Ethiopian TVET-System

Electro Mechanical Equipment Operation and Maintenance
NTQF Level –III

Module Title: Installing and Maintaining Solar Energy System for Water Pumps

TTLM Code: EIS EME3TTLM0920 v1

This module includes the following Learning Guides

LG70: Plan and prepare for Installation

LG Code: EIS EME3 M17 LO1-LG 70

LG 71: Installation of Solar Energy Equipment

LG Code: EIS EME3 M17 LO2-LG-71

LG 72: Maintenance and Service

LG Code: EIS EME3 M17 LO3-LG-72

Instruction Sheet 1	Learning Guide 70: Plan and Prepare for Installation

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics

- Solar Energy
  - ✓ Solar radiation
- Principle of solar energy
- designing Pumping system
- *Load calculations*
- selecting Appropriate location
- designing Pumping system using *solar energy data* of the area
- installation *Tools and testing devices*

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- understand Solar Energy
  - o Solar radiation
- Understand principle of solar energy
- design Pumping system
- *conduct load calculations*
- select Appropriate location
- design Pumping system using *solar energy data* of the area
- understand and identify installation *Tools and testing devices*

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described in number 3 to 20.
3. Read the information written in the "Information Sheets 1". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
4. Accomplish the "Self-check 1" in page 3.

5. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 1).
6. If you earned a satisfactory evaluation proceed to "Information Sheet 2". However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1
7. Submit your accomplished Self-check. This will form part of your training portfolio.
8. Read the information written in the "Information Sheet 2". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
9. Accomplish the "Self-check 2" in page 15.
10. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 2).
11. Read the information written in the "Information Sheets 3 and 4". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
12. Accomplish the "Self-check 3" in page 32.
13. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 3).
14. If you earned a satisfactory evaluation proceed to "Operation Sheet 1" in page _. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to for each Learning Activities .

Information Sheet-1	Solar Energy

Introduction

Solar radiation is a perennial source of energy, available all over our planet, free of charge and entirely renewable. Photovoltaic systems, once installed, do not need any fuel input and do not emit greenhouse gases. They receive and automatically convert the solar radiation into electricity, do not contain any mobile parts and thus require very limited maintenance. Solar systems therefore have highly reduced running and maintenance costs compared to engine powered water systems.

1.1. Solar Energy

What is Solar Energy?

"Solar Energy" refers to radiant heat and light from the sun.

- It is renewable, which means it cannot be used up.
- It is harnessed and converted to heat or electricity

using various technologies such as **Solar Heating** and **Solar Photovoltaics** (conversion to electricity).

1.2 Photon Energy

A photon is characterized by either a wavelength, denoted by λ or equivalently an energy, denoted by *E*. There is an inverse relationship between the energy of a photon (*E*) and the wavelength of the light (λ) given by the equation:

$$E = \frac{hc}{\lambda} \qquad (1)$$

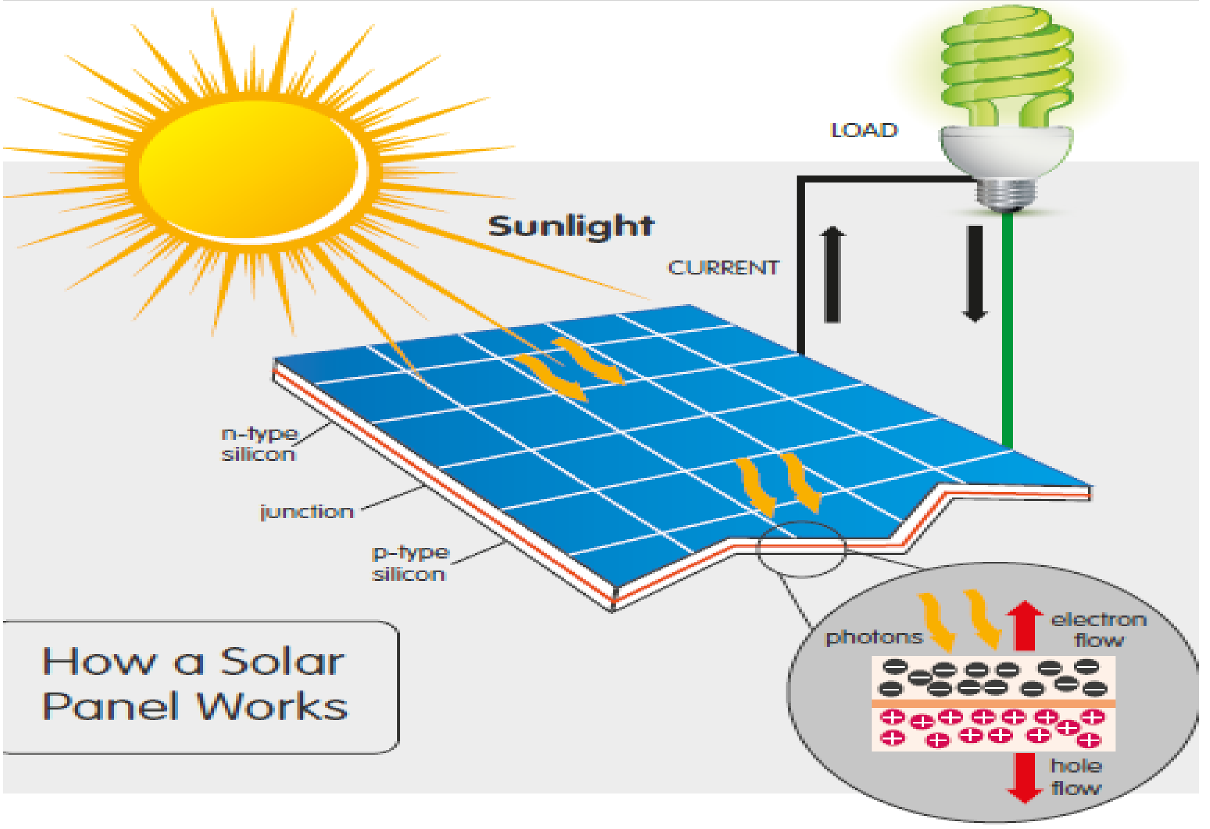


Figure 1.1: How Solar energy works

Applications or uses solar energy

1. Lighting
2. Communication
3. Powering electrical gadgets
4. Water pumping
5. Charging appliances

Self-Check 1	Written Test

Directions: - Answer all the questions listed below and write your answer on the space provided

Name ___________________

1. What is solar energy? (2pts)
2. What is application or uses of solar energy? (1pts)
3. Can solar energy be used up? If not, explain. (2pts)

Score = 6pts
Rating: ____________

Answer Sheet

Name: ___________________________
Date: ________________

Short Answer Questions

Q.1. --

Q.2.--

Q.3.--

Information Sheet-2	Principle Of Solar Energy

Introduction

In this module, an introduction of the basic electric theory is provided, necessary to understand the functioning of solar systems. The concepts of voltage, current, resistance, losses, electric power and electric energy will be presented, as well as the difference between direct current and alternating current.

2.1. Electricity Basics

A. Measuring Electricity

Voltage (V): the potential difference in electrical charge between two points measured in volts.

Current (I): the flow of electrons in a circuit/wire between two points measured in amperes.

Volts = Power ÷ Currents **V = P ÷ I** Volts

Current = Power ÷ Volts **I = P ÷ V** Amperes

B. There are two types of current:

1. Alternating Current (AC) is the type of current most commonly used in households to power electrical appliances (for example TVs, refrigerators, radios and computers). Grid supplied electricity is alternating current.

2. Direct Current (DC) is produced by PV modules and stored in batteries.

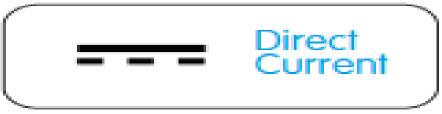


Figure 2.1a: Direct Current Figure 2.1b: Alternating Current

Resistance (R): the opposition to the flow of electrical current in the material through which it is passing measured in ohms the potential difference in electrical charge between two points measured in volts.

Resistance = Volts ÷ Current **R = V ÷ I** Ohms

Power (P): the rate of energy conversion measured in watts.

Power = Volts x Current **P = V X I** Watts

Energy (E): refers to the capacity for work i.e. the power used over time, measured in watt-hours.

Volts

Energy = Power x Time **E = P x t** Watt-Hours

Example:

If a solar panel produces 2 Amps of electricity at 12 volts, the total power it produces is 24 Watts. **(2 Amps x 12 Volts = 36 Watts)**

C. Electrical Circuits

Loads and power sources in a circuit can be connected in series or parallel. Systems may use a mix of series and parallel wiring to achieve the required voltages and amperages.

WATTS (Power)	WATT-HOURS (Energy)
A watt is the amount of power that a solar panel can produce or that a light bulb consumes.	A watt-hour is the amount of energy that a solar panel can produce or a light bulb can consume in a certain a number of hours.

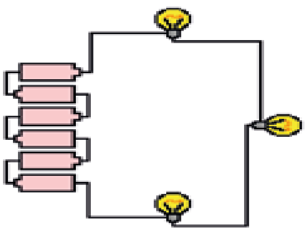


Figure 2.2a: Series Connections
increase voltage but does not increase current.

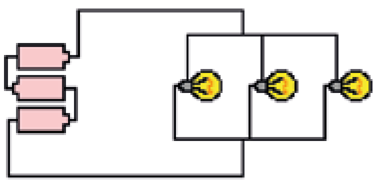


Figure 2.2b: Parallel Connections
increase current but voltage is not affected.

2.2. Energy that will be produced by a solar system

It is wise to have a discussion with a few solar panel installers on how various factors can affect solar energy output.

Solar panels show the amount of power that is expected to be produced under conditions that are ideal, which is known as the maximum power rating.

The amount of electricity produced by the solar panel depends on a couple factors:

- Does sporadic shade block sunlight from directly hitting the roof?
- What is the average amount of sunlight that the roof receives?
- What is the size of the solar panels and what is the efficiency of the cells of the solar

panel at converting energy?

The seasons and the weather have an effect on the sunlight that hits the roof. Also there is a variation in sunlight depending on the time of day. In these cases using the max power rating by itself will give an inaccurate prediction as to the power that can be expected. Nonetheless your location will give you the ability to calculate solar panels expected output.

Factors such as power, inverter efficiency and wiring will on average cause the solar system to lose energy and will only give up to 80% of its capacity.

Keeping in mind a solar panel watt rating, location, and electricity produced grid cost, a solar calculator will give a table with estimation of the amount of solar power to expect.

We enter the data as shown in the picture bellow

A. Solar Panels

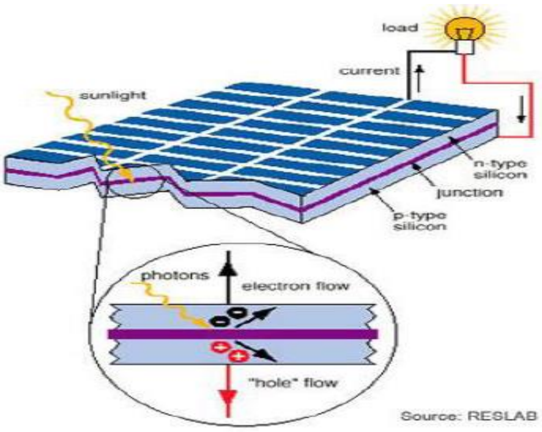


Figure 2.3: a) Solar Panels (Left); b) Solar Panels its working mechanism as solar energy converter to electric energy (right)

What are solar panels?

Solar panels are devices that allow for the input of sunlight, and convert this sunlight into electricity. As shown in figure 2.3a. The shape of solar panels can vary in different rectangular shape and a combination of these rectangular shaped panels are installed and used to produce the electricity. The solar panel consists of solar cells which are semiconductor devices that change the sunlight into electricity or direct current. The cells make up a module.

The PV photovoltaic modules comprise of photovoltaic cell circuits that are enclosed and "sealed in an environmentally protective laminate". The solar panel includes from one or more "PV modules assembled as a pre-wired, field-installable unit". The PV Array is the full unit that generates the power and includes all the elements just discussed.

The sun is a living fireball whose rays reach one side of the spherical earth during day time. Scientists have employed modern tactics to develop the solar cells that can directly convert the energy from sunlight to electrical power. Solar cell is an electronic device that converts energy. The Greek term „Photovoltaic‟ refers to the process of electricity generation from light. When a series of Photovoltaic or Solar Cells is put together, they form a Solar Panel. The panels absorb energy from the sun which is converted to electricity by the solar cells, see figure 2.3b.

Solar Cells

The standard type of solar cells consists of crystalline silicon (c-Si). There are two different variants of crystalline silicon namely: mono-crystalline and multi-crystalline (also called poly-crystalline). The difference lays in the production. Both types are produced from a melt of silica (silicon dioxide SiO_2 i.e. quartz) and carbon (like coal). In this melt the silica reduces to silicon while the carbon oxidizes to CO_2 and finally dissipates to the environment. When the melt cools down the silicon solidifies by taking a crystal structure. Naturally this process will result in many different small crystals within one block of silicon, hence it is called multi-crystalline.

However, if the cooling process is controlled well one can obtain one single crystal by using a so called breed crystal. By holding the breed crystal into the melt, slowly rotating it and applying a cooling gradient starting at the breeding crystal, the structure of the breeding crystal will be continued by the solidifying melt. Hence one cylinder of mono-crystalline silicon is obtained. As this process is more sophisticated mono-crystalline silicon is more expensive compared to multi-crystalline. However the material and electrical (I_{SC}, V_{OC}, η, etc.) parameters are better for mono-crystalline silicon, hence mono-crystalline solar cells casually give a higher power output.

You can easily distinguish both types by their shape. Since mono-crystalline silicon is obtained in cylindrical shape, but solar cells are usually squared (in order to improve the packing density within the module) the edges are cut of the cylinder resulting in a pseudo-square shape (a square with rounded corners, see **Error! Reference source not found.**).Whereas multi-crystalline solar cells are truly square shape.

