TOOLBOX ON SOLAR POWERED IRRIGATION SYSTEMS (SPIS)

POWERING AGRICULTURE:
AN ENERGY GRAND CHALLENGE FOR DEVELOPMENT

Module 7: Maintain

Food and Agriculture Organization of the United Nations · USAID · SWEDEN · german cooperation · DUKE ENERGY · OPIC

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ABREVIATIONS

Ah	Ampere hour
CWR	Crop Water Requirement
DC/AC	Direct Current / Alternating Current
ET	Evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
Gd	Daily Global Irradiation
GIZ	Gesellschaft für Internationale Zusammenarbeit
GIWR	Gross Irrigation Water Requirement
GPFI	Global Partnership for Financial Inclusion
HERA	GIZ Program Poverty-oriented Basic Energy Services
H_T	Total Head
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IRR	Internal Rate of Return
IWR	Irrigation Water Requirement
MPPT	Maximum Power Point Tracking
NGO	Non-Governmental Organization
NIWR	Net Irrigation Water Requirement
NPV	Net Present Value
m^2	square meter
PV	photovoltaic
PVP	Photovoltaic Pump
SAT	Side Acceptance Test
SPIS	Solar Powered Irrigation System
STC	Standard Test Conditions
TC	Temperature Coefficient
UV	Ultraviolet
Vd	Daily crop water requirement
W	Watt
Wp	Watt peak

MAINTAIN

1. **Establish and refine maintenance plan**

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2. **Select suitable service provider**

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3. **Implement maintenance routines**

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4. **Documentation and monitoring**

MODULE AIM & ORIENTATION

Maintaining an SPIS does not require advanced technical skills. The overall effort is relatively low when compared to most other technologies. However, it does require good and systematic monitoring to anticipate problems and react timely to service needs. Given the relatively high initial investment in SPIS, it is important to properly maintain each component. In addition, it is important to monitor changes in other factors that affect the performance of the system, such as water availability, soil health, etc.

Concrete irrigation canal

(Source: Lennart Woltering)

PROCESS STEPS

The maintenance routines will influence the efficiency of operation as well as the lifetime of the SPIS. The plan can be formulated by the producer with the help of a professional service provider. This module provides examples of maintenance checklists. It is important that the maintenance activities are documented and monitored precisely.

1. ESTABLISH AND REFINE MAINTENANCE PLAN

After installation of the system an operations manual should be handed over to the producer (see SET UP Module) by the technology supplier, or service provider. The operations manual includes instructions for operation, maintenance and troubleshooting, along with the contact details of the service provider. Based on this, the service provider and producer should develop a maintenance plan. The producer and the agricultural advisor should revise the maintenance plan regularly.

Checklists are helpful tools to ensure that maintenance is done regularly and properly. For this SPIS toolbox have been developed with checklists on the proper maintenance of the PV generator and the irrigation system. The following aspects are important for each of the main components of an SPIS:

- **Water source and pump:** Solar pumps generally do not need a lot of maintenance if used in clean water, free of sand, sediments or aquatic plant growth. The water source therefore needs to be kept clean. Under these conditions pumps can last up to 10 years.
- **Solar panels and mounting structure:** Solar panels and their mounting structure generally require very little maintenance since there are no moving parts. Panels need to be kept clean and free of shade however, while the mounting structures should be stable. The PV array should be protected from animals and falling objects. Well cared for solar panels and mounting structures last up to 20 years.
- **Electronics and controls:** As controllers/inverters are sensitive to overheating, they have to be installed in a place where faultless operation is guaranteed. Factors to be considered include the ambient temperature, the heat dissipation capability (ventilation) and the relative humidity. For service and maintenance purposes, the controller should be easily accessible. Furthermore, there has to be a circuit breaker between the PV generator and the controller. Insects and small animals, such as lizards, like to build their nests in junction boxes and may destroy electronic components (e.g. by formic acid). Proper sealing of all openings (e.g. with cable glands) is essential
- **Irrigation System:** If drip irrigation is applied, the water must be filtered because the drip emitters can clog easily. Depending on the sediment load of the water, the filters must be cleaned regularly – this can be up to several times a day. This requires a certain level of technical knowledge and skills. In addition, the drip lines must be flushed regularly and the drip elements must be examined for blockages and replaced if necessary. The SPIS tool **MAINTAIN – Water Application Uniformity Guide** is applied to check the uniformity of water distribution in a drip irrigation system. The test is part of the system acceptance (see module SET UP) but is also part of a routine check. It should also be considered that for hard water (irrigation water with high dissolved lime concentrations), scaling up and clogging of pipes will occur if pipes are exposed to heat (direct sunshine).

