VOLUME – III	**OPERATION AND MAINTENANCE REQUIREMENTS FOR PASTORAL AREAS WATER SUPPLY TECHNOLOGIES**

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Operation and Maintenance Requirements for Pastoral areas Water Supply Facilities: Volume – III, PART – E: SOLAR POWERED PUMPING SYSTEM

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5. SOLAR POWERED PUMPING SYSTEM

5.1 General

The solar pumping system serves to provide water in remote applications where electrical grid power is either unreliable or unavailable. The system pumps water using a high-voltage DC power source such as a photovoltaic array of solar panels (which is abbreviated as solar array in this manual). Since the sun is only available during certain hours of a day and only in good weather conditions, the water is generally pumped into a service reservoir or tank for further usage, and water sources are those natural or special such as groundwater, river, lake, impounding reservoir, etc. Two level switches, one is High Level Switch, the other is Low Level Switch, should be installed inside the service reservoir or tank to regulate the water level. If the water comes from a well, another two level switches should be installed inside the well. The Low Level Switch of the well serves as an indication that the well has run dry. The system will shut down to protect the pump and motor until the well has recovered as the High Level Switch is reached by water.

5.2 What makes up a Solar Power System?

Many people are just learning about the industry, and don't realize that there is more to a solar system than a panel and some cabling. This is a basic guideline to give you an idea of what you need to make a system work for you.

5.3 Building a Solar System

The first and most obvious component in the solar setup is the array of panels. An important point with solar panels is that the voltage is always higher than 12V (usually around 17.5V). When you work out your panel requirement you must use the amperage rating, not wattage, as the higher voltage means lower amperage and therefore the wattage can be misleading. You should always check the specifications when buying solar panels. Example: A 100W, '12V' panel is actually 17,5V. The amperage this panel will give out is not 100W/12V, but rather 100W/17.5V = 5.7 amps.

Your next component is the charge controller, also known as the regulator. Solar regulators are different to ones used for wind power. There are hundreds of different types of regulators with sizes ranging from 5 Amps to 80 Amps. You also get different types; the normal, straight-forward regulator which is great for smaller loads, and the MPPT regulator which adds about 20% efficiency to the system and is used for bigger systems. The regulator size requirement is determined by the amount of energy supplied by the panels. The rating of the regulator is how much energy it can handle per hour. Example: A 60 amp controller will handle 60 amps per hour. Any energy in excess of that rating (in this case 60 amps) will be wasted, therefore it is important that you don't undersize your regulator.

Next, you need batteries; there are many different makes and types available. Normal marine deep cycle batteries are more commonly used for smaller systems, while the special high amperage solar batteries are ideal for larger installations. Normal car batteries will not perform well with solar power systems because of their shorter life spans. It is a bad idea to draw all the energy out of the batteries. We give them 50% depth of depletion, to prevent damage and lengthen their life span. Example: With a battery of 105 amp hours, we work on 50 amp hours of useable storage.

An inverter is the final step in your basic solar system (before the distribution board). Solar setups are always DC (12V, 24V, 36V or 48V). What the inverter does is it converts the DC voltage into AC voltage to run your normal everyday appliances. You get appliances with 12V configurations nowadays, which allow for a direct connection from the batteries to the appliances or db board, cutting out the need for an inverter. The inverter size is determined by the peak amount of energy your load can draw at any one time. For safety, you should add 20% to the inverter requirement. Example: If you're powering 5 lights of 20W each, your inverter needs to be 5 x 20W (+20%) = 120W.

Cabling, lugs, switches and connection boxes are smaller, yet essential components. The quantities are determined by the size of your system, the number of connections and the distances between components. With a 12V system, it is advisable to keep the panels and batteries within 10m of each other. The regulator and inverter should both be placed near the battery bank. The cable thickness is determined by the size of your system and the distance that the energy will travel. If you're using a 12V, 1000W system with a distance of 10m, you need 10-12mm cabling. If the cabling is wrong, the system will under-perform or even burn the wiring.

The voltage of a system is determined by the amount of energy running through it. Anything up to 2000W can be run through 12V; from 2000W to around 5000W can be run through a 24V system; and from 5000W up to around 20 000W, a 48V system should be used. Anything higher needs 240V.

It is also a good idea to get a combiner box, which allows you to plug all of the wires from your panels into one box, with a single wire coming out from the other end. This just neatens the system and makes it more manageable for installation, maintenance and upgrades.

It is highly recommended that fuses be included in larger systems, as they prevent short circuits from happening. If the wiring has been damaged somehow and the positive and negative wires touch, a short circuit will occur, and could potentially start a fire or even cause the battery to explode.

Diodes allow the current to run in one direction only, **like a valve**, preventing the energy from running back into the panels from the battery bank. If this occurs, it can damage the panels, particularly with more powerful batteries.

5.4 Components of Solar Energy System

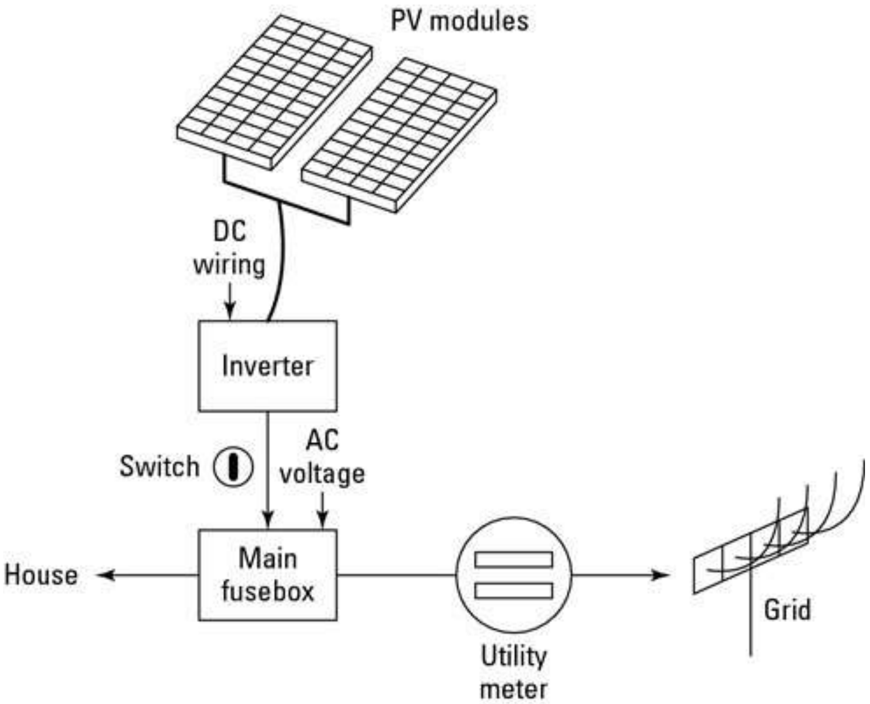
Interconnected solar cells, which convert sunlight directly into electricity, form a solar panel or “module,” and several modules connected together electrically form an array. Most people picture a solar electric system as simply the solar array, but a complete system consists of several other components. The various main components of the solar energy system is presented in Figure 5.1.

- An inverter converts the direct current (DC) electricity produced by the modules into alternating current (AC) electricity for powering lights, appliances, and other needs.
- Wiring connects the various components of a solar electric system. In some cases, the system is also interconnected to the power grid.

- Batteries are used to store solar-produced electricity for night-time or emergency backup power. Batteries may be required in locations that have limited access to power lines, as in some remote or rural areas.
- If batteries are part of the system, a charge controller is included to protect them from being overcharged or drawn down too low.
- Finally, disconnect switches allow the power from a solar electric system to be turned off to provide safety during maintenance or emergencies.

Most providers of solar electric technologies can supply you with all the components you will need for a fully functional system.

Figure 5-1: Components of Solar Energy System



5.5 Operation Maintenance Procedures

5.5.1 Modes of Operation

The operational modes for a solar energy system can be described as automatic, manual, and layup. The conditions required to initiate the particular mode, and the status of the components affected by the mode, are listed in the control mode. The corresponding control schematic shows the physical relationship of the various control components.

The operation section of the O&M manual includes a mode matrix and a control schematic that describe all possible operational modes for the specific system. They are normally provided with the construction specification and may be incorporated into the O&M Manual.

- **The automatic mode** is the normal operating mode for the solar energy system. No operator action is required in this mode when the differential temperature controller (DTC) is in the "automatic" position. The system will start, operate, and shut down automatically when the control parameters described in the control mode matrix are reached. System protection actions are also carried out automatically.

A simple checklist should be completed regularly by the operator to confirm that the solar energy system is operating normally.

- **Manual operation** of the solar systems is defined as operation of part or all of the system without automatic controls. Manual operation is primarily used for trouble shooting and performance testing. Diagnosing malfunctions requires the separate operation of individual components to isolate the fault and correct the malfunction. Performance testing may require the individual operation of components instead of the whole system.

5.5.2 Start-up

This mode should never be tried without following a specific operating procedure prepared by the solar energy system designer to take care of the specific system problem.

Prior to manual start-up of a system, certain precautions must be taken, beginning with a review of the operation control mode matrix, then proceeding as outlined below.