B. What constitutes a solar panel?

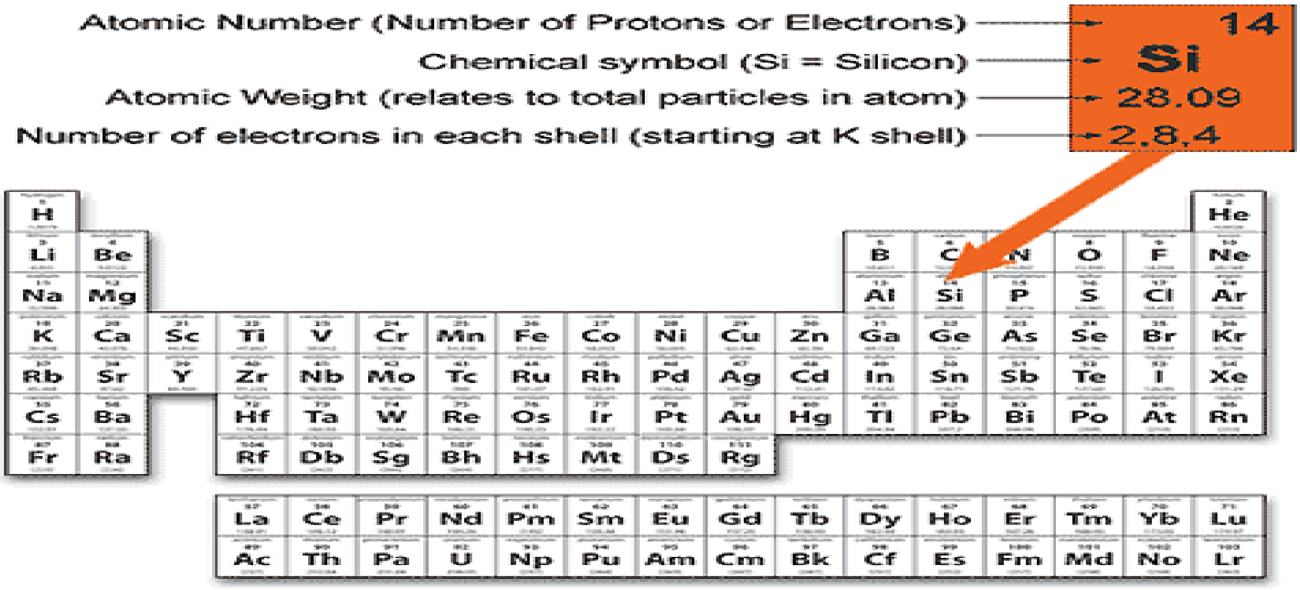


Figure 2.4: Silicon Element description in a periodic table

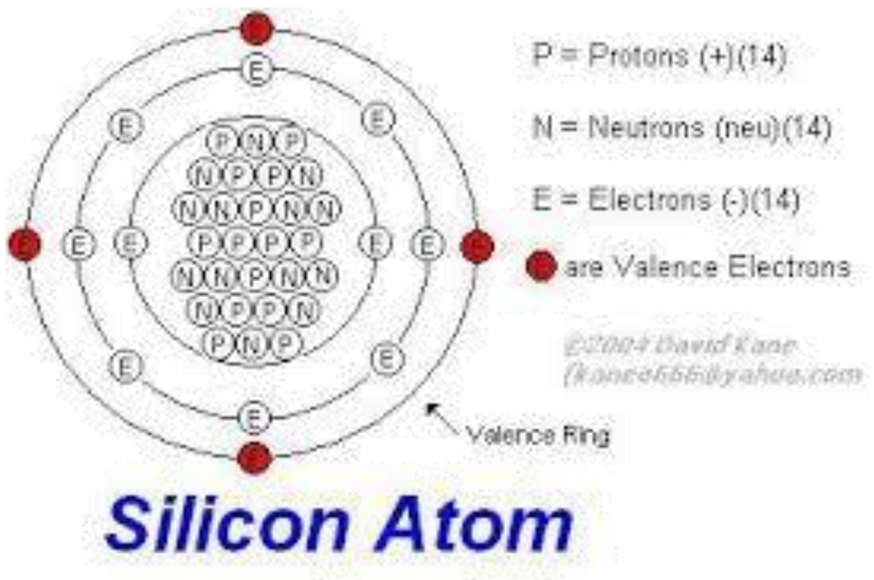
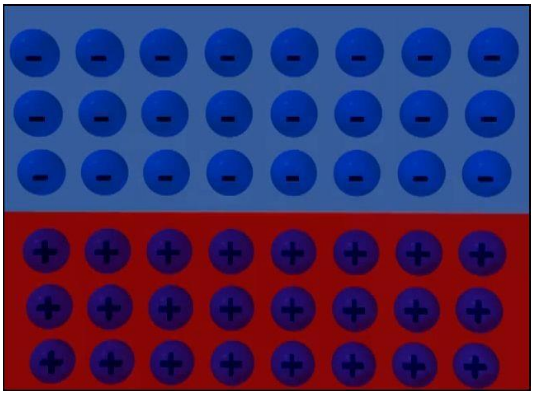


Figure 2.5: Silicon Atom Nomenclature

The primary element that makes up a solar panel is its solar photovoltaic cell which does the conversion from the sunlight to electricity. Accordingly, 80% of solar panels are made up of solar cells made of crystalline silicone meaning "monocrystalline, polycrystalline, amorphous silicon, or hybrids". The cells are placed in a grid like design.

Silicon is a semiconductor and the fourteenth component in the periodic table (see figure 2.4). It has 4 valences (electrons at the outer shell), see figure 2.5. Silicon particles offer valence electrons to achieve stability. To aggravate this stability, doping atoms are embedded into the silicon. Silicon can be combined with Bromine (positively doped) and can be combined with Phosphorus (negatively doped), see figure 2.7.

Furthermore the 20% are made up of solar cells which are made mostly from Cadmium Telluride and a small portion of CIGS or Copper Indium Gallium Selenite. These cells have an advantage of being low cost and therefore can be made into large single sheets.



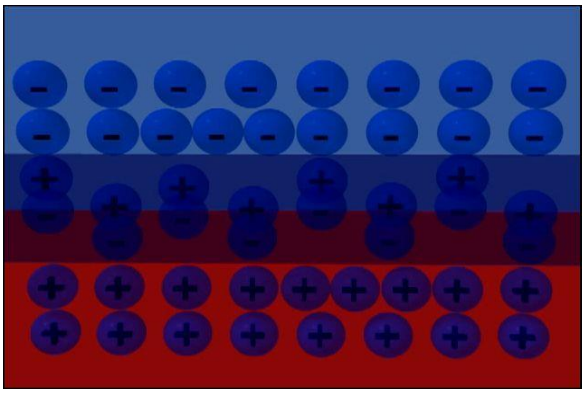


Figure 2.6: a) Closer look at the semiconductor layers (Left-Side) b) Photons coming from the sunlight create a state of unbalance (Right -Side)

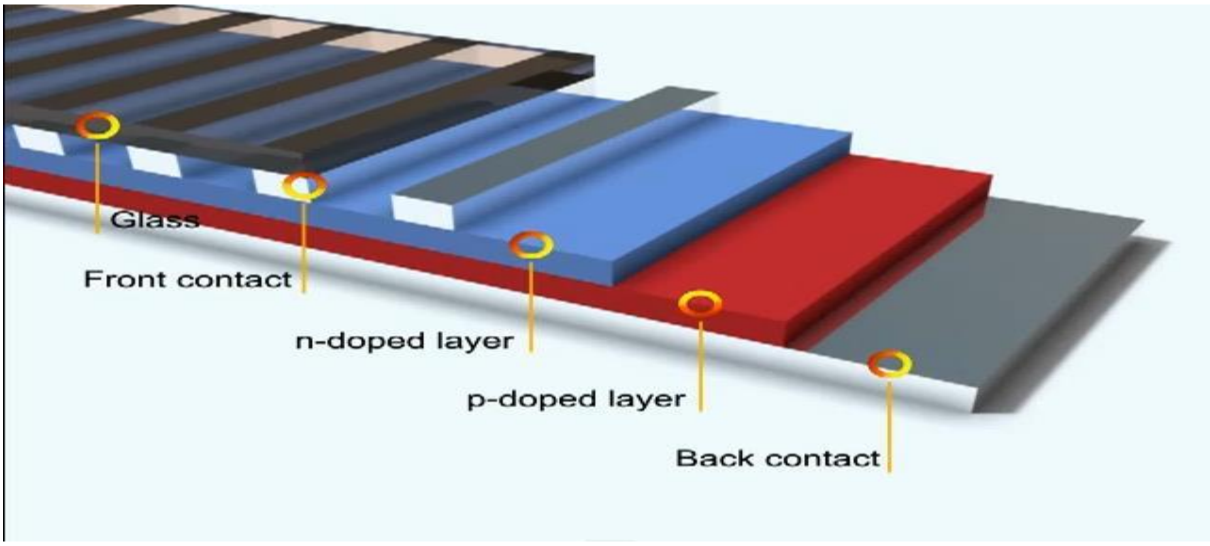


Figure 2.7: Closer look at solar cells

Solar panels are sealed hermetically or in an airtight manner in order to protect them, and are then covered in a glass that is non-reflective which protects the cells against environmental damage. The composite is then put into a frame that is rigid and sturdy. This frame prevents deformation due to freezing weather as well as strong winds. Also, the frame would include a hole that allows drainage and prevents water from building up on the device which can cause a reduction in what is outputted. The solar panel's back is also sealed and is the area in which you can find the junction box.

Self-Check 1	Written Test

Directions: - Answer all the questions listed below and write your answer on the space provided

Name ___________________

1. Describe briefly the differences between AC and DC currents? (2pts)
2. Show formula of calculations for Electric Power, Resistance and Voltage. (3pts)
3. If the values, at a certain point, of current (I) is 10A and resistance ® value is 3 ohms, what would be the calculated values of Voltage (V) and Power(P)? (4pts)
4. How can you describe characteristics of voltage and current in both series and parallel electric circuit connections? (3pts)
5. What solar panel? (2pts)
6. Describe the characteristics and uses of silicon and cadmium including positive and negative doping mechanisms in a solar panels (4pts)
7. What is photovoltaic, how it works? (3pts)

Answer Sheet

Name: ________________________

Date: _______________

Score = 19pts
Rating: ____________

Short Answer Questions

Q.1. --

Q.2.--

Q.3. --

Q.4.--

Q.5. --

Q.6.--

Q.7.--

Information Sheet-3	Designing Pumping System

Introduction

Although this subject is not specific for the use of solar systems, we still want to pay attention to it, because it is a crucial subject for the design of drinking water systems, and a basic input for all further calculations and system dimensions.

We first introduce the general method and parameters for establishing the water consumption need of the target population of a community. After this, we introduce parameters for calculating the production requirements for the water system.

3.1. Calculating the water needs

3.1.1. Project or system horizon and lifetime of system elements

A project horizon is established to take into account the use of the system in the future, with a certain population growth. What you effectively do, is over-dimension the system so that it will still be large enough in that future. The longer the time horizon is, the higher the degree of over- dimensioning compared to the current situation.

The choice of the project horizon is essentially a choice of investment policy. The further you look into the future, the less certain are the projections made. For example, it is very difficult to foresee the habits of water use of a population in 10 years, let alone in 20 or 25 years. In order to make projections, the only thing you can work with is the knowledge and information now available, and to assume that current trends will continue in the future.

The availability of investment funds, and the way they are used, are an important factor. Generally, a shorter time horizon will bring along less investment costs for a water supply system because it brings along smaller dimensions of infrastructure. This way, more systems can be constructed with the same amount of funds. With a longer time, horizon, you take better account of the future generations, but the investments costs will be higher.

The common technical lifetimes of different components of the systems are an important factor to take into account. These lifetimes can be estimated as follows:

Component	Lifetime in years
Borehole	20 - 25
Pump	5 – 10
Electric converters	10-12
Solar panels	20 – 25
Water tower	20 – 25
Water tank, concrete or steel.	20 - 25
Water tank, Poly-Ethyleen	10 – 15

Figure 3.1. Lifetime of water system elements

The choice of horizon is also a matter of financial planning and management. If you choose a horizon of 10 years, does that mean that the system will also be written off in ten years, even if most components have a much longer lifetime? Do you foresee financial reservations for the extension or replacement of the components of the system? Are these reservations included as part of the water price? If so, how do you manage these savings? If not, how does one guarantee the investments required in the future and the continuity of the water provision?

Each choice of horizon has its advantages and disadvantages. Once the water system has been constructed, there is little flexibility in its components. You could add storage capacity, but this is expensive. The highest flexibility can be found in the type of pump installed, as well as in the number of solar panels installed. The pump is the component with the shortest lifetime, which gives the opportunity to install a pump of larger capacity each 5-10 years if required (and if the capacity of the borehole allows).

3.1.2. Population and population growth factor

The design population of the project at the time of project horizon (P_n) is calculated in function of the current population P_0, the population growth factor T_c and the project in years (n), using the following formula:

$$P_n = P_o(1 + T_c)^n$$

The table underneath presents the values of the multiplication factor (P_n / P_0) for different project horizons and growth factors:

Growth factor T	Horizon in years n >				
	5	10	15	20	25
T_c = 2,0 %	1,10	1,22	1,35	1,49	1,64
T_c = 2,5%	1,13	1,28	1,45	1,64	1,85
T_c= 3,0 %	1,16	1,34	1,56	1,81	2,09

Figure 3.2. Values of the multiplication factor for different project horizons and growth factors

For instance, a population growth factor of a **Country X** is 2%. This growth rate is shown in the first row of the table above.

3.1.3. The service factors

The service factor (TD) is the percentage of the population served by the water system, divided by 100. This factor is established by the policies and objectives of the investment project. Thus, TD is used as multiplication factor, to calculate the number of people served by the system.

The value of TD cannot surpass 1,00. This value means that the investment is aiming to reach 100% of the population. Usually, the TD value is between 0,80 and 0,95. To calculate the number of people served by the system P_{ser}, multiply P_n with TD:

$$P_{ser} = TD * P_n = TD * [P_o(1 + T)^n]$$

3.1.4. **Specific consumption**.

The specific consumption C_{sp} is the (hypothesis of the) water consumption per person per day, expressed in liters/capita/day (l/c/d) or in liters/day/capita (l/d/c). Also, this water consumption level is based on the objectives and strategies of the project. It is often informed by the desired consumption level for a good hygiene level of persons and households involved, or by national or international norms and standards of acceptable water consumption levels.

The total consumption is calculated by the following formula:

$$C_{tot} = P_{ser} * C_{sp} \quad \text{(liters/day or m}^3\text{/day)}$$

3.1.5. Growth of specific consumption.

In some cases, it is assumed that the specific consumption will increase over time. For this a specific consumption growth rate is used: Tsp. The specific consumption in year n can be calculated in an identical way as is done for the population growth rate.

$$C_{sp_n} = C_{sp_0}(1 + T_{sp})^n$$

The growth rate of the specific consumption of **Country X** is 2,6%. At the same time, it recognizes that the current levels of water consumption are not yet 20 liters per day nowadays, and can better be estimated at a level of 12 l/c/d.

According to the standards for dimensioning water systems in **Country X** is, the specific consumption will reach the 20 l/c/d in the year 2032. In order to calculate the water consumption, the following table is used:

Year >	**2012**	**2022**	**2032**
Specific consumption (l/c/d)	12	15	20

Figure 3.3. Estimated growth of specific consumption in **Country X** is.

In order to do a simpler calculation, you can combine the population growth rate with the consumption growth rate, and calculate the total growth factor. This is done by multiplication. In the case of **Country X** is, the total growth rate is the population growth rate plus the consumption growth rate, 2% Td + 2,6% Tc = 4,6% per year.

This way, the calculation of the consumption in a certain year can be done using the following equation:

$$C_{tot_n} = P_0 * C_0 * (1 + T_c + T_{sp})^n \qquad [\text{litres / day}] \text{ or } [m^3/ \text{day}]$$

3.1.6. Other water needs

Depending on the policy of the project, it is possible that also other than domestic water needs are taken into account, like water needs for schools, mosques, churches, or health posts and clinics, or livestock needs. Often, such norms and standards are available from the Water Authorities of the country.

3.2. Calculating the water production requirements

After having calculated the water consumption needs, there are two factors that are usually taken into account to determine the production requirements: the system water losses and the days of peak water use.

3.2.1. System Efficiency

The efficiency of the system E is the percentage of water produced that is actually consumed (and paid) by the water users. Water produced but not consumed or paid is water loss. You can (roughly) distinguish two causes of losses: losses caused by leaking pipes or joints, and losses caused by illegal You should calculate with a factor 1/E to calculate the production needs from the consumption needs. In newly constructed systems, often an efficiency of 90 – 95% is assumed.

3.2.2. Peak day factor

Not during *all* days, it can be assumed that the water consumption is average. Some days of the year have exceptionally high-water demand, which can be caused by several reasons, like a community festivity, an exceptionally hot day, or because of some other reason. In some cases, a peak day factor is used as multiplication factor for dimensioning the system. If this peak day factor is used, usually a value between 1,1 and 1,4 is chosen.

It is a policy and design decision whether or not to use this peak day factor, and what value should be chosen. As we have seen, the system is already designed for the most critical month. In almost all other months, the system is already sufficiently powerful to meet peak day requirements.

The factor is used as multiplication factor between (average) water demand and required production capacity of the system.

3.2.3. Daily peak use factor

This factor needs to be mentioned as well. It is a factor used to take into account the fluctuations of water consumption during the day. Usually, there are two peak use periods during the day in a community: one in the morning between 7.00 and 9.00 am, and one in the evening between 17.00 and 19.00 pm.