On the next page an overview of common failures from the field and the associated fixes are given.

EXAMPLES OF COMMON INSTALLATION MISTAKES

Example of a dangerous cable connection

Although the installer already used rubber tape to insulate the wires, the cable connection is exposed on the ground. Electrical safety is questionable, particularly during irrigation or strong rains.

Galvanic corrosion of a manual tracking system

Over time, metal objects are subject to rust and corrosion. Corrosion is normally associated with non-precious metals such as steel, zinc and aluminum. In the presence of air, water or salt, these metals will corrode rapidly and need to be covered with a protective sealant.

Limited heat dissipation capability of corroded controller housing

The metal housing of the pump controller is extensively corroded. Furthermore, the housing has no natural ventilation and after closing its front door, overheating of the controller may happen.

EXAMPLES OF INADEQUATE MAINTENANCE

Accumulated grime at the lower end of a PV panel

Even though only a small part of the panel is covered in grime it has a big negative impact on the efficiency of the panel. It can be easily removed through scrubbing with a cloth covered sponge or soft brush with clean water.

Example of shadowing by not maintained ground vegetation

Solar panels produce less power when they are shaded and should be placed where there is no risk of shadows on them. A shadow falling on a small part of a panel can have a surprisingly large effect on output because the cells within a panel are normally all wired in series, the shaded cells will affect the current flow of the entire panel!

Example of a dangerous cable connection; Galvanic corrosion of a manual tracking system; Limited heat dissipation capability of corroded controller housing; Examples of inadequate maintenance Accumulated grime at the lower end of a PV panel; Example of PV shadowing by not maintained ground vegetation- (Source: Andreas Hahn, 2015)

OUTCOME / PRODUCT

- Maintenance plan;
- **MAINTAIN – Maintenance Checklist**;
- **MAINTAIN – Water Application Uniformity Guide**.

DATA REQUIREMENTS

- Instructions on proper maintenance of each component of the SPIS;
- checklist on water analysis.

PEOPLE / STAKEHOLDER

- Producers / producer groups;
- agricultural advisors;
- technology and service providers (electricians, companies providing PV systems).

IMPORTANT ISSUES

- Regular maintenance is indispensable for efficient and long term operation of any pumping and irrigation system.
- An SPIS is reliable and maintenance costs are low if maintained adequately.
- Maintenance plans should be reviewed regularly together with the technology/service provider and the agricultural advisor.

Cleaning of solar panels in Ghana as a routine maintenance activity

(Source: Lennart Woltering)

2. SELECT SUITABLE SERVICE PROVIDER

Since the SPIS contains multiple components that might not be installed by one provider, it is very likely that several stakeholders are involved in the maintenance of the SPIS.

The following **maintenance services** are relevant:

- training/introduction on operations and use of maintenance tools;
- regular inspection and maintenance visits (especially in first months of operation);
- provision of an operation manual and maintenance tools (hardcopies);
- warranty on components;
- troubleshooting service (online, telephone).

Ideally the contract with the technical provider and / or company responsible for installation should include maintenance services.

In case of system failure, do not forget to check if there is warranty on the components and service. However, do not try to repair the defective component on your own. There is a risk of losing warranty!

In case of the solar panels, warranty means performance guarantee, which usually decreases with the years (e.g. 90% performance after 10 years, 80% performance after 20 years).