1. Verify that the system is not shut down due to some automatic protection mode. For example, if the system were shut down during the automatic operator when it is started manually the system may be damaged.
2. Verify that there is fluid in a liquid system so the pumps are not operated dry. Check the fluid levels in the system against the design requirements.
3. Verify that all manual valves are in their proper position. Review the Piping and Instrumentation Diagram (P&ID) and control schematic to see the valves position requirements.
4. Verify that no personnel are close to pressure relief valves or evacuated collectors at start-up. These are the most likely components to be affected by a pressure surge at start-up.

The operator must closely follow system performance during manual operation. The operator should stay with the system during start-up, check the system periodically and stop when the reservoir is full.

Manual test operations may involve individual component, subsystem, or system functions. Typically, pumps are operated individually to check the flow rate and pressure rise. Valves are operated to check for leakage and capability to function in either the fully open or fully closed positions.

5.5.3 Leaks

Once a leak is discovered, immediate action is essential to keep damage from the leak to a minimum:

Locate the exact source of the leak. Shut down system pumps. Shut off makeup water supply, reducing system pressure at the leak. Isolate the leaking component with the closest block valves.

Once the leak is stopped and system safety is secured, fix the leak and its damage as soon as possible, following the repair/replace procedures. If the repair process is going to take some time, it may be possible to isolate the leaking section and operate the solar system.

5.5.4 Maintenance Personnel Training

Maintenance personnel training is required if the maintenance and operating personnel are not one and the same. This training should be identical to the operator training discussed. Operating and maintenance personnel should understand both operational and maintenance procedures of the solar energy system.

5.5.5 Preventive Maintenance

Preventive maintenance is required in solar energy systems, as in other systems, to maintain an optimum level of performance and to extend the life of the system. Preventive maintenance should be performed on a regular schedule and should include a visual inspection and routine major component maintenance.

The visual inspection should be performed every two or three months using a checklist tailored for the specific system. A sample detailed visual inspection checklist is shown in Annex-A. It includes a sample maintenance record form that may be used to report a full year's inspection data. The completed checklist and form become part of the system's permanent maintenance record.

The major components of a solar energy system include the water fluid, pumps, storage tanks, filters, valves, piping systems, and instrumentation and controls. Each component can have specific maintenance requirements from the manufacturer that become part of the maintenance manual.

5.5.6 Submersible pump

Submersible pumps used in solar energy systems are fluid-or self-lubricated and require basically no maintenance.

Additional periodic maintenance checks for pumps include differential pressure across the pump, and pump or motor temperature. The differential pressure across the pump, when operating, should be in the range of the value when first installed. The pump should not be unusually noisy or hot.

Measure the current drawn by the pump in normal operation and check against that measured at installation; higher amps could indicate trouble. Clean out strainers installed upstream of pumps regularly.

Installation

General Information NOTICE: The Model Number of your pump is located on the top portion of the pump shell. Record this number along with all pumps installation data and keep it in a safe place for future reference, in the event servicing is required. The most important things you should know about your well are:

1. Well total depth- the distance from the ground level to the bottom of the well.
2. Depth to water- measured from the ground level to the water level in the well when the pump is not in operation.
3. Draw down water level- the distance from ground level to the water while water is being pumped from the well. In most wells, the water level drops when water is being pumped.

4. Well capacity (m^3 /h)- the amount of water in m^3 /h the well produces without drawing down or water level dropping.

Cable Splicing Methods: When the drop cable must be spliced or connected to the motor leads, it is necessary that the splice be water tight. The splice can be made with commercially available potting or heat shrink splicing kits. Follow the kit instructions carefully.

1. Heat Shrink Tubing Method - RECOMMENDED METHOD (Kit Order #60333 - 3 wire pumps; #60332 - 2 wire pumps)
   a) Strip about 1/2" of installation from cable and lead ends.
   b) Slide about 3" long heat shrinks tubing over the cables.
   c) Connect cable and lead ends with STAKON or similar connectors
   d) Position the tubing over the connection keeping the connector at its center.
   e) Apply heat (about 135°C) evenly on the tubing and working from center outwards to avoid trapping air. While heated, the adhesive liner seals the interfaces between the tubing and the connector cable. Perfect sealing is achieved when adhesive liner flows outside the tubing and seals the ends. While heating, care must be taken not to overheat the cable outside the tubing. This will damage the insulation of the cable.
2. Tape Method (Alternative) SPLICING SUBMERSIBLE CABLES WITH TAPE, Tape splicing should use the following procedure.
   a) Strip individual conductor of insulation only as far as necessary to provide room for a stake type connector. Tubular connectors of the staked type are preferred. "STA-KON" Connector.
   b) Tape individual joints with approved rubber electrical tape, using two layers; the first extending tow inches beyond each end of the conductor insulation end, the second layer two inches beyond the ends of the first layer. Wrap tightly, eliminating air spaces as much as possible.
   c) Tape over the rubber electrical tape with approved PVC electrical tape, or equivalent, using two layers as in step "2" and making each layer overlap the end of the preceding layer by at least two inches. In the case of a cable with three or four conductors encased in a single outer sheath, tape individual conductors as described, staggering joints. Total thickness of the tape should be no less than the thickness of the conductor insulation.

The following test is recommended before installation. Cable and splice test for leaks to ground.

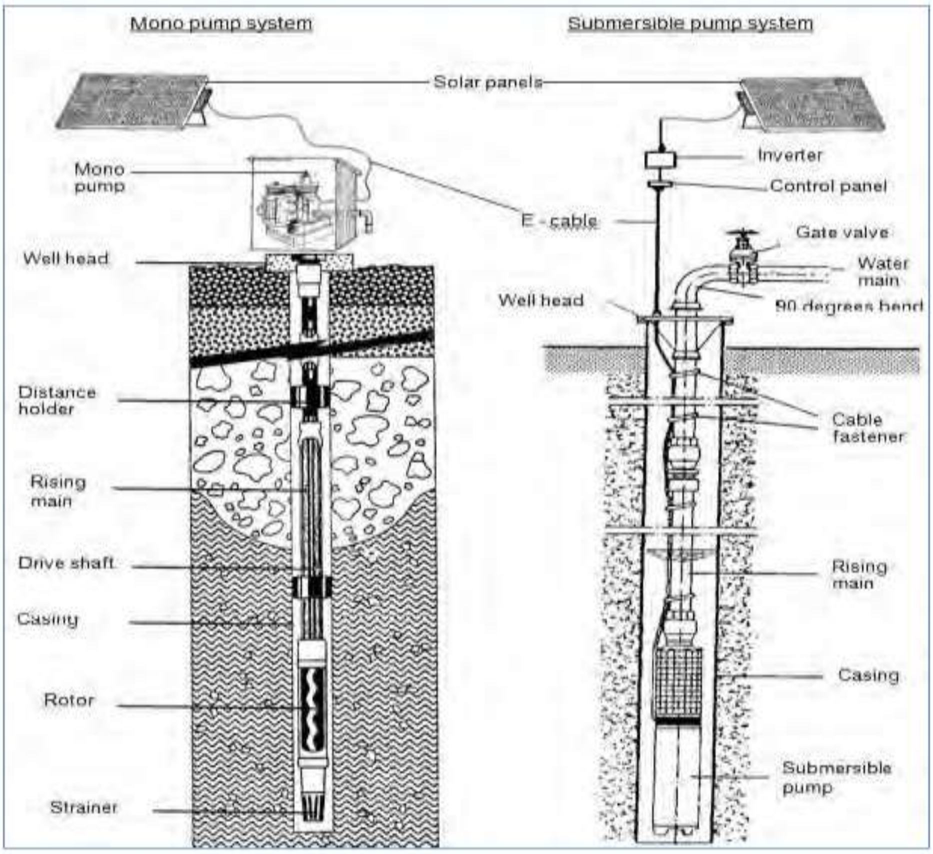
1. Immerse the cable and splice connections into a steel barrel of water with both ends out of the water and not touching the barrel.
2. Set ohmmeter on RX 100K and adjust needle to zero (0) with leads clipped together.
3. Clip one ohmmeter lead to the barrel and the other to each cable lead individually.
4. If the needle deflects to zero (0) on any of the cable leads, a faulty splice connection is indicated. To double check the faulty splice connection, pull the splice out of the water. If the needle now moves to ∝ (infinite resistance) the leak is in the splice.
5. Repairs should be made with approved electrical Rubber & PVC tape.

6. If the leak is not in the splice, pull the cable out of the water slowly until the needle moves to ∝.When the needle moves to ∝ the leak is at that point.

Installing Your Pump PUMPLOCATION Your submersible pump should be installed no less than 5 feet (1.5 meters) from the bottom of your well.

Solar energy system with the groundwater is presented in Figure 5.2.

Figure 5-2: Solar Energy System with the Groundwater



A solar-direct pump should start under the following conditions:

Box 5-1: Conditions for start of solar-direct pump

1. Clear sunshine at an angle of about 20° or more from the surface of the solar array,
2. Cloudy conditions, if the sunshine is bright enough to cast some shadow,
3. low-water probe submersed in the water source (or bypassed in the controller) – Water-Low light OFF,
4. full-tank float switch is not responding to a full tank – Tank-Full light OFF,
5. Battery system only – voltage is higher than the low- voltage disconnects point (22V or 44V).