This factor is used to calculate the need for water stocking, and also for calculating the dimension (pipe diameters) of the distribution network, so it does not play a role in calculating the total water production needs per day.

3.3. Data collection

One of the biggest constraints in designing drinking water systems and especially solar drinking water systems is the availability of data concerning population and water use. It is very important to have correct data of population when designing a new system and data concerning the use of water of existing systems for purposes of modifying the system, financial planning (how much money will be received), etc. Water consumption data should be collected on a daily basis and throughout the years to be able to calculate the growth of the system. In practice the recording of the production will be the easiest. For this purpose, a water meter needs to be installed on the head of the borehole.

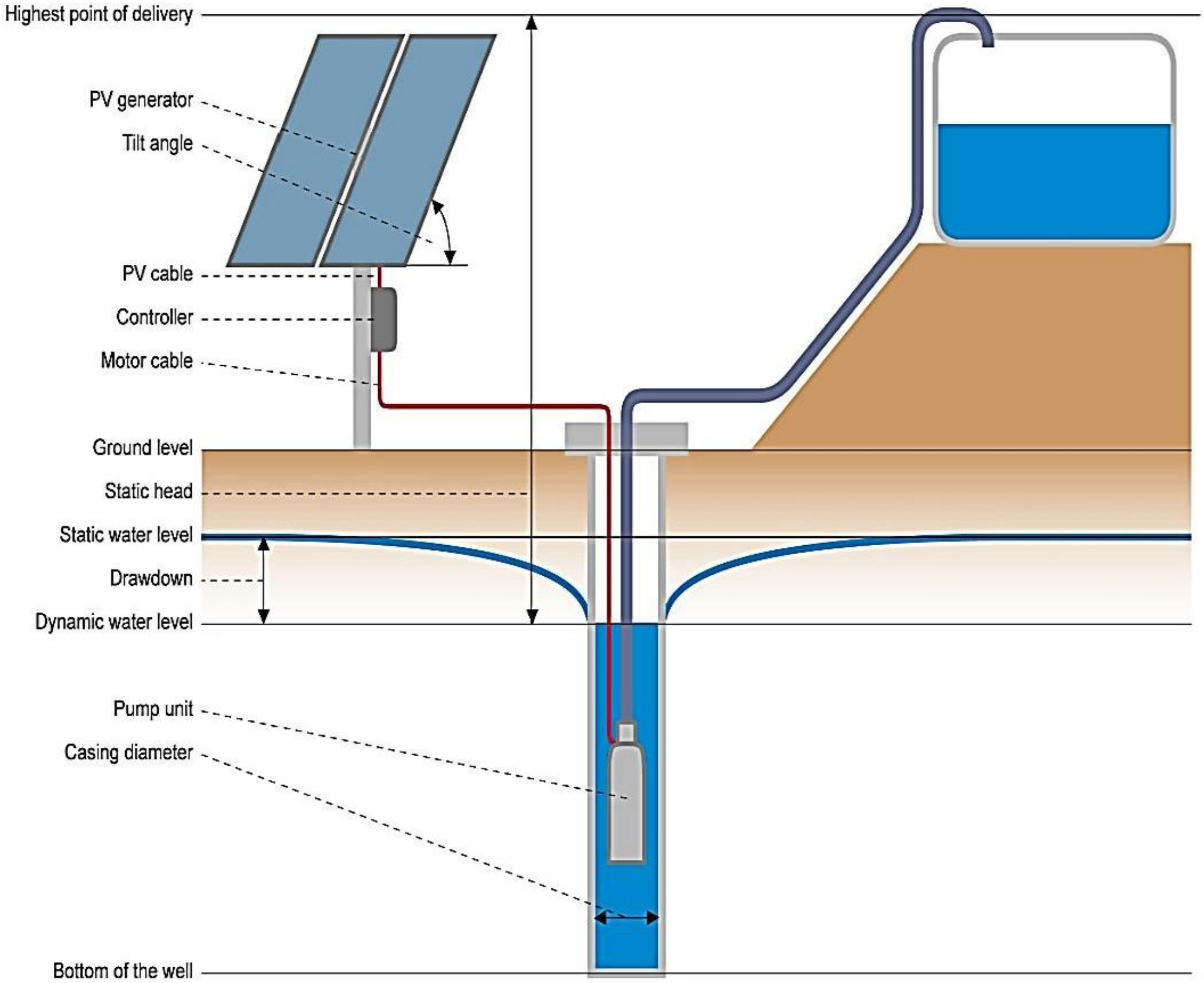


Figure 3.1 Layout of the solar water pumps

3.4. Selection of the Water Source

The type of water source and its location relative to the places where the water is to be provided defines the configuration of the watering system. The water source will either be subsurface (well) or surface (pond, stream, or spring). Wells are preferable because of the improved water quality and consistency. However, wells are expensive to drill, particularly where water tables are deep. Surface water sources may vary seasonally, such that the amount and quality of the water is low during the summer when it is needed most.

For wells, the following needs to be determined:

- Static water level

- Seasonal depth variations
- Recovery rate and
- Water quality

This information may be obtained by the well driller for a new well. For most wells, water quality is not an issue if not used for human consumption.

For surface water sources, the following needs to be determined: Seasonal variations and Water quality, including presence of silt, organic debris, etc.

3.5. Water Storage

The size and cost of the water storage system will depend on the amount of water required per day. AC pumping systems connected to a utility power grid are generally designed to run on demand with a specified flow rate. Unlike grid-tied systems, solar pumping systems are designed to provide certain quantity of water per day. Water is pumped during sunlight hours and stored in a tank.

The daily requirement is simply the total of all water required during a 24-hour period. Tanks are used to store water for use during the night or periods of cloudy weather and are usually large enough to hold three to five days of daily water output. For agricultural use, a large amount of water has to be supplied on a periodic basis. Hence, the system should have a tank large enough to hold at least one and half times the required limit.

3.6. Design of the Flow Rate of the Pump

For instance, designing the flow rate of the pump that is required for irrigating different crops farm land approaches may be as follows:

And also, most of the crops cultivated in India use 3000 m3/ha to 20000 m3/ha of water. Table 3.1 shows the water requirement of the various seasonal crops in India. In this chapter, the water needs for rice cultivation in an area of 1 ha (2.47 acres) for 120 days is considered, which is 46 m3/ha/day.

Hence, the water required for an average of 120 days is 5,600 m3/ha/day (120×5600 m3/ha) or 56,00,000 L/ha for the entire cultivating period.

Table 3.1 The water requirement of the various seasonal crops (especially in India)

Crop	Growing period (days)	Water needed for the growing period (mm)	Range (m^3/ha)
Rice	90-150	450-700	4,800-6,500
Barley/Oats/Wheat	120-150	450-650	3,300-5,800
Maize grain	125-180	500-800	3,200-4,100
Onion	150-210	350-550	3,500-5,000
Potato	105-145	500-700	3,500-4,500
Cabbage	120-140	350-500	3,500-4,800
Sugarcane	270-365	1500-2500	10,000-18,000
Banana	300-365	1200-2200	10,000-16,000

- Daily flow rate = 5600 × 1000 / 120 = 46667 L/ha/day
- Flow rate per minute = 46667 / (5.3 × 60) = 146 L/ha/min
- Flow rate per second = 146 / 60 = 2.44 L/ha/s

Self-Check 3	Written Test

Directions: - Answer all the questions listed below and write your answer on the space provided

Name __________________

1. Describe briefly that even though there is no specific relationship with solar system, why you need to learn for how to design pumping system? (3pts)
2. Show formula of calculations for water need, water production requirements and population growth? (3pts)
3. Explain how to collect data? (base on population, water resources etc) (2pts)
4. What tasks should be completed before you select pumps? (3pts)
5. Demonstrate how to calculate flow rates of pumps? (2pts)

Score =14pts
Rating: ____________

Answer Sheet

Name: _________________________ Date: _______________

Short Answer Questions

Q.1. --

Q.2.---

Q.3. --

Q.4.---

Q.5. --

Information Sheet-4	Load Calculations

4.1. Total Dynamic Head (TDH) for the Pump

Figure 4.1 depicts the head pressure that a well pump works against, which is called the total dynamic head (TDH).

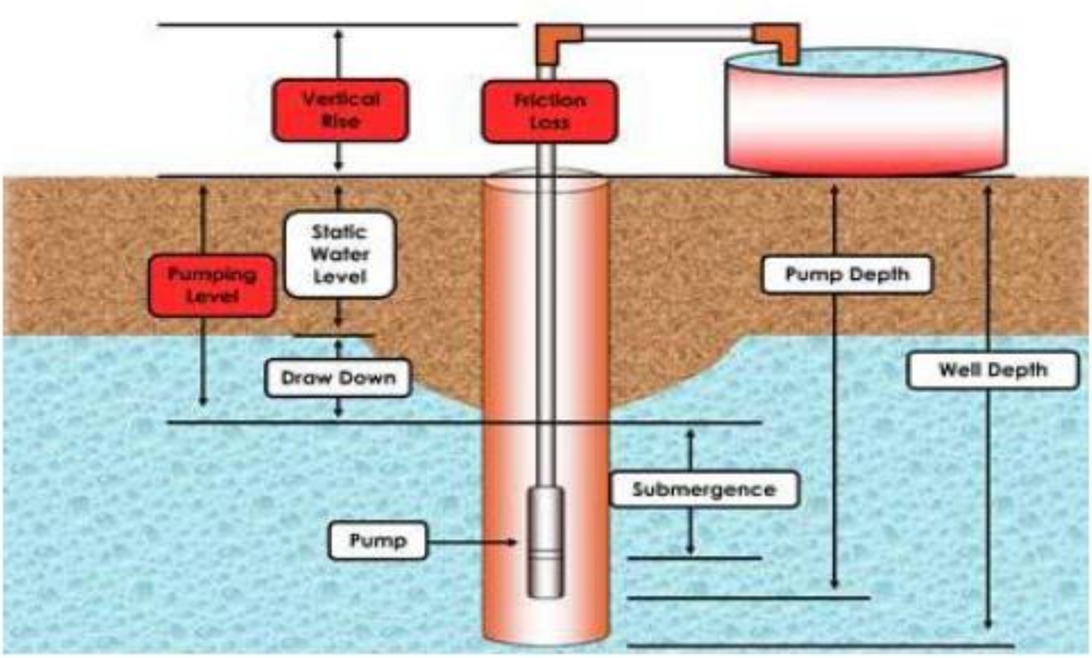


Figure 4.1 Total dynamic head for the pump

The two factors required for calculating the TDH are the desired flow rate and the total amount of lift required.

- Flow Rate
  It is the volume of fluid, which passes per unit time.
- Vertical Lift
  Submersible well pumps provide lift to overcome head pressure.

TDH = Pumping Level + Vertical Rise + Friction Loss

For a deep well,

- The static water level (SWL) to ground level is 45 m.
- The height from the well ground level to the inlet of the storage tank is 1.2 m.

☞ The height from ground to storage tank is 1 m.

Equation (4.1) gives the *Darcy-Weisbach* equation for calculating

the head loss,

$$\Delta h = \lambda \frac{l}{d_h} \times \frac{v^2}{2g} \qquad (4.1)$$

where, Δh is the head loss due to friction (m), *l* is the length of the pipe (m), and dh is the hydraulic diameter of the pipe (for a pipe of circular section, this is the internal diameter of the pipe) (m), v is the average flow velocity, experimentally measured as the volumetric flow rate per unit cross-sectional wetted area (m/s), *g* is the local acceleration due to gravity (m/s2), and *f* is a dimensionless parameter called the Darcy friction factor.

For laminar flow,

$$f = \frac{64}{R_e}; \text{ } R_e \text{ is the Reynolds Number} \qquad (4.2)$$

For Turbulent flow,

Re > 3000 (4.3)

Darcy friction loss calculation for a 1-inch pipe is 40.76 m.

Darcy friction loss calculation for a 1.25-inch pipe is 14.18 m.
Therefore, the TDH of the SPVWPS (for a 1-inch pipe) = 45 + 1.2+ 1 + 40.76 = 88 m, and the TDH of the SPVWPS (for a 1.25-inch pipe) = 45 + 1.2 + 1 + 14.18 =60 m.

4.2. Pump Selection and Associated Power Requirement

The pump is selected considering the induction motor and BLDC motor pump to deliver the water. Table 4.2 gives the rating selected for operating the solar pump to deliver 47000 L/day.

Table 4.2 Selection of power rating of the solar pump

Type of motor	Phase	Power	Voltage	Current	PV array
Induction Motor	3 Ph	1 HP	300 V	5 A	900 W_p
BLDC Motor	3 Ph	1 HP	300 V	4.3 A	900 W_p

4.3. Type of motor Phase Power Voltage Current PV array

Induction Motor 3 Ph 1 HP 300 V 5 A 900 Wp

BLDC Motor 3 Ph 1 HP 300 V 4.3 A 900 Wp

4.4. Sizing of the PV Array

PV arrays are installed so that they maximize the amount of direct exposure to the sun. This means placing the array in an area clear of shading from buildings and trees, in a southward direction, and at an angle equal to the latitude of the location. The PV array is specified in terms of wattage and voltage. It is a standard procedure to increase the specified wattage by 25% (multiply by 1.25) to compensate for power losses due to high heat, dust, aging, etc.

The total power of the PV array is (300 × 4.3) = 1290 Wp for the BLDC water pumping system. For this work, as an example, SOLKAR make panels are used.

Table 4.3 provides the specifications of this panel at standard test conditions (STC), that is, irradiation level G = 1000 W/m2; temperature T = 25oC; air mass AM = 1.5

Table 3.3 Specifications of SOLKAR PV Panel at STC

Parameters	Values
Rated Power (P_{max})	37.08 W
Voltage at Maximum power (V_{max})	16.56 V
Current at Maximum power (I_{max})	2.25 A
Open circuit voltage (V_{oc})	21.24 V
Short circuit current (I_{sc})	2.55 A
No. of series cells (N_s)	36
Array Size ($N_{ss} \times N_{pp}$)	20×2

Self-Check 4	Written Test

Directions: - Answer all the questions listed below and write your answer on the space provided

Name ___________________

1. What is Total Dynamic Head (TDH)? (2pts) How can you determine it? (3pts)
2. Describe water loss? (3pts)
3. Write down deep well levels? (3pts)
4. How can you select pumps based on induction motor consideration? (3pts)
5. What is PV sizing? How do size it? (4pts)

Score = 13pts Rating: _____________

Answer Sheet

Name: ___________________________ Date: ________________

Short Answer Questions

Q.1. --

Q.2.---

Q.3. --

Q.4.---

Q.5. --

Information Sheet- 5	Selecting Appropriate Location

5.1. Identifying a Site

Careful selection of the exact location for placement of the system is crucial to continuous and reliable system operation. Exposure to shadowing from cut hillsides, trees, utility poles or any other objects during sunlight hours will reduce power capacity and should be avoided.

5.2. To Select a Site

Shading critically affects a photovoltaic array's performance. Even a small amount of shade on a PV module can reduce the module's performance significantly. It is essential to have a clear understanding of the sun's path across the horizon from the east to the west.

Unfortunately, it is not possible or practical to monitor the sun exposure at a site through long-term observation. Solar contractor installation professionals have developed tools to provide quick insight to the solar window at a specific location.

In principle these tools evaluate a site by creating a Sun Chart. If a site is partially shaded, the sun chart will determine the amount of available sunlight.

The sun chart will determine if the solar modules will be shaded from direct beam radiation during critical times of the day or year. Unwanted shading can occur from trees, vegetation, structures, other arrays, poles, and wires. Shading is often

a greater problem during winter months when the sun's altitude is low and shadows are longer. For locations in the northern hemisphere, shadows cast on December 21st are the worst case through-out the entire year.