It is recommended to select an installer who can also provide maintenance services. If this is not possible, two or three quotations of different service providers should be obtained and compared:

- determine if prices are quoted for same range/ type of service;
- discuss proposals with other technical experts (agricultural advisors, research institutes, etc.);
- discuss proposals with technical providers to understand the details;
- decide and contract the service provider **before the system starts operating**.

OUTCOME / PRODUCT

- Service contract.

DATA REQUIREMENTS

- Quotations from service providers;
- contract details.

PEOPLE / STAKEHOLDER

- Producers / producer groups;
- agricultural advisors;
- technology and service providers (electricians, companies providing solar-powered systems).

IMPORTANT ISSUES

- Ideally, the contract with technical provider and / or the company responsible for installation should include maintenance services.
- Technology and service providers can provide valuable assistance / training, ask for it!

3. IMPLEMENT MAINTENANCE ROUTINES

Once the maintenance plan is in place and the responsible persons identified, the maintenance should become a routine.

Critical regular maintenance activities are:

1. Check daily if the system is working. If the pump is not working:
   a) check the water source and pipes (any dirt, blockage, enough water?);
   b) check the electronics (any burned parts, loose wires, emergency lights?).
2. Inspect the system once a week with respect to:
   a) energy generated by PV system;
   b) pump performance (pumping rate);
   c) condition of water source (purity of water);
   d) condition of controller and electronics (visible signs of malfunctioning);
   e) blockage of drip emitters;
   f) condition of water storage facility and pipes (leaks, water level);
   g) condition of solar panels and their mounting system (stability, cleanness).
3. Clean solar panels every two to four weeks:
   a) clean water and a little scrubbing with a cloth covered sponge or soft brush should remove the most persistent grime;
   b) clean in the early morning or late evening, when panels are cool;
   c) do not step or walk on the panels as they could be damaged.

Note: Hot panels should not be sprayed with cold water – they might crack!

Visual check of the solar panels

(Source: Lennart Woltering)

4. **Throughout the year (every two to three months)** the PV system should be checked thoroughly so that:
   a) no plants grow close to the panel, the mounting structure, water source, controller, junction box, etc.;
   b) there is no shade on the panels (plants, poles, fences etc.), so as to permit maximum radiation;
   c) the fencing of the solar array is not damaged;
   d) the mounting structures are stable.

In addition, the reservoir should be cleaned and the irrigation system should be flushed regularly.

Note: Inspect your system **always after strong winds, hail storms, lightening or earth quakes** have occurred in your region.

After the first experience with a particular maintenance plan, the timing and frequency of maintenance can be adapted to suit the local conditions and capacities of the producer.

Note: Call your technology provider (panels, pumping, and controller) or electrician (electronics) who installed the system for help – this should be part of the service contract.

OUTCOME / PRODUCT

- Maintenance plan;
- maintenance sheets;
- checklist for visits to farm;
- weekly inspection sheet;
- bi-monthly inspection sheet;
- **MAINTAIN – Maintenance Checklist**.

PEOPLE / STAKEHOLDERS

- Producers /producer groups;
- agricultural advisors;
- technology and service providers (electricians, companies providing solar powered systems).

IMPORTANT ISSUES & DECISIONS

- Maintaining an SPIS does not require advanced technical skills and the overall effort is relatively low, when compared to other technologies.
- It is important to establish inspection and maintenance routines and to schedule them as part of the work plan of the farm.

4. DOCUMENTATION AND MONITORING

The monitoring system of a SPIS contains water meters, pressure meters and other gauges. The measurement of water flow, water levels and system pressures are critical for the operation of a SPIS. In addition, the monitoring system is used to:

- provide system data for the acceptance test after installation;
- observe the system's operation and performance at any time;
- control water provision and consumption;
- prevent ground water depletion and connected environmental risks.

Even a simple monitoring system with just a water flow meter and a water level gauge will be useful for improved decision making on SPIS operation.

During daily operation and regular inspections of the SPIS, the producer should collect and register systematically data about the system and its performance. This data is fundamental for the producer and service providers, to do regular analysis of the system performance. Observations, results of performance checks and repairs should be documented systematically. The establishment of a "log book" is strongly recommended

OUTCOME / PRODUCT

- Monitoring data booklet.