CAUTION: To avoid accidental loss of the pump in the well, it is recommended that a 1/4” polypropylene rope be permanently attached to the eye provided on the discharge head of the pump. The other end of the polypropylene rope should be secured to an anchor at the well head.

5.5.7 Control Unit(s)

Controller: The controller functions to control the charge on the batteries. The controller is a solid state device which control the charging and discharging of the batteries. The controller provides temperature compensated charging so that the rate of charge is controlled for both temperature and state of charge. The controller will shut off charging when the battery reaches a charge of 15.2 VDC. The controller will disconnect the load when the battery voltage reaches 11.4 VDC. These set points have been established to prevent damage to the battery from an overcharge condition or a low voltage condition. The controller also has a manual disconnect switch that allows you to electrically disconnect the batteries from the system.

The controller provides a LCD display that cycle through a display of battery voltage, array current, and load current. Flasher: The flasher is a 12/24V DC, solid state flasher that consumes negligible power during operation. The flasher is set at the factory to provide 50 flashes per minute, for 1 or 2 circuit operation (depending on your system configuration), LED or Halogen (depending on your system configuration), and a 50% duty cycle. Battery: The battery stores the electrical energy which powers the load. Batteries are maintenance free sealed gel, absorbed mat technology. If your system is 'knocked down' by accident and your battery punctured, you will experience little to no acid spilled due to the absorbed mat technology.

Time Clock: The time clock is a solid state programmable device which will control the operation of your load based on the program you enter in the time clock. The time clock automatically compensates for daylight savings time and leap year. The daylight savings time feature can be disabled at the user's discretion. The time clock is rated at 15 amps per circuit and operates on 12V DC. The time clock usually has one relay but may come with 2 or 4 relays if the end user has requested a clock with 2 or 4 relays powered flashing beacon systems use LEDs.

Terminal Block: Normally all components are pre-wired with circular connectors for ease of component replacement. However if your system is being used to power loads other than beacons, a terminal block will be provided to facilitate termination for the load. The power terminals will be clearly identified as to positive (+) or negative (-). All Texas approved solar systems will have terminal blocks.

Connecting Battery(s): Warning: Remove the battery fuse in the battery cabinet prior to connecting the battery(s).

If you have been provided with more than one battery, you will also have red and black jumpers with ring terminals to connect the batteries in parallel. Unscrew the wing nuts from the battery terminals and attach the rings to the battery connection. The red jumper goes to the positive terminal and the black jumper goes to the negative terminal.

Thread the black and red 10 AWG ‘red and black wires of the ‘backbone’ harness through the hole in back left corner of the control compartment in the battery cabinet. These wires should have rings on the ends of them. Unscrew the wing nuts off the battery terminals and attach the red wire to the positive terminal of the battery and the black wire to the negative terminal of the battery.

5.5.8 Solar panels (photovoltaic modules)

Sunlight is converted by the solar panels to electrical energy while the batteries store the electrical energy. The solar panels are connected to the batteries through a controller which controls the charging and discharging rate of the batteries. The time clock controls the time and duration that power is applied to the load. If the system is a 24 hour flashing beacon system, then no time clock will be in the system. The flasher is a solid state, 12/24 volt DC flasher that switches the power from one beacon to the other. If the load is not a flashing beacon system, then no flasher is provided with the system.

The load is always powered from the batteries via the controller, never from the solar panels directly. Solar Panel(s): The solar panel(s) are off the shelf items, warranted for 20 years. As noted above, the panels convert sunlight to electrical energy to charge the batteries. A single panel will usually be from 40 - 130 watts. Depending on your system requirements you may have multiple panels.

Final Connections and System Checkout:

You should perform several quick checks to ensure that your wires and connections have been made correctly.

After you have made your wire and connections checks, connect the 'backbone' harness assembly from the solar panels and battery to the large circular connector on the back of the control panel. Re-install all fuses. There are 3 fuses, the load fuse, the battery fuse, and the solar panel fuse.

The controller should have at least 1 LED lit, indicating that battery voltage is present at the controller. If all wiring has been made correctly, LEDs will light on the controller.

You will see the LCD display cycling through the parameters it displays. You should see battery voltage with a reading greater than 11.4 volts, array current, and load current. You will have to wait 2 minutes after system initialization before the load current is displayed. If the load is not turned on, the reading will be 0.0 amps.

If you system has a time clock, you should also see the display on the time clock lighted. The clock should be cycling through several displays which show date, time, relays on (or off), and program running. If you have 'power fail' showing on your time clock, simply push the button on the key pad marked 'C'. This should reset the time clock. *(Refer Annex- A).*

These have no moving parts and there is very little that technically can go wrong with them. Consequently many of them have a 20 year manufacturer’s guarantee. The main risk to the panels is from theft, vandalism or children throwing stones which cause damage. Theft in particular is a major problem in most areas, so Water Administration Service/WASHCOs need to ensure thorough security measures are in place to minimize these threat and panels are well secured.

Maintenance tasks include:

- Clean solar panels weekly if they are covered with dust (in very dusty areas clean twice a week using a wet cloth)
- Protect the fragile solar panels (panels and solar pump within a fenced enclosure of 40 m radius for protection and therefore the fence requires to be kept in good condition and the gate should be safely secured).

- When carrying out any servicing of this equipment ensure the right qualified personnel do the work.

Typical output ratings of panels are show in Table 5.1.

Table 5-1: Typical output rating of panels

Panel Rating (Watt)	I - Typical	V - Typical	I - Short Circuit	V - Open Circuit
30	1.78	16.8	1.94	21.0
40	2.37	16.8	2.58	21.0
50	2.97	16.8	3.23	21.0
55	3.33	16.8	3.69	21.0
60	3.56	16.8	3.87	21.0
65	3.77	16.8	4.06	21.0
70	4.14	16.8	4.35	21.0
75	4.54	16.8	4.97	21.0
80	4.75	16.8	5.17	21.0
85	4.97	16.8	5.3	21.0

5.5.9 Motors

A solar water pumping system consists of four main parts: the pump set with motor, pump controller, the solar electric panels and a storage unit.

The pumping systems are broadly configured into five types, namely:

- Submerged borehole/ multistage centrifugal motor pump set,
- Submerged pump with surface mounted motor,
- Reciprocating positive displacement pump,
- Floating motor pump sets and
- Surface suction pump sets

Among the above-mentioned systems, submerged multistage centrifugal motor pump set is probably the most common type of solar pump used for rural water supply. The advantages of this configuration are that it is easy to install, often with lay-flat flexible pipe work and the motor pump set is submerged away from potential damage. Either AC or DC motors can be incorporated into the pump set although an inverter would be needed for ac systems. If a brushed dc motor is used then the equipment will need to be pulled up from the well (approximately every 2 years) to replace brushes. If brushless dc motors are incorporated then electronic commutation will be required. The most commonly employed system consists of an AC pump and inverter.

Some DC motors need replacement brushes; this is usually a simple operation (far simpler than, e.g. servicing a small engine powered pump).

Brushes will probably need to be replaced after two years of operation.

Table 5-2: Motor Circuit Breaker or Fuse Requirement

Rating			**Wire**	**Fuse**	**Circuit Breakers of Fuse Amps**					
HP	KW	Volt			(Maximum Per NEC)			(Typical Submersible)		
					Standard Fuse	Dual Element Time Delay Fuse	Circuit Breaker	Standard Fuse	Dual Element Time Delay Fuse	Circuit Breaker
½	0.37	115	2	1	35	20	30	30	15	30
½	0.37	230	2	1	20	10	15	15	8	15
¾	0.55	230	2	1	25	15	20	20	10	20
1	0.75	230	2	1	30	20	25	25	11	25
1.5	1.1	230	2	1	35	20	30	35	15	30
½	0.37	230	3	1	35	20	30	30	15	30
½	0.37	115	3	1	20	10	15	15	8	15
¾	0.55	230	3	1	25	15	20	20	10	20
1	0.75	230	3	1	30	20	25	25	11	25
1.5	1.1	230	3	1	35	20	30	30	15	30
2	1.5	230	3	1	30	20	25	30	15	25
3	2.2	230	3	1	45	30	40	45	20	40
5	3.7	230	3	1	80	45	60	70	30	60
7.5	5.5	230	3	3	80	45	60	70	30	60
7.5	5.5	575	3	3	30	20	25	30	12	25
7.5	5.5	460	3	3	40	25	30	35	15	30
10	7.5	575	3	3	45	25	35	40	20	35
10	7.5	460	3	3	60	30	45	50	25	45

5.5.10 Inverter (AC) Automatic/Regulator (DC)

Inverter: On rare occasion, the end user may need to power a 120/24V AC load. If you have specified a requirement for AC power, your system will have an inverter installed.

Maintenance:

The system does not have any moving parts and therefore requires only minimal maintenance. The system owner should periodically (e.g. monthly) check that the system is still operating, this can be most easily done by either:

- Checking that all inverters are operating (the green light is on in good weather conditions),
- Visual display shows an increased value over a period of a day.

The most common explanation for complaints about system performance can be traced to the system being accidentally turned off.

It is recommended that the system is thoroughly checked at least once a year, to ensure that it remains in good working order and operating as expected.

a) Yearly check Table

The checks shown below should be made each year by suitably qualified personnel using calibrated test equipment, preferably during the summer months and compared to previous results. Judgment is required to interpret test results in relation to weather conditions. The yearly maintenance that needs to be checked is presented in Table 5.3.