When a site is being considered, be sure that the following parameters are considered:

- Assure the array is not shaded from 9 a.m. to 3 p.m. on any day (this is the optimum solar radiation collection time known as the solar window).
- Assure the array is not shaded in any month of the year during the solar window.

- ☞ Identify the obstacles that shade the array during the solar window.
- ☞ Eliminate any shading, or move the array to avoid shading, or contact

TESSCO Technologies to increase the size of the array to offset losses due to shading at the site location.

- Keeping the above factors in mind when installing the Ventev Solar Power Systems will help ensure optimal, reliable performance of your system based on the original, specified design parameters.

Self-Check 5	Written Test

Directions: - Answer all the questions listed below and write your answer on the space provided

Name ___________________

1. Describe briefly what affects photovoltaic critically? (2pts)
2. What is the sun chart?. (3pts)
3. What conditions may affect power capacity of sunlight? (8pts)

Score =8pts
Rating: _____________

Answer Sheet

Name: ___________________________ Date: ________________

Short Answer Questions

Q.1. ---

Q.2.---

Q.3. ---

Information Sheet-6	Identifying and Selecting Solar System Components

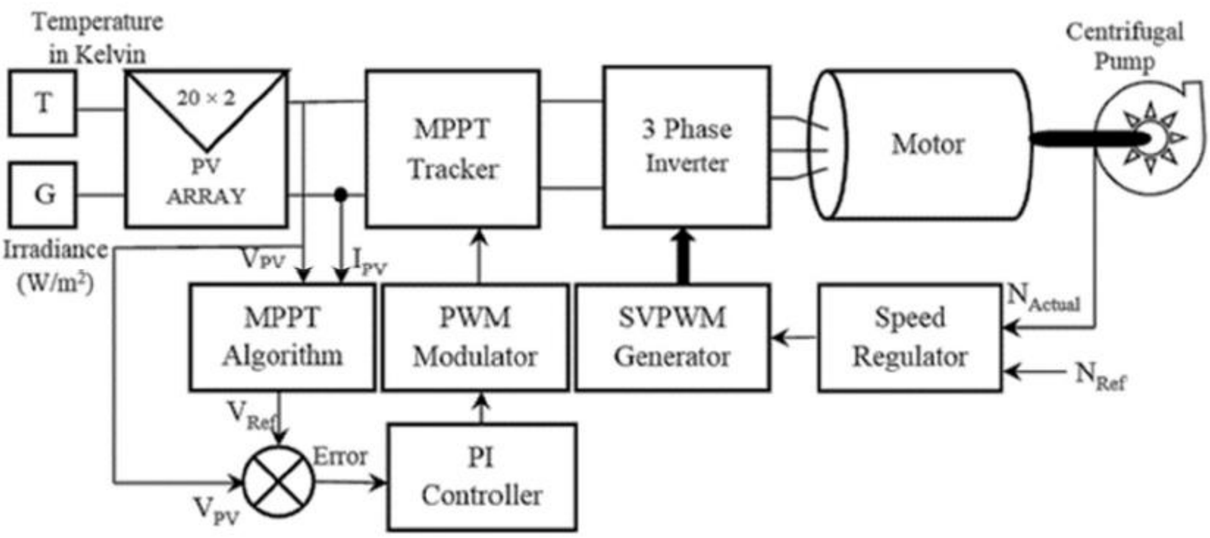
Introduction

There are many factors to be considered while designing a solar pumping system. This chapter provides the information to select a pump, controller, sensors, solar array, wiring, and piping for the solar pumping system. A simple solar water-pumping system that is installed for a pumping operation includes the PV array, the controller, the pump, and accessories.

The size of the array and the pump will be determined by several factors. In this chapter, the methodology used to determine the size of the system is described.

6.1. System Description

Figure 6.1 shows the various components of the system, which includes the solar PV (Photovoltaic) array, a boost converter that acts as the Maximum Power Point Tracker (MPPT), a three-phase full bridge inverter and the AC motor, which drives the centrifugal water pump. A unique step-by-step procedure for the simulation of



photovoltaic modules

Figure 6.1 Block diagram of the solar photovoltaic water pumping system

A solar photovoltaic (SPV) water pumping system consists of the following components

A. PV Array:

Selecting a suitable array size based on the load requirement, here in this case an AC motor operating a centrifugal or helical pump.
Should be mounted on a suitable structure with a provision of tracking the sun or with a fixed tilted position to obtain the optimum incidence of sunlight over the array panels.

B. Electric Control Boxes in a solar pumping system (Pump Control Unit/ Controllers):

The pump controller is a highly specialized item and can vary significantly between manufacturers. A technical term for a pump controller is a 'linear current booster.' The purpose of the pump controller is to regulate and match the flow of DC electricity to the needs of the pump. In this manual, we only talk about AC water pumps operating on solar panels, so without batteries. The pump control unit usually contains the following components:

- MPPT
- Inverter
- Control boxes

Certain types of pumps (for example the small SQFlex pumps of Grundfos) have a control box integrated in the submerged part of the pump that is placed in the borehole. This way, they are less sensible to overheating. Other pumps are delivered with a separate control box placed above ground level.

1. Maximum Power Point Tracker (MPPT)

Selecting power converters to convert the electrical power from the SPV array to the load effectively. To convert and obtain the maximum power, the Maximum Power Point Tracker (MPPT) is used.

A pump control unit can be equipped with a Maximum Power Point Tracker. In this device, the charge controller looks at the DC output of the solar panels, changes it to high frequency AC, and figures out what is the best voltage and current to operate the pump. It takes this figure, and converts the AC current back to DC, but to a different DC voltage and current to exactly match the best voltage for pump operation.

Most modern MPPT's are around 93-97% efficient in the conversion. The power gained by a MPPT is around 10-15%, so the net effect of a MPPT is a power gain of around 10%.

Figure 6.2 Two different examples of MPPT's

2. Inverter

Selecting the appropriate power converters such as the DC-AC converter (inverters) to transfer the power from the MPPT to the AC motor. Direct current can be converted to alternating current using an *inverter*. This conversion cannot be made without the loss of some power. Almost all solar installations that drive water pumps have an inverter.

There are variable frequency inverters and fixed frequency inverters. For pumps, the variable frequency inverter is most often used. This type adjusts the output frequency of the AC current depending on the amount of sunshine received by the panels. With this frequency regulation, the pump speed is regulated, and by consequence the pumping power.

For power supply to an electric grid from a solar installation, a fixed frequency inverter is used, because the grid requires a fixed frequency (mostly of 50 Hz).

3. Control boxes

Control unit to track the PV voltage and current to meet the reference value and to have a simplified control of the AC motor to deliver constant throughput.

Control boxes are electronic devices with in-built feedback loops that provide an automatic response to undesired situations. There are situations in which we want the system to shut down or the pump to stop pumping immediately, in order to prevent (further) damage of the system, or in order to optimize the functioning of the system. Five of such situations are the following:

1. Lack of water in the borehole.

Without water in the borehole, it is better to stop the pump. The pump motor is cooled because water flows around it in the borehole. Without (sufficient) water flow, the motor is at risk of overheating, and this can seriously damage the motor. It makes no sense anyhow to have the pump running when there is no water in the borehole. So, a sensor is placed within the pump, which automatically sends an “emergency” signal to the control box when the water level in the borehole is too low.

2. Overheating of the electric motor of the pump.

Overheating of the motor can have a number of reasons, one of which is lack of water in the borehole. But also other reasons can cause overheating of the motor, for example a mechanical defect in the motor itself. So a good quality motor is equipped with a sensor for overheating that sends a signal to the control box that switches off the power supply in case of overheating.

3. The water storage tank is full.

Further pumping makes no sense. In this case, a sensor can be placed in the storage reservoir to detect this situation. This sensor will provide a signal to the control box, so that pumping will stop.

It is a design choice whether or not to use such a sensor. In some situations, it can be decided to use the overflow of the tank for additional purposes, like irrigation of a vegetable garden or watering of cattle. In such cases, no such sensor will be installed and used.

4. Over-voltage or over-current -The system can be automatically switched off in case of too high voltage or current. For example, in case of a short-circuit in the system.
5. Inverse polarity-A protection of the system in case wires are wrongly connected.

Self-Check 6	Written Test

Directions: - Answer all the questions listed below and write your answer on the space provided

Name ___________________

1. List Solar equipment commonly required in solar water pumping installation and maintenance (4 pts)
2. What is Solar Module? (2pts)
3. Write the function the main components of Solar systems(3pts)

Answer Sheet

Score = 9pts
Rating: ____________

Name: ___________________________ Date: ________________

Short Answer Questions

Q1 --

Q.2. ---

Q.3. ---

Operation Sheet 1	Identifying and Selecting Solar System Components

Direction: Identifying and Selecting Solar System Components Procedure

1.1. The Solar system components identifying process:

First, the design has to begin with the water required for drinking or irrigation proposes over a period of time and the water source where the pump can be installed.

1.2. Solar system components selecting procedure.

Operation Sheet 2	Designing Pumping System

Direction: Select any of appropriate village or groups of community nearby you

Step 1- Determine their water need as per standard

Step 2-Calculat the water production requirement

Step 3- Collect and analysis necessary data

Step 4- Select appropriate water source type, pump type and pump capacity based on step 1, 2 and 3

Step 5- Determine capacity of a required Storage

Step 6- Design flow rates of the pump you selected

Step 7- Determine the volume of water to be pumped each day for the group you selected

Operation Sheet 3	Designing Pumping System

Direction: Select any Pumping station nearby you

- Determine the total dynamic head
- Determine water pump flow rate and water loss
- Determine whether the pump is selected considering the induction motor not
- Calculate the pump rate from the number of sunlight hours (based on peak sun)
- Select the pump referring to catalogues of reputed manufacturers concerned
- Calculate and select appropriate size of solar PV array

Instruction Sheet	Learning Guide 71: **Installation of Solar Energy Equipment**

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics

- Series and/or parallel connections solar modules
- Installing Solar system components
- Installing Pump
- Installing Grounding and lightning protection
- inspecting the system

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- do series and/or parallel connections solar modules
- Install Solar system components
- Install Pump
- Install Grounding and lightning protection
- inspect the system

Learning Instructions:

15. Read the specific objectives of this Learning Guide.
16. Follow the instructions described in number 3 to 20.
17. Read the information written in the "Information Sheets 1". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
18. Accomplish the "Self-check 1" in page __.
19. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 1).
20. If you earned a satisfactory evaluation proceed to "Information Sheet 2". However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1
21. Submit your accomplished Self-check. This will form part of your training portfolio.
22. Read the information written in the "Information Sheet 2". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
23. Accomplish the "Self-check 2" in page __.

24. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 2).
25. Read the information written in the "Information Sheets 3 and 4". Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
26. Accomplish the "Self-check 3" in page __.
27. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 3).
28. If you earned a satisfactory evaluation proceed to "Operation Sheet 1" in page _. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to for each Learning Activities .

Information Sheet-1	Series and/or parallel connections of solar modules

Introduction

In this chapter, the solar cell, solar panel and solar array are introduced and explained with their basic characteristics. The effects of irradiance level and temperature are presented. Attention is paid to how and where to place and locate a solar array in a water system, and what can be done against theft and vandalism. The effect of shadow is explained. As last subject, we introduce the electric losses and the electric efficiency.

1.1. The solar panel

PV cells are combined to make solar panels, also called modules. The PV cells are grouped together, and encased in glass or clear plastic in order to protect the cells, whilst in the same time allowing the sun light to reach the cells. The glass or plastic often has an anti-reflective coating to minimize reflection of light from the panel. The panels have such a size that they yield a reasonable amount of electricity, but are still easy to handle and transport.

There are many producers of solar panels, and they produce panels of many different sizes, depending on the need of the customer and the application they are used for. The price of solar panels have dropped enormously in the last 40 years. Compared with the year 1970, the prices have gone down by as much as 90%, and it is expected that they will drop further. Because of this price reduction, solar panels have become more and more interesting as alternative energy source.

Much research and development are being carried out to increase the efficiency of the cells and panels. The most efficient PV cell currently has an efficiency of around 25%. However, this type of cell is very expensive, and for that reason cannot yet compete with the lower priced PV cells available.

The most important characteristics of a solar panel are:

- How much voltages it produces (in full sunshine conditions)
- How much current it produces (in full sunshine conditions)

How much power and energy it produces?

1.1.1. The Photovoltaic cell

The basic element of a solar panel is the photo-voltaic cell, or PV-cell. Solar panels are built from a number of such cells. They are made of semiconducting materials that can convert sunlight directly into electricity. When sunlight strikes the cells, it dislodges and liberates electrons. An electron carries a very small electric load. When electrons start to move, they produce a direct electrical current (DC).

The cells may be round, square or some other shape. Each cell produces about 0,5 Volt, no matter what the size is. The number of amperes a cell can produce does depend on its size; larger cells produce more amperes. As each cell only produces about 0,5 Volt, many cells have to be connected in series to produce a high enough voltage. Usually there are from 30 to 36 of these cells on a panel intended to charge a 12 V battery.

Figure 1.1. Photovoltaic cell

Most commercial PV cells are made from silicon. There are three general types: monocrystalline, multi-crystalline, and amorphous or thin film cells.

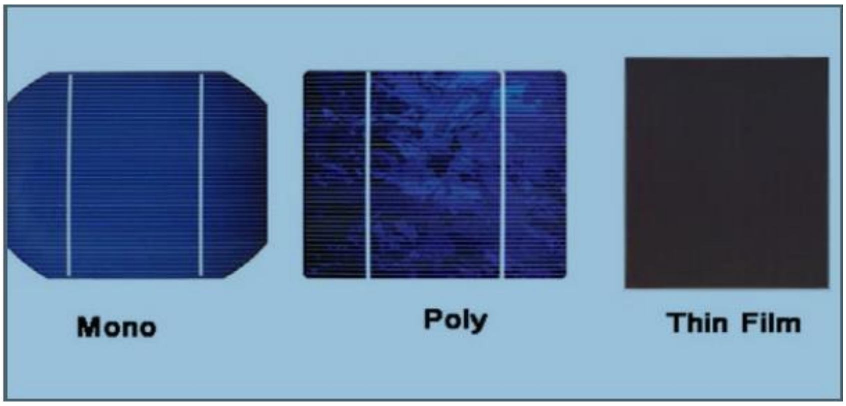


Figure 1.2: Different cell types

Single crystal or monocrystalline cells are made using silicon wafers cut from a single, cylindrical crystal of silicon. This type of PV cell is the most efficient, with approximately 15% efficiency.

This efficiency means that 15 % of the energy of the sun beam is converted into electricity. It is also one of the most expensive to produce. ***Multi-crystalline or***

polycrystalline silicon cells are made by casting molten silicon. They crystallize into a square solid block of intergrown crystals. Multi-crystalline cells are less expensive to produce than monocrystalline ones, due to the simpler manufacturing process and lower purity requirements for the starting material. However, they are slightly less efficient, with average efficiencies of around 12%.

Amorphous silicon PV cells are made from a thin layer of non-crystalline silicon placed on a rigid or flexible substrate. They are relatively easy to manufacture and are less expensive than monocrystalline and polycrystalline PV, but are less efficient with efficiencies of around 6%. Their low cost makes them the best choice where high efficiency and space are not important.

1.2. Solar Arrays

Solar arrays consist of a group of solar panels, placed together in a certain configuration. The panels are grouped together in order to produce the right amount of voltage, and sufficient current and power for the purpose they serve.