DATA REQUIREMENTS

- Costs incurred for replacements and services (bills, dates, brief description of cause);
- findings during maintenance visits by agricultural advisors and/or technology/service providers (maintenance check list);
- system failures (date, description).

PEOPLE / STAKEHOLDERS

- Producers /producer groups;
- agricultural advisors;
- technology and service providers (electricians, companies providing solar powered system).

IMPORTANT ISSUES

- Collecting data should be linked to the maintenance plan;
- data should be compiled regularly;
- producer might need assistance or/and training initially to enable correct data registration and analysis;
- maintenance efforts can be obsolete when groundwater in the region is not managed adequately. Groundwater levels should therefore also be monitored.

FURTHER READING, LINKS AND TOOLS

Links

NETAFIM: Drip Irrigation Maintenance. Retrieved from http://www.netafim.com/

SPIS tools

MAINTAIN – Maintenance Checklist

MAINTAIN – Water Application Uniformity Guide

The following tools that are assigned to other Modules are also relevant:

DESIGN – Site Data Collection Tool: on the human resources available on the farm for operation and maintenance

TECHNICAL GLOSSARY

Aquifer	Underground geological formation(s), containing usable amounts of groundwater that can supply wells or springs for domestic, industrial, and irrigation uses.
Chemigation	The process of applying chemicals (fertilizers, insecticides, herbicides, etc...) to crops or soil through an irrigation system with the water.
Conveyance loss	Loss of water from a channel or pipe during transport, including losses due to seepage, leakage, evaporation, and other losses.
Crop coefficient	Ratio of the actual crop evapotranspiration to its potential (or reference) evapotranspiration. It is different for each crop and changes over time with the crop's growth stage.
Crop Water Requirement (CWR)	The amount of water needed by a plant. It depends on the climate, the crop as well as management and environmental conditions. It is the same as crop evapotranspiration.
Current (I)	Current is the electrical flow when voltage is present across a conductor, or the rate at which charge is flowing, expressed in amperes [A].
Deep percolation	Movement of water downward through the soil profile below the root zone. This water is lost to the plants and eventually ends up in the groundwater. [mm]
Drawdown	Lowering of level of water in a well due to pumping.
Drip irrigation	Water is applied to the soil surface at very low flow rates (drops or small streams) through emitters. Also known as trickle or micro-irrigation.
Emitter	Small micro-irrigation dispensing device designed to dissipate pressure and discharge a small uniform flow or trickle of water at a constant discharge which does not vary significantly because of minor differences in pressure head. Also called a "dripper" or "trickler".
Evaporation	Loss of water as vapor from the surface of the soil or wet leaves. [mm]
Evapotranspiration (ET)	Combined water lost from evaporation and transpiration. The crop ET (ETc) can be estimated by calculating the reference ET for a particular reference crop (ETo for clipped grass) from weather data and multiplying this by a crop coefficient. The ETc, or water lost, equals the CWR, or water needed by plant. [mm]
GIWR	The Gross Irrigation Water Requirement (GIWR) is used to express the quantity of water that is required in the irrigation system. [mm]
Fertigation	Application of fertilizers through the irrigation system. A form of chemigation.

