital for the safety and efficiency of a solar pumping system.

- **Loose Wires:** Check for loose connections or frayed cables.
- **Rodent Protection**: Use protective conduits and check for signs of animal damage.

5.5. Pump Maintenance

Regular pump maintenance is crucial for ensuring efficient operation and extending the lifespan of the system. Key practices include:

- **Ensuring a consistent water supply to prevent dry running**: dry running cause overheating which damages bearing. It can also lead complete failure.
- **Frequently checking and cleaning filters and strainers to avoid clogging**. This prevents build of debris (dirt, trach, broken parts, etc.) that blocks flow of water.
- **Lubricating moving parts as recommended for the specific pump type**. This prevents overheating and ensure smooth operation of the pump.
- **Overheating monitoring to maintain proper cooling**.

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For the water meter maintenance:

- Check the cleanliness around the meter.
- Check the meter connection point.
- Check if the meter reading is accurate by comparing with the previous readings.

5.6. System Monitoring

Effective system monitoring and record-keeping are essential for tracking performance and identifying potential issues early.

- **Daily Energy Check**: Keep on tracking of energy production and usage.
- **Logbook:** develop a simple log of system status, cleaning dates, and any issues.

6. Troubleshooting Common Issues

Table 1: Diagnostic steps for common problems

Issue	Possible Causes	Suggested Actions
Inadequate power generation from the solar array	• Shading • Damaged panels • Long cables with high power losses • Dirty or loose connections • Array not facing the right direction • Dirt on panels (soiling loss)	• Remove the cause of shading. • Align the array in the correct direction and tilt. • Replace any faulty panels. • Check voltage drops and power losses in DC cables. If losses exceed 3%, increase cable size or reduce length.
Pump not starting	• Power supply issues • Controller issues • Motor issues	• Check wire connections. • Check if solar panels and controller are working properly. • Check for error codes in the controller. • Ensure motor protection circuit breakers are not off.
Water tank not supplying enough water	• Reduced water levels in the tank • Problems with inlet or outlet pipes • Pressure issues	• Check water levels in the tank; refill if reduced. • Check inlet and outlet pipes for damage or improper installation; repair or fix if needed. • Check water pressure; if insufficient, inspect pipes for leaks or low water supply.

When to Contact a Professional Technician

Always call professional technician when there are persistent problems in water flow, electricity connection and supply, charger controller, inverter and battery performance that cannot be resolved using basic miniatous skills of the users.

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About SESA

SESA is a collaborative project between the European Union and nine African countries (Kenya, Ghana, South Africa, Malawi, Morocco, Namibia, Tanzania, Rwanda, and Nigeria) that aims at providing energy access technologies and business models that are easily replicable and generate local opportunities for economic development and social cohesion in Africa.

Through a series of local living labs, the project facilitates the co-development of scalable and replicable energy access innovations tested, validated, and later replicated throughout the African continent. These solutions include decentralised renewables (solar photovoltaics), innovative energy storage systems including the use of second-life electric vehicle batteries, smart microgrids, waste-to-energy systems (biomass to biogas), climate-proofing, resilience and adaptation, and rural internet access.

SESA Partners