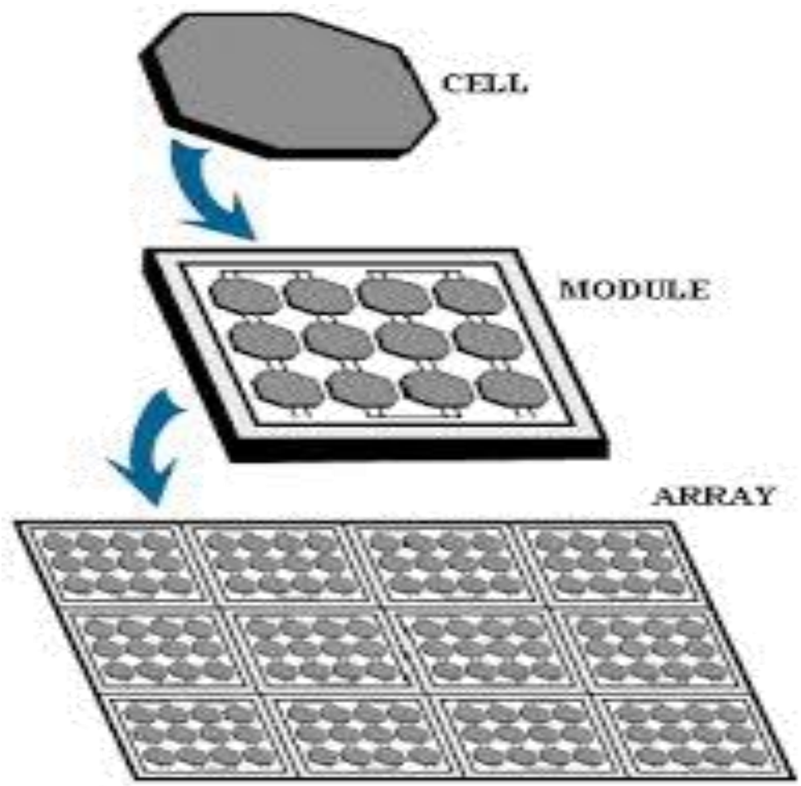


Figure 1.3. Composition of a solar array

1.3. Parallel and Serial Configuration

Basically, solar panels can be connected in series, or parallel.

a) Series Connection

When electrical elements are connected end to end, they are said to be connected in series. To connect two wires in series, one end of the first wire is connected to one end of the second wire, creating a single wire as long as the two together. This is like connecting two batteries of 12 V to make 24 V. When more voltage is needed than a single panel can provide, additional panels are connected in series. If one panel provides 24 V, two panels in series will provide 24 + 24 = 48 V. For every 24 V panel connected in series, the voltage will increase by another 24 V.

The amount of current (Amperes) provided by panels in series is the same as that provided by one panel because the same electricity flows through all the panels, as they are connected in one line. As power in Watts equals Volts * Amperes, the power increases as panels are added. (see figure 1.4 and 1.5)

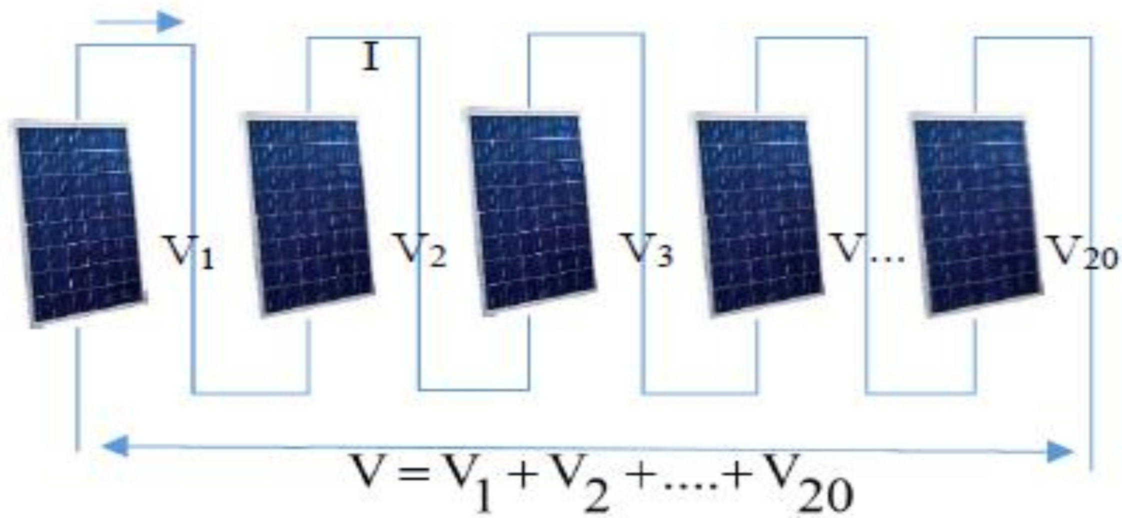


Figure 1.4 Solar PV panels connected in series to meet the voltage Requirement

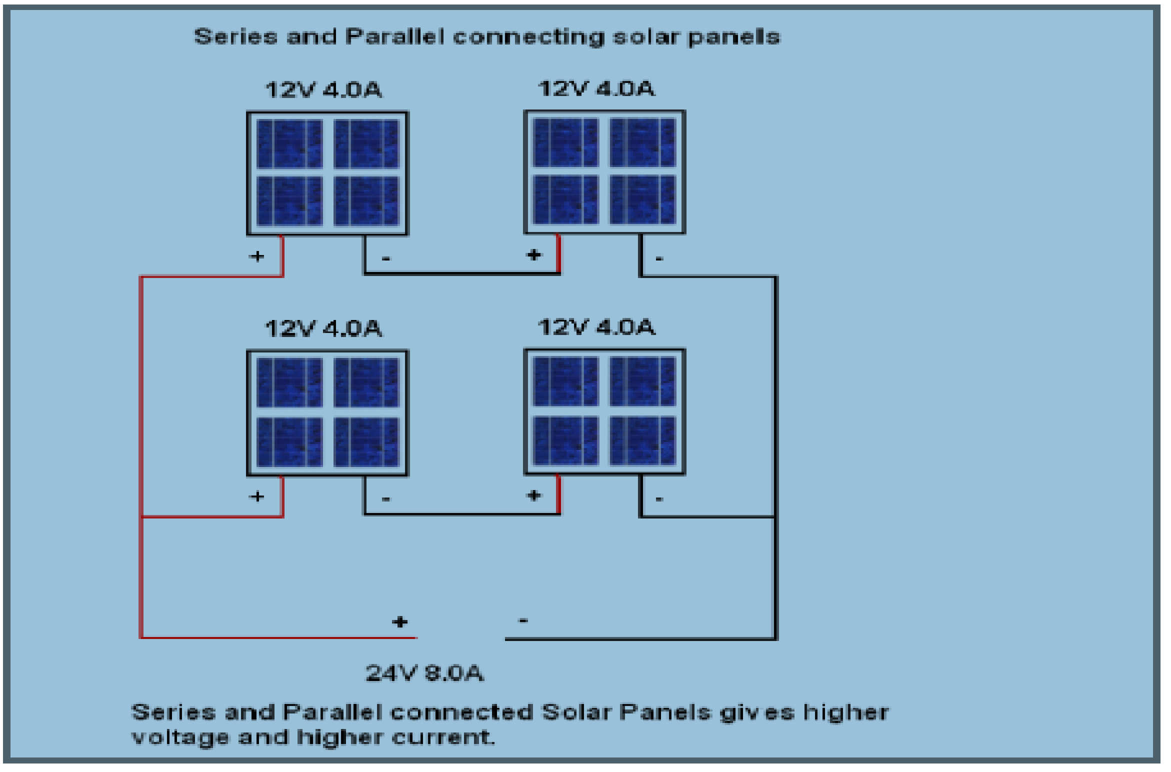


Figure 1.5 Series and parallel connections

b) **Parallel connection**

When the voltage from a single panel is sufficient, but the amount of current needed is not enough, panels can be connected in parallel. If one panel provides 4 Ampere in bright sunlight, two panels in parallel will provide 4 + 4 = 8 Amperes. For each of these 4A panels connected in parallel, an extra 4 A will be produced in bright sunlight. As power in Watts equals Volts * Amperes, the power increases as panels are added.

Note that for both series- and parallel-connected panels, the power increases as the number of panels is increased. Two panels in parallel produce the same power as two panels in series, but the voltage and amperage are different. (see Figure 1.5 and 1.6)

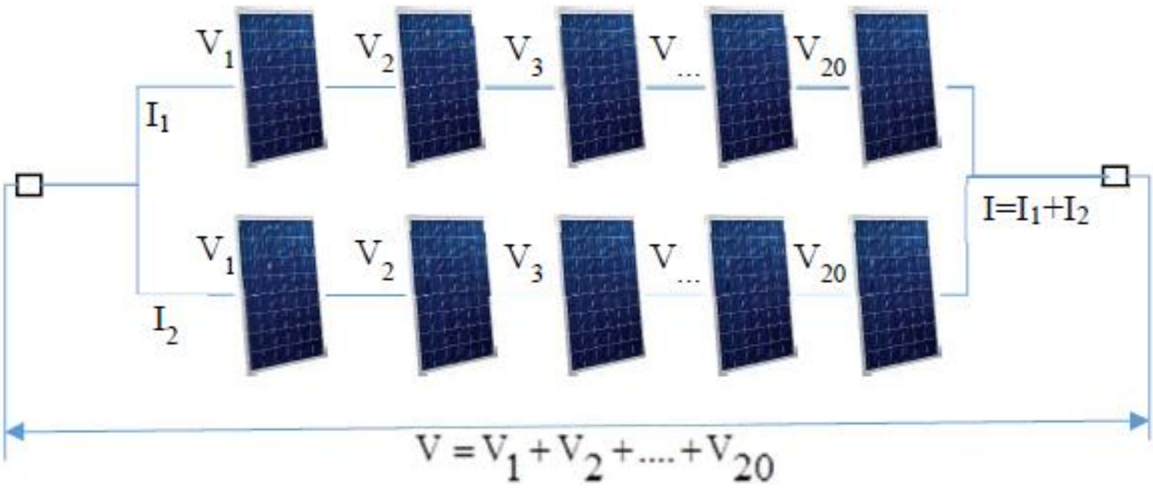


Figure 1.6 Solar PV panels connected in series and in parallel to meet both current and voltage requirements

For the control of speed, the electric motor rating is selected to have a DC voltage of 400 V. To supply the required power to the motor from the PV system, 20 PV panels are connected in series to provide (16.5 V × 20) 330 V to the maximum power point tracking (MPPT). The MPPT provides the rated supply voltage for the motor to operate

1.4. Current-Voltage Diagram

Each solar cell, and each combination of them into solar panels and solar arrays, has a current- voltage relation. This means that at a certain voltage V, they can deliver a certain current I. Now remember that the most important purpose of a solar panel or array, is that it gives us electric power. This is the multiplication of V and I. So: not only I and not only V but maximum P = V * I

The **open circuit voltage** Voc is the voltage of a cell or solar panel in the situation that no electric current is flowing. In this case, the panel is not used, but it is placed in full sunshine conditions: It is the maximum voltage situation that can occur. In this situation, no power is produced, because V = Vmax, but I = zero Ampere. Vmax is important because it represents the maximum voltage a system can produce. The materials used must be able to withstand this voltage.

When the panel is connected and electricity is flowing, the voltage produced will drop. When there is no resistance in the line, the situation is called short-circuit. At this situation, the voltage will drop to virtually zero, whilst the current is at maximum (Imax).

This maximum current is also indicated as Ish (Current at short-circuit) or Icc (French for current at “court circuit”). But the power produced in this situation is zero, because V = 0.

Maximizing the power means *optimizing* the relation between Voltage (V) and current (A). The Voltage-Current diagram is a characteristic of the cell or panel. The shape of this diagram is presented in the following figure:

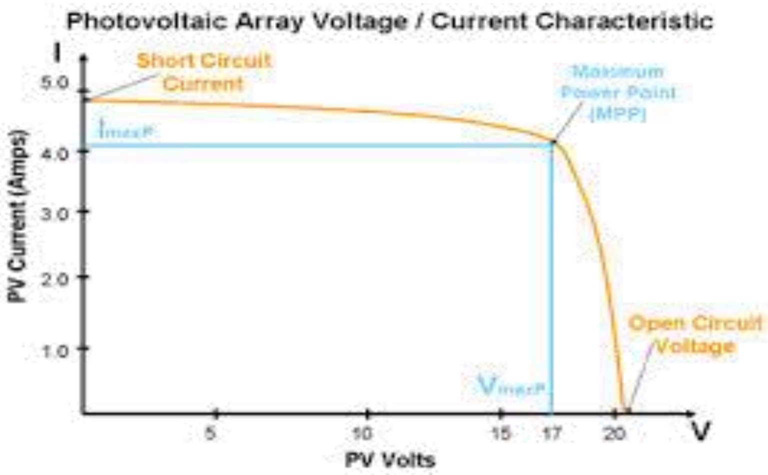


Figure 1.7 Voltage-Current Diagramme

In this figure, the orange line represents the current voltage diagram. The relation between the voltage and the current is optimal, when the size of the square enclosed by the curve has the largest surface. In this situation, the current is ImaxP and the Voltages is VmaxP. The size of this square represents the power produced. So, the optimal relation between the voltage and the current is at the Maximum Power Point (MPP), as indicated in the figure.

A Maximum Power Point Tracker (MPPT) is an electronic device that automatically adjusts the voltage to produce the maximum power of the solar array in place.

A very important characteristic of a solar panel is how much power it can produce in full sunshine

conditions. This figure is called Peak Watt (Wp) or Watt Crête in French (Wc).

1.5. Current-Power Diagram

For a single PV cell, but also for a solar panel, one can construct a current-power diagram. On the x- axis, the voltage is displayed, and on the vertical axis, the produced power in Watts in displayed. This will typically produce a curve like the blue line in the following figure:

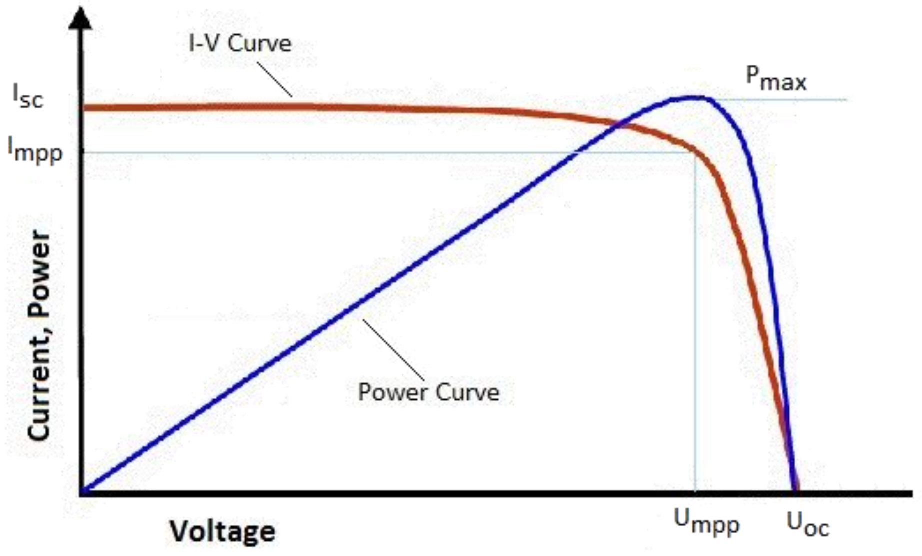


Figure 1.8 Current-Power Diagram

1.6. Effect of Irradiation

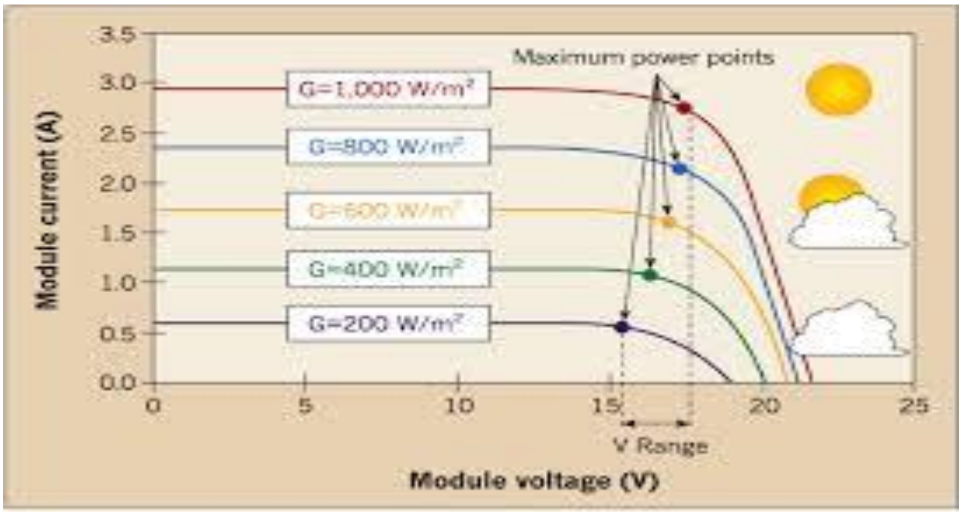


Figure 1.9 Relation between irradiance and PV output.