Table 5-3: Annual System Maintenance checks

Check	Method for testing	Expected value	Possible reason for error
Inverter power output	Each inverter indicates AC power on its display. The irradiance must be measured in order to estimate the expected value.	At STC1 Inv: 0.7 kW (nominal)	Inverter or PV array fault – continue with further checks to determine cause of fault.
Inverter loss of mains	Isolate the AC isolator to disconnect the inverter from the mains.	Inverter indicates error (loss of mains)	If inverter does not indicate error, inverter is faulty.
String open-circuit voltages	Leave inverter isolated from mains. Isolate the inverter from the PV array using the DC isolator. Disconnect the string from the inverter. Measure Voc.	See table 4 for Voc values at STC[2]	Faulty PV module, connection or DC isolator.
String short-circuit currents	Method as for Voc, but measure Isc. Take care when making the short circuit.	See table 4 for Isc values at STC[2]	Faulty PV module, connection or DC isolator.
Correct inverter operation 1	If all above measurements are correct, re-connect the PV array to the inverter and close the DC isolators.	Inverter lights may flash but should not indicate generation.	If inverter indicates it is generating (yellow light blinking), it is faulty.
Correct inverter operation 2	Re-connect the inverter to the mains by closing the AC isolator.	Inverter orange light for 180s, then green light constantly.	If there is sufficient daylight and the yellow Led is not blinking after five minutes, the inverter is faulty.
Wear and tear	Examine all internal cabling and isolators for visible signs of damage or wear and tear. Replace any faulty equipment.		

b) Five year check Table

It is recommended that the checks detailed in Table 5-4 are undertaken on a 5-yearly basis. When undertaking a detailed inspection and cleaning of the roof mounted array, appropriate notice should be taken by staff and due consideration should be made of the need for appropriate roof access equipment to be used. A further maintenance schedule should be determined when this first extended check has been carried out.

Table 5-4: Periodic System Maintenance checks

Check	Method for checking	Action to be taken
Mounting system	Check for wear and damage	Replace any missing or damaged fitments
PV modules	Examination of all PV modules for damage or signs of wear and tear	Replace any severely damaged modules if they are no longer weatherproof
Cabling	Check integrity of all cabling and for any signs of damage	Replace any damaged cabling
Cleaning	N/A	Laminates should be cleaned using water/ mild detergent as used for window cleaning

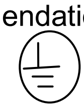
5.5.11 Wires

Wiring terminals are different in shapes and combinations, depending on different sizes of solar pump controller. Terminals Arrangement of solar pump controller Capacitors inside the solar pump controller can still hold lethal voltage even after power has been disconnected. Allow five minutes for dangerous internal voltage to discharge before removing solar pump controller cover to access the terminal.

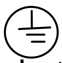
Power-In DC Wiring For Solar Pumping Systems, a two-pole DC disconnect switch must be installed between the solar array and the solar pump controller. Connect the cables which comes from the two-pole DC disconnect Switch downstream terminals marked with “+” and “-” (positive and negative poles of Solar panel output), to solar pump controller’s terminals block labelled as “R”, “T”.

Before connect DC wiring, the following steps are need to be followed to prevent hazardous electric shock resulting in serious injury or device burning.

- Make sure that the external DC disconnect switch is off.
- Make sure that AC power is disconnected (if AC power supply is wired as backup power)
- Make sure that all wires are properly identified and marked:
  - a) The cable from the PV to the external DC disconnect switch
  - b) The cable from the external DC disconnect to the solar pump controller

Do not connect a solar array directly to the DC input of the solar pump controller without protection such as DC disconnect switch. In this controller, the integral solid state short circuit protection of motor wiring does not provide circuit protection of wiring for input power. Input wiring protection must be provided in accordance with all applicable national and local electrical codes. In addition, follow any manufacturer’s recommendations for protection of a photovoltaic (PV) array and protection of a generator, if used. 

Ground Wiring:

Ground terminal (GND) is labelled as this icon.  Please refer to the instruction to this icon, or other equivalent icon or sign by local electrical codes or international standard. Connect the ground wire to the ground terminal of solar pump controller. Correct Grounding helps to prevent shock hazard if there is a fault in the motor.

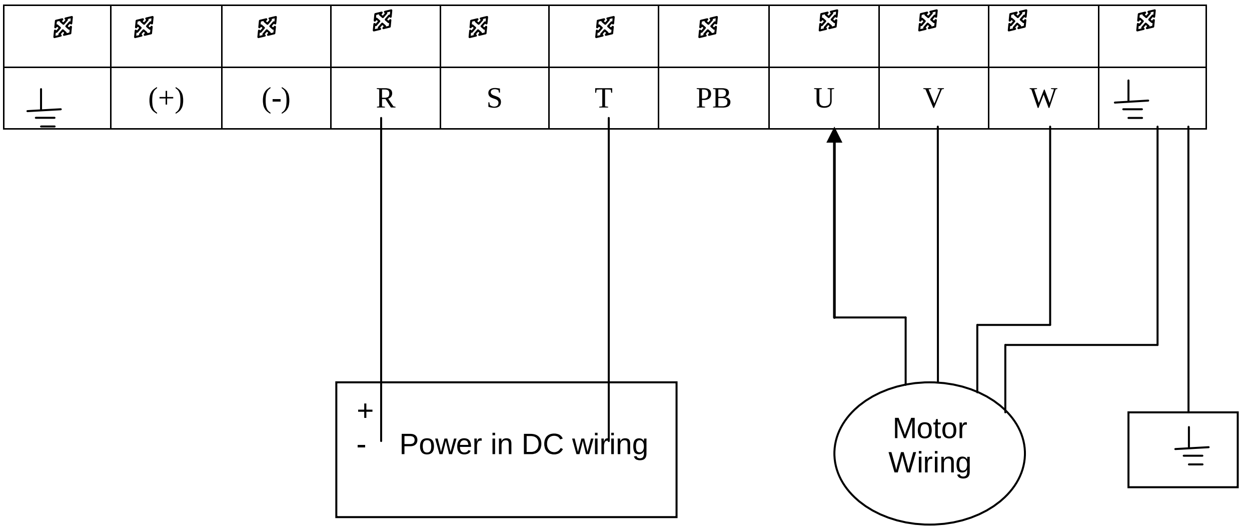
Serious or fatal electrical shock may result from failure to connect the ground terminal to the motor, the solar pump controller, metal plumbing and all other metal near the motor, or cable to a proper earth ground in accordance with local codes, using wire no smaller than motor cable wires. To minimize risk of electrical shock, disconnect power before working on or around the solar pumping system. Do not use motor in swimming areas.

Motor Wiring:

Connect the cable with four wires from the Motor to the controller terminal block to terminals U, V, W, and GND (See Figure 5-3). (Do not over-tighten the screws.).Motors with international leads are as shown in the table in Figure below. Check motor lead colour to ensure correct installation. Note: To reverse direction of motor rotation, reverse any two wires.

US	Black (BLK)	Red (RED)	Yellow (YEL)	Ground (GND)
International	Gray (GRY)	Black (BLK)	Brown (BRN)	Ground (GND)

Figure 5-3: Motors wiring with International leads



Main Terminals Wiring

5.5.12 Pulleys and Belts

Belt gearing with V-belts guarantee quiet, calm and smooth operation. Its advantage is a possibility to smooth sudden load changes as well as damping of vibrations. Simple and cheap construction do not require special service and special maintenance what reduce costs of operation. Used up V-belts can be quickly and easily exchanged without prolongation of machine downtime.

Factors influencing belt durability:

a) Number of belts in one set

Belt gearing is designed for optimal number of used belts. If the number of belts in one set decrease, lifetime of remain belts lowers disproportionately. If for example: according to calculations drive requires usage of 10 belts, and if one belt will be removed, lifetime of remain belts decreases not by 10% but by 30%

b) Belts tension

For excellent drive transferring and for reaching required belts durability a very important factor is to ensure correct belts tension. Belts should be tensioned as appearing slippage at the pulley not exceed 1%. Too small tension causes excessive belts slippage at belt pulley; too big tension – decrease belt lifetime as well as quicker bearings wear in propulsion machinery and driven machinery.

c) Correct belt pulley selection

Important factor of reliability and equal operation of V-belts is exact fulfilling of conditions specified for belt pulleys:

- belts should work at grooved pulleys of dimensions fitted to belt section, as only side (working) walls of belt were in contact with walls of pulley grooves;
- Pulley grooves should be smooth, without deformations, snagging and contaminations, particularly grease and oils. Surface coincides of groove pulleys should not be painted

d) Usage of tension rollers.

In a gearing, where is not possible to strain a belt by changing a distance between driving machine and driven machine, a tension roller can be used for belt tension. Other phenomenon, which require usage of tension roller are vibration of long belt tie rod of small tension or short tie rod during rapid load changes. Each usage of rollers increase frequency of belt inflection and introduce additional bending stresses that shorten its lifetime.

e) Cleanliness

Belt gearing is sensitive for chemical influence of environment, its temperature and humidity, as well as lubricants and pollutions. In case a gearing operate in an environment of increased pollution, then it should be protected by special covers. Power bands require special protection from environmental pollution. Oils and lubricants cause decreasing of coupling between belt and pulley as well chemically affect at belt causing its quick destruction.

f) Storage of belts

Properly stored V-belts do not lose their properties rods for years. Rubber products stored in adverse conditions together with bad handling change physical properties. These changes are caused by influence of oxygen, ozone, extremely unfavourable temperatures, light, humidity or solvents.