Financial viability	The ability to generate sufficient income to meet operating expenditure, financing needs and, ideally, to allow profit generation. It is usually assessed using the Net Present Value (NPV) and Internal Rate of Return (IRR) approaches together with estimating the sensitivity of the cost and revenue elements (See Module INVEST).
Friction loss	The loss of pressure due to flow of water in pipe. It depends on the pipe size (inside diameter), flow rate, and length of pipe. It is determined by consulting a friction loss chart available in an engineering reference book or from a pipe supplier. [m]
Global solar radiation (G)	The energy carried by radiation on a surface over a certain period of time. The global solar radiation is locations specific as it is influenced by clouds, air humidity, climate, elevation and latitude, etc. The global solar radiation on a horizontal surface is measured by a network of meteorological stations all over the world and is expressed in kilowatt hours per square meter [kWh/m²].
Gravity flow	The use of gravity to produce pressure and water flow, for example when a storage tank is elevated above the point of use, so that water will flow with no further pumping required.
Head	Value of atmospheric pressure at a specific location and condition. [m]: Head, total (dynamic) Sum of static, pressure, friction and velocity head that a pump works against while pumping at a specific flow rate. [m]; Head loss Energy loss in fluid flow. [m]
Infiltration	The act of water entering the soil profile.
Insolation	The rate at which solar energy reaches a unit area at the earth measures in Watts per square meter [W/m²]. Also called solar irradiance.
Irradiation	The integration or summation of insolation (equals solar irradiance) over a time period expressed in Joules per square meter (J/m2) or watt-hours per square meter [Wh/m²].
Irrigation	Irrigation is the controlled application of water to respond to crop needs.
Irrigation efficiency	Proportion of the irrigation water that is beneficially used to the irrigation water that is applied. [%]
Irrigation head	Control unit to regulate water quantity, quality and pressure in an irrigation system using different types of valves, pressure regulators, filters and possibly a chemigation system.
Lateral	Pipe(s) that go from the control valves to the sprinklers or drip emitter tubes.
Latitude	Latitude specifies the north–south position of a point on the Earth's surface. It is an angle which ranges from 0° at the Equator to 90° (North or South) at the poles. Lines of constant latitude, or parallels, run east–west as circles parallel to the

	equator. Latitude is used together with longitude to specify the precise location of features on the surface of the Earth.
Leaching	Moving soluble materials down through the soil profile with the water.
Maximum Power Point Tracking (MPPT)	An important feature in many control boxes to draw the right amount of current in order to maintain a high voltage and achieve maximum system efficiency.
Net Irrigation Water Requirements (NIWR)	The sum of the individual crop water requirements (CWR) for each plant for a given period of time. The NIWR determines how much water should reach the crop to satisfy its demand for water in the soil. [mm]
Power (P)	Power is the rate at which energy is transferred by an electrical circuit expressed in watts. Power depends on the amount of current and voltage in the system. Power equals current multiplied by voltage (P=I x V). [W]
Photosynthesis	Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can later be released to fuel the organisms' activities (energy transformation).
Pressure	The measurement of force within a system. This is the force that moves water through pipes, sprinklers and emitters. Static pressure is measured when no water is flowing and dynamic pressure is measured when water is flowing. Pressure and flow are affected by each other. [bars, psi, kPa]
Priming	The process of hand-filling the suction pipe and intake of a surface pump. Priming is generally necessary when a pump must be located above the water source.
Pump	Converts mechanical energy into hydraulic energy (pressure and/or flow). Submersible pump: a motor/pump combination designed to be placed entirely below the water surface. Surface pump: pump that is not submersible and placed not higher than about 7 meters above the surface of the water.
Root Zone	The depth or volume of soil from which plants effectively extract water from. [m]
Salinity (Saline)	Salinity refers to the amount of salts dissolved in soil water.
Solar panel efficiency	Solar panel efficiency is the ratio of light shining on the panel, versus the amount of electricity produced. It is expressed as a percentage. Most systems are around 16% efficient, meaning 16% of the light energy is converted into electricity.
Suction lift	Vertical distance from the surface of the water to the pump. This distance is limited by physics to around 7 meters and should be minimized for best results. This applies only to surface pumps.

Surface irrigation	Irrigation method where the soil surface is used to transport the water via gravity flow from the source to the plants. Common surface irrigation methods are: Furrow irrigation – water is applied to row crops in small ditches or channels between the rows made by tillage implements; Basin irrigation – water is applied to a completely level area surrounded by dikes, and Flood irrigation – water is applied to the soil surface without flow controls, such as furrows or borders.
Transpiration	Water taken up by the plant's roots and transpired out of the leaves. [mm]
Voltage (U or V)	Voltage is the electric potential between two points, or the difference in charge between two points, expressed in Volts [V].