The current-voltage diagram presents the power output of the PV cell or panel at full sunshine conditions. The current production of the cell (or module) is almost proportional to the irradiance. This means that if the irradiance G is at 50%, then also the current production will be at 50% of the maximum production. In the next figure, this relation is shown for a solar panel of 50 Watt and 18V.

Note that also the voltage output drops at low irradiance levels, but not as much as the current. In the figure above, the voltage output of the panel is 18V at maximum irradiance, and 16V when irradiance is 200 W/m2 .

1.7. Effect of temperature

It is important to remember that when a cell is exposed to light, it will convert around 15% of the irradiance into electricity. The rest of the energy is converted into heat, resulting in a rise of temperature of the cell and panel. As a result, the cell will operate at a temperature above the ambient temperature.

The open circuit voltage (Voc) of the PV cell decreases by 2,3 mV per ˚C increase in temperature,

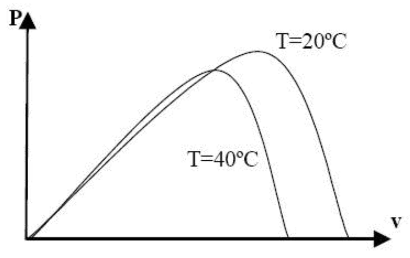


Figure 1.10 Relation between Temperature and Power

which amounts to almost 0,5%/ ˚C. This means that a rise in temperature of 10 ˚C causes the cell to be 5% less efficient.

In this figure, the effect of a temperature is displayed. At 40 ˚C, the module produces less voltage, and thus also the power output reduces compared to the situation of 20 ˚C.

In order to make optimal use of the panel, it is important that the panel is ventilated. If mounted on a roof, it is good to have some ventilation space between the roof and the panel. Metal roofing like corrugated iron sheets can become very hot themselves when exposed to full sunshine conditions. It is not therefore not advisable to mount solar panels on an iron roofing.

Usually, manufacturers of panels indicate the performance characteristics of the panel on a sticker on the back side of the panel. This sticker displays the performance under

Standard Test Conditions (STC). The panels are tested with an irradiation of 1000 W/m2 and a cell temperature of 25 °C. These test conditions do not represent operating conditions, because the irradiation will almost always be lower, and the cell temperature almost always higher especially in African conditions.

The **Nominal Operating Cell Temperature** (NOCT) is the temperature the cells will reach when operating in an ambient temperature of 20 ˚C at 800 W/m2 (G = 0,8) and a wind speed of less than 1 m/s. The NOCT is a characteristic of the solar panel. This NOCT often around 48 °C, depending on the construction of the panel. A cell operating in an ambient temperature of 30 ˚C will have an even higher cell temperature than the NOCT value. If this rise in ambient temperature of 10 ˚C also results in a rise of cell temperature of 10 ˚C, you should reduce the expected power output by 10° C x 0,5% = 5%.

Self-Check 2	Written Test

Directions Answer all the questions listed below and write your answer on the space provided

1. What is solar panel? (3pts)
2. Write the difference between Series and parallel solar panel connections? Describe by using current (Ampere) and Voltage (volt) and power (watt) values determinations(4pts)
3. Describe for current-voltage, current-power and voltage-current diagrams and effects irradiance with PV array output (6pts)

Answer Sheet

Score = 13pts

Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Q1.____

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Q2.____

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Q3.____

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Operation Sheet #1	Series and Parallel Connections of Solar panels

Directions **Collect PV arrays and appropriate tools**

- Connect the PV arrays in Series and Parallel
- Determine the similarities and differences of Current, Voltage and power accordingly

Information Sheet-2	installing solar system components

2.1. Determining the Solar Module Tilt Angle

The sun's height above the horizon is called altitude, which is measured in degrees above the horizon. When the sun appears to be just rising or just setting, its altitude is 0 degrees. When the sun is true south in the sky at 0 degrees azimuth, it will be at its highest altitude for that day. This time is called solar noon.

A location's latitude determines how high the sun appears above the horizon at solar noon throughout the year. As a result of the earth's orbit around the sun with a tilted axis, the sun is at different altitudes above the horizon at solar noon throughout the year.

Photovoltaic module(s) or arrays work best when the sun's rays shine perpendicular (90 degrees) to the cells. When the cells are facing the sun in both azimuth and

altitude, the angle of incidence is "normal", as shown in Figure 2.1

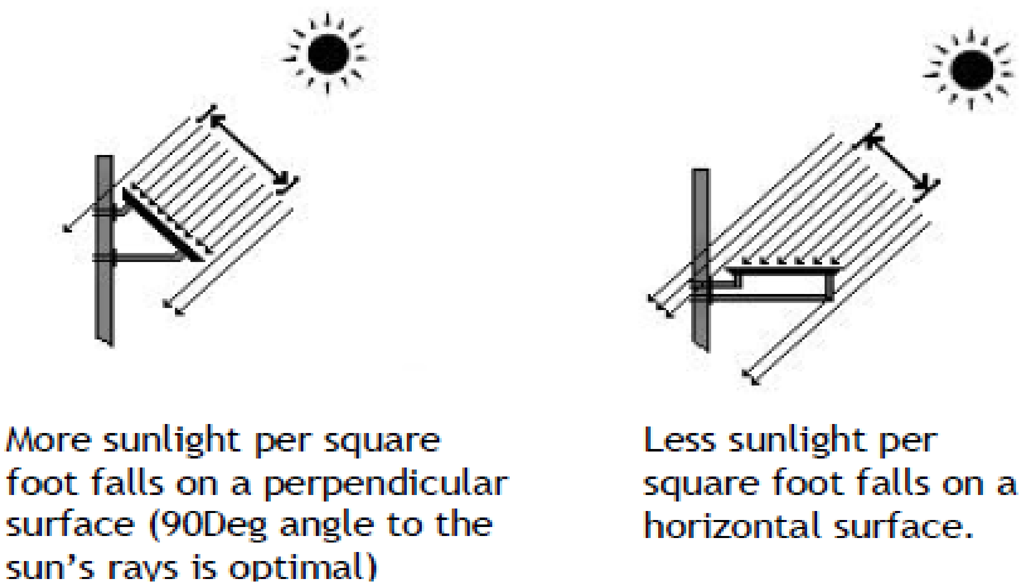

Figure 2.1: Angle of Incidence on a Solar Module

Seasonal changes of the sun's altitude must be considered to optimize a system's performance. When the array is installed, it should be tilted at an angle that yields the

highest value of insolation during the worst-case month in the year. This ensures that the system is designed to meet the load demand and keep the battery fully charged in the worst month for the average year. The following general guidelines outline a rule of thumb tilt angle of a solar module for different seasonal loads.
For example,

- ☞ Winter loads Northern Hemisphere: Tilt angle = site latitude + 15°
- ☞ Winter loads Southern Hemisphere: Tilt angle = site latitude – 15

The best method to determine the optimal tilt angle is to perform a site survey; contact TESSCO Technologies for assistance with these professional services.

More sunlight per square foot falls on a perpendicular surface (90Deg angle to the sun's rays is optimal) Less sunlight per square foot falls on a horizontal surface.

2.2. Assembling and Mounting the Solar Module Support Structure

The load capacity, equipment size and geographic location of the Solar Power System purchased determines the number of solar modules needed. Also, mounting configurations are driven by the pole size and number of solar modules needed.

The following figures show various pole mounting configurations for the solar modules and how the module interconnect conduit assembly is installed in a 2-solar module mount assembly.

Figure 2.2: Pole Mounted Module

Figure 2.3: Dual Arm Single Module Mount

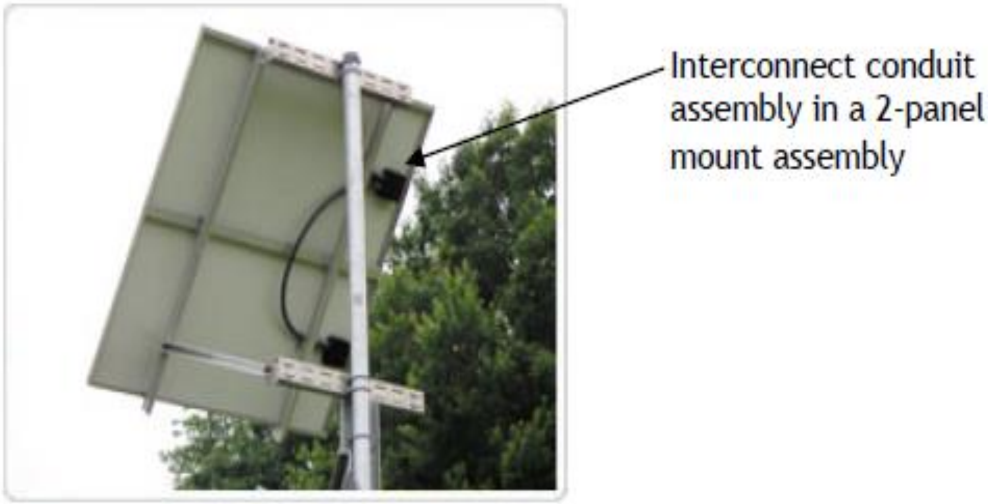

Figure 2.4: Two Module Mount with Module Interconnect Conduit Assembly

2.3.1. Assembling and Mounting Guidelines

Figure 2.5 illustrates the proper orientation and wiring configuration for connecting the junction boxes of multiple modules.

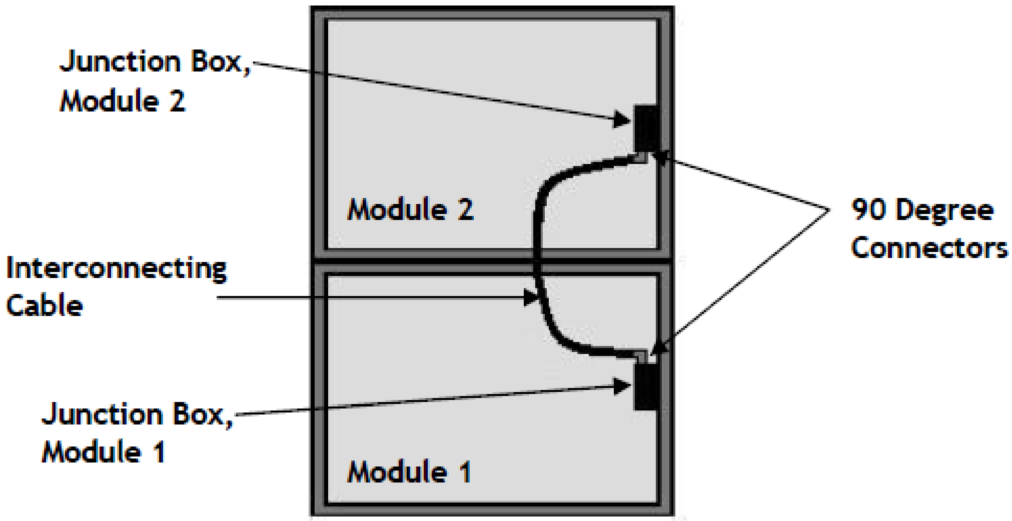

Figure 2.5 Module Junction Box connection

Be certain to position the modules such that the junction boxes are on the same side in the series. For easiest access, use the junction box penetration hole toward the center of the module for attaching the 90 degree connectors. Instructions for connecting multiple modules follow.

- Lay the modules face down on a flat, protected surface when attaching the support rails to prevent damaging the glass and to eliminate electrical hazard.
- Take great care in the use of hand tools in the vicinity of modules' back surface. The module back surface materials are easily punctured, and any opening in the back surface will allow the entry of moisture which can shorten module service life. If punctures occur, seal with a non-acidic, commercial grade RTV sealant.
- Remove the junction box hole tab closest to the middle of the module. Attach the 90 degree connectors as shown in Figure 2.5.
- Connect wiring to the terminals in the configuration shown in Door Wiring Diagram for the system delivered.
- Look for specific manufacturer's instructions in the packaging, and if found, follow them carefully.

2.3.2. Mounting the Battery Enclosure

The physical size and weight of the batteries varies depending on storage capacity dictated by design requirements. The batteries are housed in the bottom of the enclosure which is attached to the pole.

2.3.3. Mounting Enclosure to Pole

a. **T**ake the two clamps/U-bolts from the hardware bag for the appropriate pole size, hex nuts, bolts and washers.

b. Position the battery box against the pole and install the clamps/U-bolts loosely using hardware described above.

c. Position the enclosure against the north side of the pole (opposite the array, to take advantage of any shading available for reduced heat on the battery(s) and electronics in the enclosure) and tighten the bolts (Check for level before tightening), with the conduit knockouts on the bottom.

2.4. System Wiring

CAUTION: Remove all fuses and turn OFF all circuit breakers before beginning any wiring.

1. **Grounding**

a. Ground the support rails in accordance with site Local codes.

b. Ground the enclosure according to local codes.

2. **Load Wiring**

a. Locate the wiring diagram on the door.

b. Wire the load equipment to the Solar Controller terminal blocks according to the wiring diagram, carefully observing correct polarity.

3. **Array Wiring**

The customer load requirements, geographic location of the system, and available sunlight are among the factors that dictate the number of modules provided with the system and determines the circuit wiring configuration specific to the site needs. The Solar Module has a junction box located on the back side of the module. The junction box is designed to accommodate standard wiring and/or conduit connections. All wiring and electrical connections should comply with the National Electrical Code (NEC), Article 690 Solar Photovoltaic (PV) Systems. A cable clamp with a minimum rating of IP65 must be used to maintain the weatherproof integrity of the junction box. Bypass diodes are preinstalled at the factory.

The following figures illustrate the various module wiring configurations of the Solar Power Systems. To determine the module wiring configuration for your system, locate the wiring diagram on the door of the enclosure for your system and compare the module wiring to your system.

4. **Single Module Solar Module Wiring**

CAUTION: Remove all fuses and turn OFF all circuit breakers before beginning any wiring.

Keep solar modules face down on a flat surface and/or cover the module(s) face with a sun protective cover while wiring.

Shorting solar module terminals together can damage the modules, so use care in handling connected wiring.

Figure 2.6 illustrates the terminal connections on a single solar module.

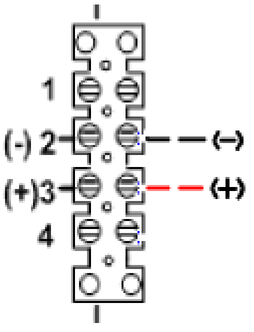

Figure 2.6: Single Module Terminal Wiring

5. The process for wiring a single module panel terminal block:

1. Open the solar module junction box by loosening the screws.

2. Connect #10 AWG black wire from the solar module terminal two (2) to the terminal block that connects to the Solar Controller Terminal three (3).