Solar tracking

This innovative technology enables several rows of solar panels to follow the sun thanks to a single lightweight but precise master control system which uses a low driving force.

The amount of energy produced by the solar panels is directly dependent on the intensity of the sun's rays picked up by the receiver. In the case of a fixed panel, this intensity varies over the day. The tracking system enables the unit to optimize the amount of solar energy collected, and thus to increase its efficiency. However, classical solar tracking technologies are complex, relatively unreliable and involve a great amount of maintenance.

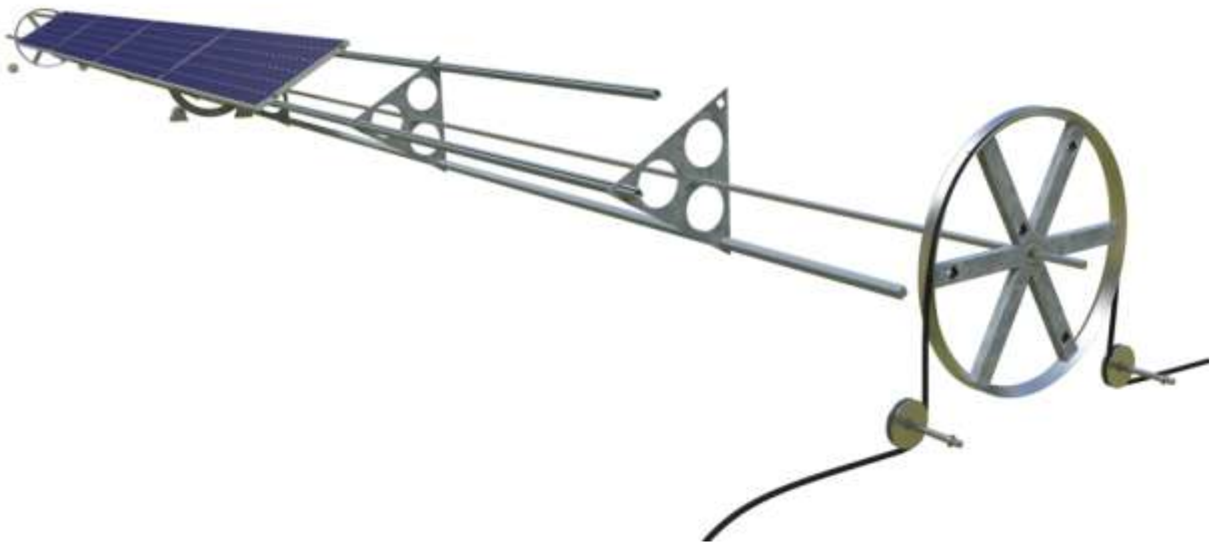
Description

Our patented technology enables rows of panels to move together in a coherent and precise way. The technology can be applied to both types of solar panels (photo-voltaic and thermal) and also to mirrors in the case of a solar power station. This solar tracking technology operates thanks to a foundation frame, rotating frames, interconnecting cables and a control system.

1. Foundation frame

A supporting frame is fixed onto a limited number of foundation blocks. Once the frame is in place, it takes the weight and fixes the whole of the structure above it – the rotating frames which carry the weight of the panels, the tracking driving and control systems.

2. Rotating frames



Each rotating frame is constructed around a central rotating axis within a frame providing the necessary rigidity and with a pulley at each end. This solid structure can then rotate easily on its axis. The frame supports a row of panels.

3. Interconnecting cables

The rotating frames are interconnected via a unique system of cables fixed to driving pulleys at each end.

4. Control system

A driving force winds and unwinds the cable, thus producing a simultaneous angular movement of all the rotating frames. The control system ensures the rotating angle corresponds to the movement of the sun.

Recent solar trackers like iPV do not use pulley and belt but use another mechanism to adjust the solar panel towards the sun as discussed below.

iPV Solar Tracker Features

“This is the unique solar tracker and it has already acquired numerous invention patents in EU, Japan, USA, China and etc.

There are many mechanisms to drive solar trackers. The most common one is a pair of dual solar wheel axes which allows rotation up to around 270 degrees. Topper Sun’s iPV Solar Tracker adopts a unique universal axis design that couples with affordable and stable steel cable pulley system. It is the first solar tracker in the world that can rotate 360 degrees (elevation angle of 40-130 degrees). Its “dynamic balancing” structure moves similarly to an elevator or a seesaw -- the four corners of the solar panel platform are secured and strengthened by steel cables and the structural flexibility is enhanced by shock springs that are fixed to the ground. Each iPV Solar Tracker is equipped with a calendar program that calculates the sun’s orbit. By simply setting the latitude and longitude of the location, the system will automatically adjust its angles every five minutes to track the sunlight. Accordingly, the iPV Solar Tracking system is so simple that energy consumption and maintenance costs are very low.

For Maintenance of pulley Refer Annex- H

5.5.13 Exposed terminals (on panels or inverter)

Exposed terminals are the source of danger and injuries to unman body and can cause fire to the neighbouring equipment. Every terminal shall be insulated or caped properly if it is not connected to its destination.

The following precondition shall be met to avoid exposed terminals from the system

- All cables leading to the controller must be disconnected from the power supply and it must be ensured that they cannot be unintentionally reconnected during installation.
- Each connection terminal must only be connected to a single conductor.
- The protective earth conductors (PE) from the mains cable and pump and valve cables must be connected to the protective earth conductor terminal block.
- All cables must be laid so that persons cannot stand on them or trip over them.
- The local power supply must match the specifications on the type plate of the controller.
- The power supply cable is to be connected to the mains power as follows: –
  - using a plug connected to a wall mains socket or
  - Via an isolating mechanism allowing complete isolation in the case of permanent wiring.
- The power supply cable must be laid in conformance to all applicable legal guide- lines and regulations of the local electricity supplier.

5.6 Non-Routine Maintenance / Troubleshooting

5.6.1 Diagnostics and Troubleshooting

The solar pump controller will attempt to drive the pump to deliver water even under adverse conditions. To ensure years of reliable service, it must also protect the system components from conditions that might result in equipment damage. When adverse conditions arise, the controller will continue to deliver as much water as possible at reduced output if necessary, and will shut down only in extreme cases. Full operation will resume automatically whenever abnormal conditions subside. Error conditions may suspend certain features, reduce output, or shut down operation of the controller for varying amounts of time depending on the nature and severity of the error. Problems that merely reduce features or performance generally restore full operation when the trouble condition subsides without stopping the pump or flashing an error code. A severe error such as short circuit or over current requires stopping the motor immediately. An overload error stops the controller with a delay by time-load curves defined internally. The error code is shown on the LED display. If the controller has stopped to indicate a fault code on the display, the associated time-out delay will vary depending on the nature of the fault.

Troubleshooting requires a systematic approach to diagnose the problems, for example, starting with:

- The system does not work.
- What part of the system? Collector loop.
- What part of the collector loop? Pump.
- What aspect of pump operation? Control.
- Start-up signal? Yes. Contactor operational? No.
- Manually operate contactor--Pump starts!
- Therefore, bad contactor. Replace contactor.

Troubleshooting does not always go that easily. Sometimes the diagnosis requires chasing a fault around checking the components serially. The key to troubleshooting understands the system, having the necessary instruments installed in the system, and using a systematic approach.

These troubleshooting and corrective action guidelines are provided as a sample listing of the problems that may be encountered. The system has been installed and a checkout performed that showed the system to be operating correctly. Tailor the guidelines, through deletions and additions, to each specific site. List the probable causes for each problem in the order of priority in which they should be evaluated to minimize expensive or unnecessary repair work.

Table 5-5: Troubleshooting for Solar Energy System

Item No	Problem	Cause	Corrective Action
1	Your pump delivers little or no water	a. Water level in a low producing well drops too low while pump is operating, causing it to air lock. (Resulting in loss of prime and possibly serious damage to the pump)	a. Lower the pump further into the well, but make sure it is at least five feet from the bottom of the well. Install a control valve in the discharge pipe between the pump and pressure tank. Use the control valve to restrict the flow until the discharge rate does not exceed well recovery rate.
		b. Intake screen is partially plugged.	b. Lime or other matter in the water may build up on screen. Pull pump and clean screen.
		c. Check valve(s) may be stuck.	c. Make sure that the built-in check valve in the pump and any check valves in the discharge line are free to open properly.
		d. Voltage is too low; the motor runs slowly, causing low discharge pressure (head) and high operating current draw.	d. Have a certified electrician verify voltage at the electrical disconnect box (2 wire) or control center (3 wire) while the pump is operating. If the voltage is low, the power company may need to raise it or installation may require larger wire. Discuss this

Item No	Problem	Cause	Corrective Action
			with the power company or a licensed electrician.
2	Air or milky water discharges from your faucets	Well water may be gaseous	If your well is naturally gaseous and your system has a standard tank, remove the bleeder orifices and plug the tees. If the condition is serious, check with certified well professionals
3	Pump starts too frequently	a. Leak in the pressure tank or plumbing.	a. Check all connections with soapsuds for air leaks. Fix any leaks you find. Check the plumbing for water leaks. Fix any leaks you find.
		b. Pressure switch is defective or out of adjustment.	b. If necessary, replace switch.
		c. Check valve is leaking.	c. Inspect valves and replace if necessary.
		d. Tank is waterlogged.	d. Captive Air® Tanks: Check the tank for leaks; correct if possible. Recharge tanks to 18 PSI with a 20-40 PSI switch, 28 PSI for a 30-50 PSI switch, 38 PSI for a 40-60 PSI switch, etc. Standard tanks: Check the tank for leaks; correct if possible. Check bleeder orifices and clean bleeders; replace if necessary.
		e. Drop pipe leaking.	e. Raise one length of pipe at a time until the leak is found. When water stands in the pipe there is no leak below this point.
		f. Pressure switch is too far from the tank.	f. Move the pressure switch to within one foot of the tank.
4	Fuses blow or overload protector trips when the motor starts	a. Fuses or wires are too small.	a. Replace with correct wire sizes.
		b. Low or high voltage.	b. While motor is running, voltage should not exceed plus 5% or minus 5% or rated voltage shown on motor nameplate. Call the electric power company to adjust line voltage if not within these limits.
		c. Cable splices or motor windings grounded, shortened, or open.	c. Consult certified electrician or service technician.
		d. 3-wire only; Cable leads may be improperly connected	d. Check wiring diagram on pump control box (also see Figure 9 on Page 9) and colour coding of drop

Item No	Problem	Cause	Corrective Action
		in pump control box, pressure switch or fused disconnect switch. e. 3-wire only; there may be a broken wire in the pump control box. f. 3-wire only; Starting or running capacitor in control box may be defective or vented (blown out).	cable. e. Employ certified electrician examine all connections and wiring in control panel. If necessary, repair them. f. Inspect capacitors. Employ a certified electrician to check capacitors and replace them if necessary. WARNING! Hazardous voltage, can shock, burn or cause death. Capacitors may still carry voltage charges even after being disconnected from wiring. Have them checked by a certified electrician.
5	Motor will not start but does not blow fuses. WARNING! Hazardous voltage. Can shock, burn or cause death. Employ a qualified electricians should work on electrical service.	a. No voltage to motor. b. Cable splices or motor windings may be grounded, shorted or open-circuited. c. Open circuit in pump control box (3-wire only); faulty connections; faulty wires. d. Faulty pressure switch. e. 3-wire only; Cable leads improperly connected in the control center.	a. With a voltmeter check; 1) fuse box to make sure full voltage is available; 2) pressure switch terminals, to make pressure switch is passing voltage correctly; and 3) terminal strips in pump control box or disconnect switch box to make sure voltage is available there. On 1-1/2 through 3 HP: Push red overload reset button(s) on the bottom of control center. b. Consult certified electrician or service electrician. Do not attempt to disassemble pump or motor. c. Examine all connections and wires; examine terminal strips in the control center (3-wire only); repair if necessary. d. Check pressure switch; replace if necessary. e. Check wiring diagram on control center panel (or see Figure 9 on Page 9 of this manual) and color coding of drop cable.
6	Pressure switch fails to shut off pump	a. Voltage is too low; motor will run slowly, causing low discharge pressure (head) and high operating current draw.	a. Have a certified electrician verify voltage at the electrical disconnect box (2-wire) or the pump control box (3-wire) while the pump is operating. If the voltage is low, your power company may require larger wire. Discuss with the power

Item No	Problem	Cause	Corrective Action
			company or a certified electrician. Check voltage with a recording meter if trouble recurs.
		b. Faulty pressure switch.	b. Replace switch.
		c. Drop pipe is leaking.	c. Raise one length at a time until the leak is found. When water stands in the pipe, there is no leak below this point.
		d. Water level in the well may become too low when pump is running	d. Lower pump further into well, make sure it is between five and ten feet from the bottom of the well. Install a valve into the discharge pipe between the pump and the pressure tank. Use the valve to restrict flow until discharge rate does not exceed the well recovery rate. WARNING! To prevent the possibility of dangerous high pressure, install a relief valve in the discharge pipe between the pump and flow restriction valve. The relief valve must be capable of passing full pump flow at 75 PSI
7	Fuses blow or overload protector trips when motor is running	a. Low or high voltage.	a. While the motor is running, voltage should not exceed plus 5% or minus 5% of rated voltage shown on motor nameplate. Call your power company to adjust line voltage if it is not within these limits.
		b. 3-Wire only: High ambient (atmospheric) temperature.	b. Make sure the pump control box is installed out of direct sunlight.
		c. 3-Wire only: Pump control box is wrong horsepower or voltage for installation.	c. Compare horsepower and voltage rating of motor (from motor nameplate) with those of the pump control box (from pump control box nameplate). These numbers must match.
		d. Wire size is too small. Improperly connected in the pump control box.	d. Make sure the wire sizes match specifications in the Table.
		e. Cable splices or motor windings may be grounded, shorted or open-circuited	e. Consult certified electrician or a service technician to determine if this is the cause of the problem or not. Do not attempt to disassemble pump or motor.

5.7 Miscellaneous

5.7.1 Storage Tanks

Drain and flush out water storage tanks annually to remove sediment from the bottom of the tank. Excessive amount of sediment may indicate corrosion problems; test the water and treat it.

5.7.2 Strainer (Filter)

Check and clean strainers (filters) at least twice a year. Finding excessive sediment in the filters for liquid systems could signify corrosion problems. Check and treat the fluid and schedule more frequent cleaning of the strainers.

5.7.3 Valves

Some remotely operated valves require scheduled lubrication. Refer the manufacturer's literature for the maintenance requirements. Cycle these valves periodically to be sure they are working properly.

Check pressure and pressure relief valves periodically but never when the collectors are stagnating. Manually operate the valves using the lift lever. Replace any valves that are stuck (frozen) shut or leaking.

Check automatic air vent valves periodically by: (1) removing cap, (2) depressing valve stem until small amount of fluid is released, and (3) replacing cap, taking care to only tighten two turns to allow proper venting.

Inspect check valves periodically. The inspection should include, if possible, opening the valve (after isolating it from the system) to verify that there has been no erosion or corrosion, that the seat is not damaged, and that the valve operates freely (does not stick), and that the flapper or plunger is not pitted or scaled.

Cycle all manual valves (i-e., opened, closed, and returned to design position) periodically. This prevents freeze-up of the valves. Consult manufacturer's literature for any lubrication requirements.

5.7.4 Fans

Fans, like pumps, can require lubrication on a scheduled basis. Follow the manufacturer's recommendations. In addition, check the fans frequently for noise, loose drive belts (if applicable) and speed, and promptly take corrective action, when needed. Check the operating current draw (amperage) for variation from the as-installed value.

5.7.5 Instrumentation

The primary maintenance of instrumentation is calibration of flow meters, pressure gauges, thermometers, and temperature sensors. Use the manufacturer's literature for the calibration schedules, requirements, and procedures.

5.7.6 Control system

Preventive maintenance for the control system includes repeating the acceptance test control checkout outlined in the installation Manual. The equipment typically required for the check- out includes a multicentre and variable resistance potentiometer.

Annexes

Annex A: Pre-Turn on Checks

1. On the solar panel leads, check the voltage between the two leads. This voltage should read approximately 16-20 volts. Your reading is __________________.
2. On the terminal block marked 'BAT+' and 'BAT-' check the voltage between the 2 terminal blocks. This voltage should read between +11.4 volts and +13.4 volts. Your reading is ______________________. Post-Turn On Checks
3. Verify the LED that is lit on the solar controller Record the colour of the LED that is lit _____________________________.
4. Record the solar voltage being displayed on the controller __________V.
5. Record the array current being display on the controller __________amps and the time of day ____________ and weather status (sunny, cloudy, raining) ____________________.
6. Turn on the load and record the load current being displayed on the controller _________________amps.

Annex B: Solar Panel(s)

The current and power output of your solar panel is proportional to sunlight intensity. It is important to install your solar panel so that it is not shaded during daylight hours. The season of the year as well as the azimuth of your panel will affect the output of your solar panel.

Your panel is composed of crystalline cells interconnected to effect the wattage rating of the panel. Further the connection is such that damage to one cell(s) only reduces the output of the panel by the power lost from the cell(s). Thus if only one cell is damaged your panel will still continue to produce power close to the rated output of the panel. The crystalline cells are encapsulated between tempered glass and an EVA potting with PVF back sheet to provide the maximum protection to your cells from environmental factors. The panel is housed in an anodized aluminium frame to provide structural strength and ease of handling.

Annex C: Trouble shooting if the solar pump does not run

Most problems are caused by wrong connections (in a new installation) or failed connections, especially where a wire is not secure and falls out of a terminal. The System ON light will indicate that system is switched on and connected to the controller. It indicates that VOLTAGE is present but (in a solar-direct system) there may not be sufficient power to start the pump. It should attempt to start at intervals of 120 seconds.

Pump attempts to start every 120 seconds but does not run. The controller makes a slight noise as it tries to start the pump. The pump will start to turn or just vibrate a little.

1. There may be insufficient power reaching the controller. A solar-direct (non-battery) system should start if there is enough sun to cast a slight shadow. A battery system should start if the supply voltage is greater than 22 V (24 V system) or 44 V (48 V system).

2. If the pump was recently connected (or reconnected) to the controller, it may be running in reverse direction due to wiring error.

3. If the motor shaft only vibrates and will not turn, it may be getting power on only two of the three motor wires. This will happen if there is a broken connection or if you accidentally exchanged one of the power wires with the ground wire.

4. The pump or pipe may be packed with mud, clay, sand or debris.

5. Was the pump stored in water for more than three months? This might cause the pump to seize. Pumps will not be damaged, but might have to be pulled to free them again. Let stored pumps run every 2 – 3 months in order to avoid seizure.

6. Helical rotor models: The rubber stator may be expanded from heat, due to sun exposure or pumping water that is warmer than 72°F (22°C). This may stop the pump temporarily, but will not cause damage.

7. Helical rotor models: The pump may have run dry. Remove the pump stator (outer body) from the motor, to reveal the rotor. If there is some rubber stuck to the rotor, the pump end must be replaced. (for surface pumps)

8. Helical rotor models: The check valve on the pump may be faulty or stuck, allowing downward leakage when the pump is off. This can prevent the pump from starting.

9. Is the pump installed in a negative suction head application? This is an abnormal situation and will pull the rotor out of the pump stator causing possible damage inside the motor as this is an abnormal working direction for all pumps. Negative suction head means that you do not need a pump at all since the delivery point is below the water source level in the source (wells, ponds etc.).

Annex D: Inspecting the Solar Energy System

a) Inspect the solar array

1. Is it facing the sun?

2. Is there a partial shadow on the array? If only 10 % of the array is shadowed, it can stop the pump!

b) Inspect all wires and connections

1. Look carefully for improper wiring (especially in a new installation).

2. Make a visual inspection of the condition of the wires and connections. Wires are often chewed by animals if they are not enclosed in conduit (pipe).

3. Pull wires with your hands to check for failed connections.

c) Inspect the controller and junction box

1. Remove the screws from the bottom plate of the controller. Move the plate downward (or the controller upward) to reveal the terminal block where the wires connect.

2. First, check for a burnt smell. This will indicate a failure of the electronics. Look for burnt wires, bits of black debris, and any other signs of lightning damage.

3. Open the junction box. Is the Power IN switch turned ON? Pull on the wires to see if any of them have come loose.

4. Inspect the grounding wires and connections! Most controller failures are caused by an induced surge from nearby lightning where the system is NOT effectively grounded. Ground connections must be properly made and free of corrosion.

Check the low-water probe system

If the controller indicates "SOURCE LOW" when the pump is in the water, inspect the low-water probe system. The probe is mounted on, or near the pump. If inspection is not feasible, you can bypass the probe or test it electrically.

Annex E: Electrical testing of the Solar Energy System

1. If the probe is NOT being used, there must be a wire between terminals 1 and 2.

2. The probe is a cylindrical plastic device mounted on or near the pump. It contains a small float on a vertical shaft. The float must be able to move up to indicate that it is submerged, and down to indicate that it is dry.

3. The probe must be positioned vertically (within about 10°).

4. The probe or a probe wire may be broken. Inspect the wires for damage.

5. Does the pump run when the probe is OUT of the water? This can happen if the float in the probe is stuck. In surface water, this can happen from algae, a snail, or other debris.

6. If the pump was purchased before and stored for long, it may have a wet-electrode probe. In case of trouble, it can be replaced with a new (mechanical float) probe, with no changes to wiring or controller.

Check the full-tank float switch:

If the controller indicates "TANK FULL" when the storage tank is not full, inspect the float switch system. If your system has a float switch, it will be mounted in the tank. If inspection is not feasible, you can bypass the switch or test it electrically.

1. If a float switch is NOT being used, there must be a wire between terminals 4 and 5.

2. Inspect the float switch. Is it stuck in the UP position?

3. There are two types of float switch, normally-open and normally-closed. Check to see that the wiring is correct for the type that is used.

Force a quick start:

If you restore a connection or bypass the probe or float switch, there is no need to wait for the normal time delay. Switch the on/off switch (or the power source) off then on again. The pump should start immediately if sufficient power is present.

Annex F: If the pump runs but flow is less than normal

1. Is the solar array receiving shadow-free light? (It only takes a small shadow to stop it.) Is it oriented properly, and tilted at the proper angle?

2. Be sure you have the right pump for the total lift that is required, out of the well + up the hill. In the case of a pressurizing system, the pressure head is equivalent to additional lift (1 PSI = 2.31 feet, 1 bar = 10 m).

3. Be sure all wire and pipe runs are sized adequately for the distance. Refer to wire sizing in the pump sizing table,

4. Inspect and test the solar array circuit and the controller output, as above. Write down your measurements.

5. There may be a leak in the pipe from the pump. Open a pipe connection and observe the water level. Look again later to see if it has leaked down. There should be little or no leakage over a period of hours.

6. Measure the pump current and compare it with the table in the previous reading.

7. There is a “max. RPM” adjustment in the controller. It may have been set to reduce the flow as low as 50 %.

Has the flow decreased over time?

1. Is the AC motor current lower than normal? The pump end (pumping mechanism) may be worn from too many abrasive particles (sand or clay) in the water.

2. Is the AC motor current higher than normal? Doesn’t start easily in low light? This is likely to be related to dirt in the pump and/or pipe.

3. Look in the water tank or pipes to see if sediment has been accumulating.

4. Run the pump in a bucket to observe.

5. Remove the pipe from the pump outlet (check valve) and see if sand or silt is blocking the flow.

6. If the check valve itself is clogged with dirt,

7. To help prevent dirt problems, try to Coping with Dirty Water Conditions.

8. After years of use, it may be necessary to replace the pump end. Call your pumps supplier for advice

Annex G: GENERAL SOLAR PV Inspection and Routine Maintenance Guide

If the pump runs but flow is less than normal

A grid connected General Solar PV system is a potentially dangerous, high voltage electrical generator and should be inspected at least every six months to ensure that all system components are working correctly.

Appropriate maintenance should occur at least before the onset of both summer and winter.

CAUTION

General Solar PV photovoltaic modules produce electrical energy when exposed to the sun, including under cloud, or other light sources. The power of an individual module is not considered dangerous but when connected in series and / or parallel the danger of an electric shock will increase.

The DC voltage produced by General Solar PV modules can reach up to 1000V during the day even if the inverter is not switched on. The module surface can become slippery when wet and operatives must follow appropriate safe working practices when accessing General Solar PV systems.

GENERAL ADVICE

- Ensure that appropriate safety signs are in place at each access point to the installation.
- When working on a roof, ensure you are properly tethered and that your safety equipment is in safe operating condition.
- Avoid walking on photovoltaic modules and utilize access routes where provided.
- Do not cut or fold the photovoltaic modules for any reason.
- Do not apply screws, nails etc and avoid letting pointed or heavy objects fall onto any part of the module. Such action could cause shock, generate flame, and invalidate any warranty.
- Do not place any device on top of the photovoltaic modules.

INSPECTION & MAINTENANCE GUIDANCE

The following procedures should be completed during each operation and maintenance visit:

- Visually check that each laminate is bonded perfectly to the waterproof membrane. If any areas of the laminate are NOT perfectly bonded, mark the product with a permanent marker or crayon. If this de-bonding gets worse over subsequent maintenance visits, carry out the following repair advice:

  Re-establish the adhesion by a combination of hot air and pressure from a Teflon coated roller or by applying Solar fill glue and pressing the two elements together until they adhere.

- Check the top surface of each laminate for any scratches or surface damage. Patch any surface damage in accordance with module manufacturer repair guidelines without delay. If the PTFE top surface becomes damaged and is not repaired quickly, system performance can be degraded and the laminate could fail.

- Visually inspect cables and cable ducting, verifying that adequate strain relief is provided and the connections are tight, secure and free from corrosion. Ponding water on laminate surface should be avoided, laminates should not be subjected to ponding water and cables should be housed off the membrane surface in an appropriate free-draining cable tray. The most appropriate time to carry out this inspection is just before and/or just after the winter (or rainy) season.

- Cable trays should be secured to the roof membrane with the Security of attachment should be visually checked.

- Clean laminates which are particularly dirty or have localized shading (bird droppings, leaves, etc.).

- During the pre-summer visit, check the extent of dirt on the module surface and perform cleaning if this is warranted.

- Verify that all laminates are located in areas that have no shading, and remove temporary objects that may be shading the array and reducing system performance. For example, prune trees that may be shading the array during the summer months.

- Ensure that the drainage system is not blocked and that there is no potential for water pooling on the laminates.

SYSTEM COMMISSIONING & TROUBLESHOOTING FOR ELECTRICIANS AND MAINTENANCE STAFF

The following tests should only be performed by trained and qualified personnel. The best weather conditions that will provide the most accurate system tests are cloudless days with strong sun conditions.

- Before starting PV system maintenance, check that metal parts (array frames, junction box enclosures, DC disconnect switch enclosures, inverter enclosures) are earthed properly.

- When working on the PV Laminates, always wear electrical gloves and shoes and use only insulated tools rated for the maximum rated system voltage (i.e. 600 VDC), disconnect all energy source (i.e. battery and/or utility) and short-circuit the output of the PV Laminates.

- If more than one ground rod is being used, verify that all ground rods are bonded together with appropriately sized conductors.

- Measure and record the open circuit voltage of each series string, verifying that all strings that are feeding the same inverter have the same polarity and a similar open circuit voltage (within ± 5V of each other). If the variation in string voltages is greater than 5V, check the individual connections to that string of laminates.

- Measure and record the operating current of each series string and verify that all strings with the same number of laminates have a similar operating current (within ±

1A of each other). A variation in operating current can indicate areas of the array which are shaded or are particularly dirty and should be investigated further.

- Check the alarm status of each inverter and also the historical alarm log if this is available (refer to inverter manufacturer's manual). Any alarm which indicates either a low resistance or an earth leakage fault should be investigated as soon as weather conditions permit, by suitably qualified personnel.
- Record DC and AC power (at the input and output of the inverter) and determine inverter operating efficiency.
- Perform and record insulation resistance (Riso) on the input to each inverter.
- Checks that system fuses and DC disconnect switches are operational.
- Check for loose wires or connections at all solar system array controller (voltage regulator), Combiner Boxes, and/or other Junction Boxes within the system.
- Perform maintenance on the inverter(s) as stipulated by the manufacturer (clean filters, etc.).
- Confirm that no new loads have been added to the system and that loads are operating for the specified number of hours per day.

CLEANING PV LAMINATES

Generally, a good rain is sufficient to clean the PV Laminates. However, in dusty arid locations the PV Laminates can be cleaned with water or mild soap and water in accordance with the following procedure. However avoid cleaning the panels in the middle of the day and do not use abrasive soaps or solvents.

GENERAL RECOMMENDATIONS

- Wear rubber soled boots and cut resistant gloves when cleaning laminates.
- Survey the roof for any loose wires, damaged modules and tough stains that will require special attention.
- While surveying, remove all large debris from the roof surface.
- Use a leaf blower to remove all small sized debris from the roof surface.
- Use a garden hose to get the entire PV laminate wet, making sure not to spray water on electrical wires.

WHEN TO CLEAN

The amount of electricity generated by a solar cell is proportional to the amount of light falling on it. A shaded cell will produce less energy. The non-stick PTFE top surface of General Solar PV modules promotes automatic self-cleaning. It is normally NOT necessary to perform an all-encompassing cleaning of dirt from the solar array, provided that the array is installed on more than a 5% slope.

Cleaning should be performed on any modules that are excessively affected by a collection of bird droppings, dirt, or miscellaneous debris, such as fallen leaves. This cleaning should be performed at each maintenance visit. The monetary value of cleaning dirt and debris from the array is a trade-off between the cost of the cleaning, increased energy production as a result of the cleaning, and the inevitable re-soiling of the laminates over time once they have been cleaned.

To help determine the performance benefit of cleaning, perform the following steps to measure the short circuit current of individual laminates before and after cleaning: Measure and record the operating voltage of each series string and verify that all strings feeding the same inverter have a similar operating voltage (within ± 5V of each other). Any difference greater than 5V between strings requires investigation.

- Isolate a single string, making sure all the DC isolation switches are open (OFF) and all the string fuses have been removed.
- Disconnect the laminates that will be used for the test by opening connections via an MC4 disconnect tool.
- Verify that the current sunlight is effectively constant (clear sky, strong sunshine, no clouds)
- Connect a DC millimetre across the terminals (10A or greater) to measure and record short circuit current.
- Clean the laminate as described in the Cleaning Procedure below.
- Measure and record the current and verify the percentage difference between the two readings. This percentage difference is the potential gain that will be derived from cleaning the product.

<u>CLEANING PROCEDURE</u>

Clothing	-	Anti-slip rubber shoes and gloves.
Tools	-	Soft brush, dry cotton mop or clean broom.
	-	Low pressure water or portable pressurized water tank.
	-	Biodegradable, non-abrasive mild detergent.
	-	Clean water source.

- Check earth connection of PV modules and inverter.
- Examine the roof for damaged modules or persistent staining.
- Remove all waste matter lying on the modules.
- Wet the area avoiding the electrical cables.
- Using soft brush remove excess dirt.
- Pressurized power washers should **NOT** be used directly on the laminates. If these devices are being used to clean the roof around a solar array, ensure that the nozzle of the power washer remains at least two feet away from the surface of the laminates at all times while cleaning.

- When spraying a module, **do NOT** spray water directly on the electrical connections or at the leading edge of the PV laminate.
- Use caution when cleaning PV modules, as the combination of water and electricity may present a shock hazard.
- Use a soft brush to scrub stubborn stains, be careful not to scratch the surface.
- Rinse with water to remove all traces of detergent.
- Dry any puddles left on the roof post cleaning.

Annex H: Typical failures of V-belts and their reasons

No	Type of failure	Probable reasons
1	Belt rapture after short period of operation	▪ belt tearing during mounting on pulley; ▪ drive blockage with respect to failure of driven machine or foreign body entrapped inside the drive; ▪ poorly calculated drive with too small number of belts (poorly calculated coefficient of conditions of operation kT);
2	One-side usage of belt at its side wall	▪ too big not-parallelism of belt pulleys axis;
3	Earlier usage of side surfaces at whole length of belts	▪ too big torque (mainly for drives with big start-up torque during driving machine start- -up and big resistance torque during start-up of driven machine is necessary to use equipment ensuring soft start); ▪ improper angle or excessive usage of groove of pulley; ▪ too small belt tension; • too often short-term overloads of gearing with respect to failure of driving machine; ▪ too small number of belts; ▪ lack of parallelism of belt pulleys setting; ▪ minimal pulley diameter is exceeded; ▪ surface of grooves possess to big roughness
4	Local usage of side surfaces	▪ too small belt tension; ▪ blockage of driven machine pulley with respect to bearing failure
5	Grooves at side surface at whole belt length	▪ belt friction because with contact with part of a machine; ▪ belt works in used-up groove of pulley; • improper groove cross-section
6	Transversal belt breakage at the bottom side.	▪ usage of external tension roller instead of internal;

		▪ too small diameter of tension roller; ▪ excessive or too small temperature of operation; ▪ too big slippage; ▪ chemical influences; ▪ excessive belt tension;
7	Indurations and ruptures of a wrap.	▪ strong influence of dust; ▪ too big ambient temperature; ▪ influence of chemicals
8	Detachment of cloth wrap and symptoms of rubber bulging.	▪ reason of long-term influence of oil, grease or other chemicals at a belt
9	Strong vibration.	▪ base of axle bigger then is recommended; ▪ big shock load; ▪ too small belt tension; ▪ non balanced grooved pulleys; ▪ overloaded drive; ▪ angle of groove is not correct
10	Twisting of belt	▪ lack of coaxiality in pulleys setting; ▪ not correct belt or groove profile; ▪ excessive vibration; ▪ too small belt tension; ▪ penetration of foreign material into grooves; ▪ overloaded drive;
11	Falling of belts from pulleys after short period of operation	▪ too small belt tension; ▪ too small frequency of control and adjust- ment of belt tension;
12	Too loud operation of gearing	▪ belt pulleys are not set coaxial; ▪ too small belt tension; ▪ overloaded drive; ▪ grooved pulleys not balanced;
13	Uneven belts stretching.	▪ faulty belts grooves;

		▪ used belts do not create a set of belts; ▪ a few belts from a belt unit were replaced by new ones; ▪ unit of belts composed of from belts of different producers;
14	Excessive heating of bearings.	▪ bearings not lubricated; ▪ grooved pulleys not balanced; ▪ too big tension
15	. Lowering of speed of driven pulley;	▪ .check relationship between diameters of pulleys and their speeds; ▪ too small tension;
16	Different tension of single belts working in belt unit.	▪ belts do not create a set of belts or do not possess marking L=L; ▪ different pitch diameters of particular grooves in belt pulley; ▪ usage of belts of different quality in one set as well as belts; ▪ coming from different producers; ▪ a few belts from a belt unit were replaced by new ones.

Annex - I: Solar System Maintenance Schedule

Maintenance Task	Daily	Weekly	Monthly	3 Months
Visual Inspection of system wiring, Lights and vaccine freezer		√		
Solar Panel Maintenance				√
Battery Inspection		√		
Battery Cleaning			√	
Wiring Inspection		√		
Inverter/Battery Charger		√		
Charge Controller		√		
Battery "top-up"			√	

Annex J: Panel Maintenance Log Sheet (every 3 months)

Date	Name of Maintenance Technician	PV Module Clean		Array Frame			Array Cabling	Array Output voltage
		Yes	No	Good	Fair	Bad		

Annex K: Weekly Battery Inspection Log Sheet for "Deep Cycle Flooded" Lead acid Battery

Date	Battery Number	Specific Gravity	Terminals/Connection Tight		Voltage	Water Level			Action Taken
			Yes	No		Good	Fair	Low	

Annex L: Weekly Battery Inspection Log Sheet for AGM and GEL Batteries

Date	Battery Number	Terminals/Connection Tight		Voltage	Action Taken
		Yes	No		