3. Connect #10 AWG red wire from solar module terminal 3 to the fuse block that connects to Solar Controller Terminal four (4).

6. **Multiple Modules Connected in Series**

Figure 2.7 shows the wiring configuration for multiple modules connected in series.

This configuration allows solar modules to be grouped to match voltage levels required in the system design (two 12 Volt modules wired in series converts to a 24 Volt system). Note and carefully observe polarity while connecting the modules.

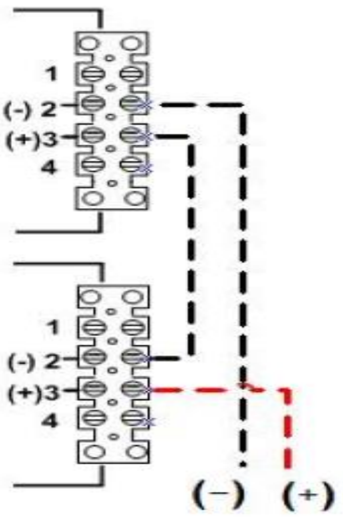

Figure 2.7: Multiple Solar Modules Connected in Series

Carefully observe and note polarity when wiring the modules. Steps for wiring modules in series as shown in Figure 2.7 include:

1) Open the solar module junction boxes on all modules by loosening the screws.

2) Connect #10 AWG black wire from terminal two (2) (negative) on the first solar module in the series to the Solar Controller Terminal three (3) (negative).

3) Connect #10 AWG red wire from terminal three (3) (positive) on the last solar module in the series to the terminal block that connects to the Solar Controller Terminal four (4) (positive).

4) Connect a #10 AWG black wire from terminal two (2) (negative) on the first module in the series to terminal three (3) (positive) of the second module in the series.

5) Repeat step three until all modules have been wired together.

6) Connect #10 AWG red wire from the last module in the series terminal 3 to the fuse block that connects to Solar Controller Terminal four (4).

7. **Multiple Modules Wired in Parallel**

Multiple modules wired in parallel as illustrated in Figure 15 enables power wattage to be incrementally increased while retaining the voltage levels of each individual module (i.e. If the modules in the figure are 12 volts each, then 12 volts are presented to the Solar Controller with the power capacity of all three combined.

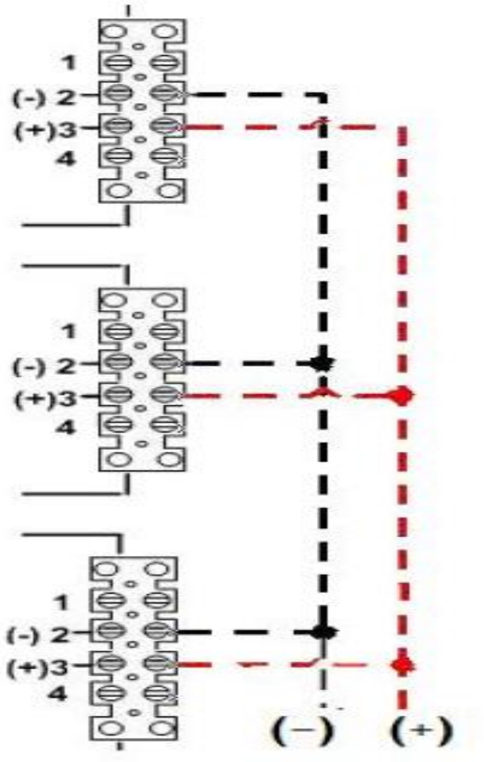

Figure 2.8: Multiple Solar Modules Connected in Parallel

Figure 2.9 illustrates the junction box used in wiring multiple modules in parallel.

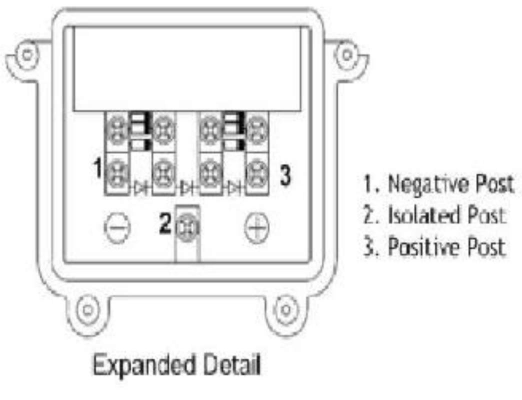

Figure 2.9: Solar Module Junction Box

The steps involved in wiring multiple modules in parallel include:

1 Remove the strain relief locknut from the conduit end marked "ARRAY". Insert the end into the junction box, replace the locknut and tighten.

2 Terminate the 30" interconnect cable as shown in Figure 2.5.

3 Terminate the wire ends as shown in the Door Wiring Diagram and Figure 2.7 (Red +, Black -). Tighten the terminal screws to no more than 21 in-lbs. Check your connections to make sure they are the correct polarity. Close and secure the cover.

4 Locate the hole in the back or bottom of the battery enclosure.

5 Remove the strain relief locknut from the conduit end. Insert the conduit end into the battery enclosure, replace the locknut, and tighten.

6 Connect the array wires to the terminals marked "Array +" and "Array -" (Red positive, Black negative).

8. Wiring and Installing the Battery

Battery(s) are shipped separately and not installed in the enclosure before shipment. Observe the following guidelines when working with batteries.

CAUTION: Electrical Burn Hazard

A short-circuited battery can produce thousands of amperes that will melt hand tools and cause severe burns. Take great care when handling the batteries and installing their interconnection wiring.

CAUTION: Wear eye protection and gloves. Remove all metal that can come in contact with battery terminals.

TIP: Keep the array, batteries, and loads as close together as possible. Due to electrical resistance of the interconnect wires, the electrical output drops over long distances.

Shorter distances between the components of the PV power system minimize voltage drop and will also reduce wiring costs.

CAUTION: Use extreme care in placing the battery(s) into the enclosure, being careful not to short battery terminals to the enclosure casing.

NOTE: Consult the wiring diagram on the enclosure door of the delivered system to determine the configuration of the battery(s) supplied. Locate that configuration in this section then follow the installation instructions herein for your system.

To accommodate varying load requirements, the Ventev Solar Power Systems come equipped with the number of batteries and various battery amp-hour capacities required to meet design. The number of batteries depends on the required load and geographic location where the system will be installed. 12 Volt and 24 Volt solar power systems are provided and since all batteries used are 12 volts, the batteries are often connected in series to yield 24 volt capacity. With amp-hour capacities designed to fit load demand, geographic location, and available sunlight, the battery capacity and physical size varies from system to system.

9. Single Battery Connection

Figure 2.10 illustrates a single battery configuration.

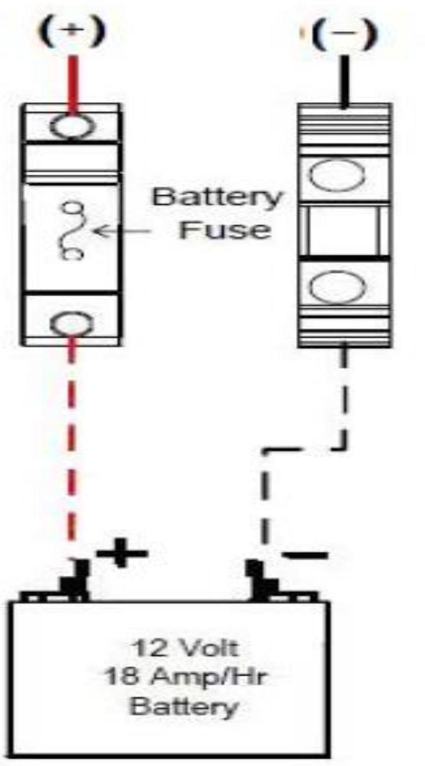

Figure 2.10 Single Battery Connection

The dashed lines indicate wiring that must be connected on site after the batteries are positioned and anchored.

10. To Install and Wire a Single 12 Volt Battery

1 Remove the appropriate punch-outs from the battery label to indicate the month and year of installation (6 = 2008). This step is very important for tracking battery performance and warranty information.

2 Set the battery into the enclosure.

3 Connect the RED lead(s) to the POSITIVE (+) terminal of the battery using the bolts, washers, and nuts provided. Tighten battery connections to 100 in-lbs.

Take care not to short circuit the battery terminals with the wrench to the negative terminal or to the enclosure casing.

4 Connect the BLACK lead(s) to the NEGATIVE (-) terminal of the battery in the same way, observing the same precautions.

5 Make sure that the battery terminals are completely covered by the insulating boots.

11. Multiple 12 Volt Batteries in Parallel

Connecting 12 Volt batteries are in parallel enables incremental increase in amphour capacity. For example, two 40Amp-Hour batteries connected in parallel increases total capacity to 80Amp-Hours. Figure 18 shows the wiring configuration for parallel battery connection.

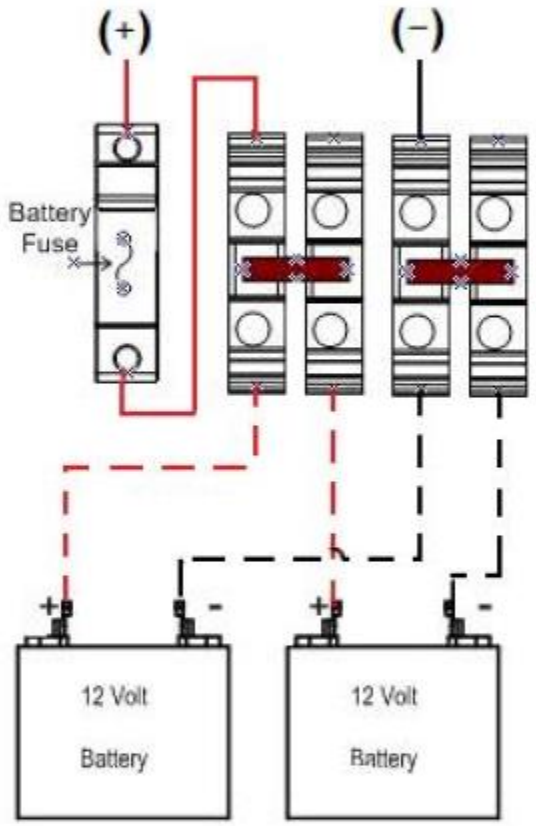

Figure 2.11 Parallel 12 Volt Battery Configuration

The dashed lines indicate wiring that must be connected on site after the batteries are positioned and anchored.

To Install and Wire Multiple Batteries in Parallel

1. Remove the appropriate punch-outs from the battery labels to indicate the month and year of installation (6=2008). This step is very important for tracking battery performance and warranty information.

2. Set the batteries into the enclosure**.**

3. Connect the RED leads to the POSITIVE (+) terminals of each battery using the bolts, washers and nuts provided. Tighten battery connections to 100 in-lbs.

Take care not to short circuit the battery terminals with the wrench to the negative terminal or to the enclosure casing.

4. Connect the BLACK leads to the NEGATIVE (-) terminal of the batteries in the same manner, observing the same precautions.

5. Make sure the battery terminals are completely covered by the insolating hoods.

12. Multiple Batteries Connected in Series

Connecting multiple batteries in series increases the overall voltage by the number of batteries multiplied by the voltage of each. Given the two batteries in Figure 2.12 are 12 volts, the resulting voltage is 24 volts.

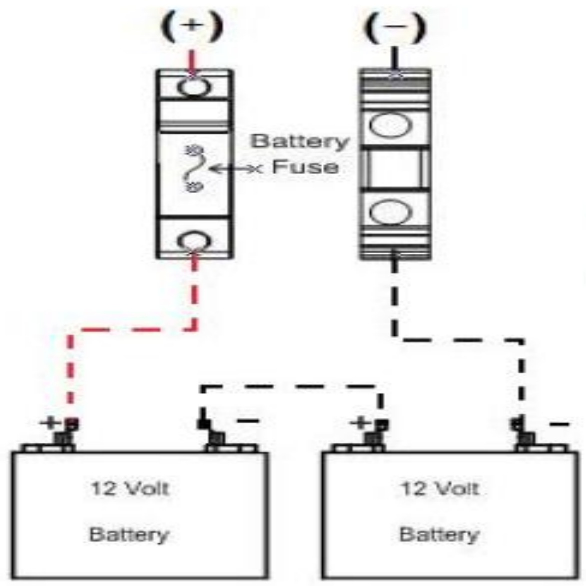

Figure 2.12 Multiple Batteries in Series

The dashed lines indicate wiring that must be connected on site after the batteries are positioned and anchored.

DANGER: Closing the fuse holder to energize the system may create sparks. Never energize the system in the presence of explosive vapors. Close all fuse holders to energize circuitry.

After the mechanical and electrical installation is complete, check the integrity of all electrical terminations and mechanical fasteners. Perform the electrical checkout described below**.**

1) Check the solar module orientation using a compass (or GPS); make sure it is facing true south.

2) Check all mounting fasteners to make sure the mounts are secure.

3) Test the polarity, voltage, and amperage produced by the array. On a clear sunny day, the readings should be approximately equal to those listed specifications for the system.

4) Check the voltage of the batteries. The voltage should be approximately 12 VDC.

5) Verify the "CHARGING" light on the Solar Controller is ON. If it is not ON, recheck all connections for tightness. Ensure that the controller has been set for the correct battery type.

6) Turn on the load and verify its proper operation. Perform a series current draw reading while the load is operating and confirm that they are within the design limits of the system.

7) The solar power system is now fully functional.

8) Recheck all electrical connections at the battery bank and the charge controller.

9) Close and secure the enclosure

Self-Check 2	Written Test

Directions Answer all the questions listed below and write your answer on the space provided

1. Write at list three components of Solar system and their uses(6pts)
2. What is the purpose use of battery in solar system? (4pts)
3. Describe the junction box purpose of use in PV solar equipment installation and list down the components to be configured with its terminals? (5pts)

Answer Sheet

Score =15pts

Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Q1.____
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Q2.____
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Q3.____
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Operation Sheet #1	Installing Solar System Components

Directions:

- Implement solar equipment procedural installation performance in installation field, if appropriate. If not, just demonstrate at your learning workshop areas as appropriate.
- Identify and collect required equipment and tools for Solar equipment installation
- Follow and implement all safety rules and regulations Additional information for the Operator

The tasks to be implement are as follows:

1. Mount solar module at appropriate direction and position (apply it for single module and multiple module)
2. Wire solar equipment such as battery, junction box, terminals and PV array using single solar module and multiple module
3. Inspect, test (if defects, correct) and the verify for operationality of the solar equipment you mounted and wired under steps 1 and 2

Information Sheet-3	Installing Grounding and Lightning Protection

2.1. Installing Grounding and Lightning Protection

Grounding

c. Ground the support rails in accordance with site Local codes.

d. Ground the enclosure according to local codes.

Self-Check 2	Written Test

Directions answer all the questions listed below and write your answer on the space provided

1. Describe how to ground when wiring solar component? (3pts)
2. Explain what methods are to be use to protect lighting problems for solar system installation? (4pts)

Answer Sheet

Score = 7pts
Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Q1.____
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Q2.____
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Operation Sheet #1	Installing Grounding and Lightning Protection

Directions:

- ☞ Implement solar equipment procedural installation performance in installation field, if appropriate. If not, just demonstrate at your learning workshop areas as appropriate.
- ☞ Identify and collect required equipment and tools for grounding and lightening protection installation
- ☞ Follow and implement all safety rules and regulations Additional information for the Operator

The tasks to be implement are as follows:

1. Install appropriate grounding and lightening protection as per rules and regulations (apply it for single module and multiple module)
2. Inspect and test for rectifications

Instruction Sheet-3	Learning Guide : 72 Maintenance and Service

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics

- Maintenance and services
    - system maintenance
- Periodic/preventive maintenance
- Troubleshooting

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Conduct Maintenance and services
    - system maintenance
- do periodic/preventive maintenance
- Troubleshoot

Learning Instructions:

29. Read the specific objectives of this Learning Guide.
30. Follow the instructions described in number 3 to 20.
31. Read the information written in the “Information Sheets 1”. Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
32. Accomplish the “Self-check 1” in page __.
33. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 1).
34. If you earned a satisfactory evaluation proceed to “Information Sheet 2”. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to Learning Activity #1
35. Submit your accomplished Self-check. This will form part of your training portfolio.
36. Read the information written in the “Information Sheet 2”. Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
37. Accomplish the “Self-check 2” in page __.

38. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 2).
39. Read the information written in the “Information Sheets 3 and 4”. Try to understand what are being discussed. Ask you teacher for assistance if you have hard time understanding them.
40. Accomplish the “Self-check 3” in page __.
41. Ask from your teacher the key to correction (key answers) or you can request your teacher to correct your work. (You are to get the key answer only after you finished answering the Self-check 3).
42. If you earned a satisfactory evaluation proceed to “Operation Sheet 1” in page _. However, if your rating is unsatisfactory, see your teacher for further instructions or go back to for each Learning Activities .

Objectives:

To give detail information regarding the types of preventive maintenance and breakdown maintenance work to be done in solar PV pumping system. Again, this chapter also includes the common types of problems that occur in such systems and their troubleshooting methodology.

1.1. Routine Maintenance and Preventive Maintenance

It does not take much time and money to regularly maintain a solar PV pumping system but it may take a lot to repair the system if it fails. Regular maintenance makes the difference between a PV pumping system that works without problems for years and one that is always breaking down. While installing PVWPS every care must be taken to minimize the cable losses as far as possible by keeping pump and PV arrays as close as possible. The PV array is to be installed carefully at a proper location to avoid shadowing of any part of the array or other obstructions throughout the year. The array should be inclined facing south in case of Northern Hemisphere. Solar pumps should not normally require more than a simple maintenance, which only demand rather basic skills. The main problem with them is lack of familiarity.

1.1.1. PV Array

- Check the PV array/panel mounting to make sure that it is strong and well attached. If it is broken or loose, repair it.
- Check that the glass is not broken. If it is, the PV array/panel will have to be replaced.
- Check the connection box to make sure that the wires are tight and the water seals are not damaged.
- Check to see if there are any shade problems due to vegetation or new building. If there are, make arrangements for removing the vegetation or moving the panels to a shade-free place.

1.1.2. Wires

- Check the wire covering (insulating sheath) for cracks

or breaks. If the insulation is damaged, replace the wire. If the wire is outside the building, use wire with weather-resistant insulation.

- Check the attachment of the wire to the building to make

  sure, that it is well fastened and cannot rub against sharp

  edges when the wind blows.

  - If someone has changed the wiring since the last check, make sure that it is the correct size, that it has suitable insulation, that the connections are properly made and that it is fastened securely in its new place.

  - If someone has added more wires to the PV system to operate additional appliances, advise the owner that this may seriously lower the reliability of the system. Advise increasing the panel and to handle the increased load.

- Check the connections for corrosion and tightness.

1.1.3. Power Conditioner

- Check that the junction box is still firmly attached. If it is not, attach it correctly with screws.

- Keep the junction box clean.

1.1.4. Appliances

- Turn on each appliance and check that it is working properly.

- Check that appliances are mounted securely. If loose or incorrectly mounted, attach them securely.

- Clean all exposed parts of each appliance. Clean light bulbs and plastic covers.

1.1.5. Pump:

- In case of submersible pump electrical connections have to be checked at least once every six months

- The brushes, if any, are to be changed after six months of continuous use.

- The inverter connected to the pump has to be checked at least once a month for proper operation.

Besides there are a number of simple faults that can arise which needs immediate corrections:

- Poor electrical connection caused by dirty, wet or corroded terminal or plugs
- Blocked strainers and filters on the pump
- Failure of suction pump due to loss of prime caused by faulty foot-valve or air leaks in suction line (specially in case of surface pump)
- Leaking pipe and hose connections
- Leaking pump gland seal
- Some pumps need frequent replacement parts as suggested by its manufacturers
- In case of positive displacement pumps, loosening of belts and chains may occur hence requiring tension adjustments.

Self-Check 1	Written Test

Directions Answer all the questions listed below and write your answer on the space provided

1. Describe how to Repair and service solar system component? (3pts)
2. Explain what methods are to used up for solar system maintenance and service? (4pts)

Answer Sheet

Score = 7pts
Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Q1.____
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Q2.____
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Operation Sheet #1	Maintenance and Services

Directions:

- Implement solar equipment procedural installation performance in installation field, if appropriate. If not, just demonstrate at your learning workshop areas as appropriate.
- Identify and collect required equipment and tools for grounding and lightening protection installation
- Follow and implement all safety rules and regulations Additional information for the Operator

The tasks to be implement are as follows:

3. Install appropriate grounding and lightening protection as per rules and regulations (apply it for single module and multiple module)
4. Inspect and test for rectifications

Information Sheet-2	Periodic/Preventive Maintenance

In many cases the manufacturers may have special recommendations for routine and preventive maintenance. These recommendations have to be strictly followed for proper and safe operation of the complete system.

In each station there must be card mentioning the dates when routine and preventative maintenance are carried out. If any fault has been observed it must be registered in this card. This card must be accessible all the time at the site.

i. Monitoring and Evaluation of Installed water pumps

The purpose of Monitoring and Evaluation (M&E) is to make sure that the system works properly and satisfy the users as foreseen in the design phase and in the long run it becomes sustainable.

Monitoring and evaluations of installed pumps should be carried out after one month of complete and successful installation to answer the following questions:

- Is the system performing as per the specification of supplier (this may include parameters like discharge of water at specified total dynamic head, ambient temperature and insolation)?
- Has the system brought positive social changes in the area?
- Have the suggestions and comments of users group been incorporated?
- Have the users paid back the loan component in time if any?

The same procedure mentioned above should be repeated after six months, twelve months after a complete successful installation. Then after, monitoring and evaluation be carried out once every six months.

Self-Check 2	Written Test

Directions Answer all the questions listed below and write your answer on the space provided

1. List preventive maintenance activities for Solar system? (3pts)
2. What is preventive maintenance? (4pts)

Answer Sheet

Score = 7pts
Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Q1.____

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Q2.____

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Operation Sheet #2	Periodic/Preventive Maintenance

Directions:

- ☞ Implement solar equipment procedural installation performance in installation field, if appropriate. If not, just demonstrate at your learning workshop areas as appropriate.
- ☞ Identify and collect required equipment and tools for grounding and lightening protection installation
- ☞ Follow and implement all safety rules and regulations Additional information for the Operator

The tasks to be implement are as follows:

1. conduct appropriate preventive maintenance as per rules and regulations (apply it for single module and multiple module)

Information Sheet-2	Troubleshooting

1.1. Trouble Shooting

Well-designed, well-installed and well-maintained solar PV systems are reliable and can have a long trouble-free life, but sooner or later there will be a failure. The process of finding the cause of the failure is called troubleshooting. The process of making the system work properly again is called repair.

1.1.1. Types of System Failure

There are three types of solar PV system failure:

Each type of system failure has a different cause and troubleshooting methods are different.

Failure type 1: The system stops working entirely. None of the appliances work.

Failure type 2: Some appliances work normally, others do not.

Failure type 3: The system works but runs out of power too quickly.

Each type of system failure has a different cause and troubleshooting methods are different.

1.1.1.1. Failure type 1: Total system

If the system fails completely, the reason is usually a broken wire, poor connection or controller failure. The problem is to isolate the fault in the system.

- **Fuse or circuit-breaker problem:**

Make sure that all appliances are switched off. Check any fuse or circuit- breaker in the panel to the whole circuit.

Corrective action: Disconnect the loads at the controller. If the fuse is blown, replace it with the correct type and ampere capacity of fuse. If the circuit-breaker is tripped, turn it back on. If the fuse or circuit breaker blows again, there is a problem with the wiring between the panel or with the controller. Continue with this checklist. If the fuse or circuit-breaker does not blow, reconnect the load and turn the appliances on. If the fuse or circuit-breaker blows again, there is a short in the appliance wiring or in an appliance.

- **Faulty panel or panel wiring:**

Disconnect the leads to the panel terminals of the charge controller. Check the voltage across the two wires from the panel when the sun is shining. If the voltage is less than 12 V, there is a problem with the panel or the panel wiring. If the voltage is 12 V or more, measure the amperes from the panel. If the amperes are very low for the panel that is installed, the connections to the panel may be loose or corroded. Also the panel may be damaged.

Corrective action: Disconnect all the panels and carefully check that each one is working properly (voltage and amperage). Replace panels that are not working well.

Clean all terminals and wires: Reconnect the panels, making sure that the correct wires are connected to the correct terminals. Also make sure that the panels are not shaded.

- **Faulty controller:**

Check the voltage at the panel connections on the controller when the sun is shining. If the voltage at the pump connection is less than 13.5 V and the voltage at the panel connection is more than 14 V, the controller has probably failed. Some types of complex, computerized controllers cannot be tested with simple voltmeters. If that type of controller is thought to have failed, one have to replace the controller with one known to work properly and wait to see if that cures the problem.

Corrective action: Replace the controller.

- **Faulty wiring between controller and pump**

Measure the voltage at the pump connections and controller connections. If the voltage is more than 0.5 V lower at the controller, there is a wiring problem.

Clean all connections and wires: Replace wires in connectors and terminals and tighten all connections. Make sure that the wire connecting the controller and the pump is the correct size for the current being carried.

- **Fuses or circuit-breakers**

Check all fuses and circuit-breakers. If they have opened the circuit there is a short circuit in the wiring or appliances. Check all appliances and the wiring from the controller to the appliances.

Corrective action: Fix shorted wiring or faulty appliances, replace fuses and reset circuit-breakers.

- **Wiring between controller and appliances**

Turn on at least one appliance and check the voltage at the load connections on the discharge controller.

Corrective action: Clean all connections, replace all wires that are damaged or that are not the correct size for their length.

- **Faulty switch**

If there is one switch that controls all appliances, it may be the problem. Using a short wire, connect across the switch terminals. If the appliances work, then the switch is faulty.

Corrective action: Replace the switch.

- **Controller failure**

Measure the voltage at the load terminals. If the load terminal voltage is zero or much lower than other terminal voltage, the discharge controller may not be working properly. Corrective action: Replace the controller.

Failure type 2: Some appliances work but some do not

This type of failure is rarely due to PV panel. It may be caused by:

1. **A faulty appliance switches**

   Use a short wire and connect the switch terminals together. If the appliance works, the switch is faulty.

   Corrective action: Replace the switch.

2. **An appliance has been wrongly connected**

   Check the connection at the appliance. Make sure that wire of the appliance is connected to the wire (+) of the controller.

   Corrective action: Connect the wires correctly.

3. **The wire size is too small or too long**

   Measure the length of the wire run.

   Check to see if the wire is too small for its length.

   Corrective action: Replace the wire with one of the correct size.

4. **Connections are loose or dirty**

   Remove wires from all connections between the appliance and the controller. Clean the wires and terminals. Replace the wires and tighten the connections.

1. **Failure type 3: The system works but runs out of power**

This is the most common problem with solar PV systems and can be caused by many things acting alone or in combination. This may be caused by:

1. **Too little energy from the panels**

   The reason for this may be shading, damaged panels, wiring too small or too long, dirty or loose connections, panels not facing in the right direction or dirt on the panels.

Corrective action: Remove the cause of the shade or move the panels so they are no longer shaded and are facing in the right direction, clean and replace the panels if damaged, check the wiring on the panels.

2. Incorrect adjustment of the charge controller

This may prevent the getting energy for the pumps. In some cases, a special controller tester will be available but, when it is not, it can be checked by asking the user to keep appliance use to a minimum for several sunny days. Come to the site in the late afternoon of the third or fourth sunny day while the sun is still shining. Check the voltage at the connections and at the panel terminals of the controller. If the two voltages are about the same and they are both above 13 V for a 12 V system, or 26 V for a 24 V system, then the charge controller is probably working properly. Corrective action: Replace the controller and send the old one for repair.

Troubleshooting

- Inspect the system many problems can be located by simple inspection.
- Inspect the solar array: 1.is it facing the sun? (For details, see solar array orientation)

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

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.

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. Indicate a failure of the electronics. Look for burnt wires, bits of black debris, and any other signs of lightning damage.

2. Open the junction box. Is the power in switch turned on? Pull on the wires to see if any of them have come loose.

3. Inspect the grounding wires and connections.

4. 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, it can be bypassed the probe or test it electrically.

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
3. up to indicate that it is submerged, and down to indicate that it is dry.
4. The probe must be positioned vertically (within about 10°).
5. The probe or a probe wire may be broken.
1. Inspect the wires for damage.
6. 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.

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 the system has a float switch, it will be mounted in the tank. If inspection is not feasible, it can be bypassed the switch or test it electrically.

1. If a float switch is not being used, there must be a wire between the terminals.

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 it is restored 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.

Electrical Testing

A "multimeter" is required and a clamp-on ammeter is helpful. Test the solar array circuit

1. Open circuit voltage: This is "idle" voltage. It is normally high because no current is being drawn (it's doing no work).

Short circuit current or spark test: This is helpful if the pump is trying to start or does not seem to get full power. Disconnect the array from the controller before making this test.

(A short circuit at the array will only cause current slightly higher than normal.) If there is no a DC amp meter, a spark that can jump 1/4" (6 mm) indicates a good probability that the array is working properly.

3. Voltage under load (with pump running)

4. Current under load was connected to the controller with reverse polarity? No lights will show on the controller. This will not cause damage.

Test the motor circuit (resistance test with power off), make this test if there is proper voltage at the controller input but the motor does not run. It will confirm the condition of the entire motor circuit, including the motor, pump cable and splice.

Test the running current of the motor circuit (AC amps), this is one of the most useful trouble shooting techniques because it indicates the force (torque) that the motor is applying to the pump. For greatest ease, use a clamp-on ammeter, available from local electrical equipment suppliers. It allows to measure current without breaking connections.

The current stays nearly constant as voltage and speed vary. The measurements may vary by as much as 10% and more if temperature is out of the normal range. Comparing the reading with the standards provided by manufacturers, this will indicate whether the workload on the motor is normal for the lift it is producing.

Future changes may indicate pump wear, or change in the level of the water source.

Higher current (especially pump overload light) may indicate:

1. The pump may be handling excessive sediment (sand, clay). The total dynamic head (vertical lift plus pipe friction) may be higher than expected it is.

3. There may be an obstruction to the water flow- sediment in the pipe, ice in the pipe, a crushed pipe or a partially closed valve. (Is there a float valve at the tank?)

4. Helical rotor models: Water may be warmer than 72°F (22°C). This causes the rubber stator to expand and tighten against the rotor (temporarily, non-damaging).

5. Helical rotor models: 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.

To reset the over load shut off (red light), switch the pump controller off and on.

Lower current may indicate:

1. In a deep well, the level of water in the source may be far above the pump intake, so the actual lift is less than expected. This is not a problem.

2. The pump head may be worn, thus easier to turn than normal (especially if there is abrasive sediment).

3. There may be a leak in the pipe system, reducing the pressure load.

4. Helical rotor models: Water may be colder than 46°F (8°C). This causes the rubber stator to contract, away from the rotor. The pump spins easier and produces less flow under pressure.

Test the low-water probe circuit

If the controller indicates “source low” when the pump is in the water, the low-water probe system may be at fault. When the water level is above the probe, the switch in the probe makes contact. That causes the applied voltage to drop toward zero. The systems “sees water” and allows the pump to run. If the voltage is greater than 3V, dry shut off is triggered. The low-water probe has an internal 1K resistor in series with the switch. When closed (in water), the normal resistance is around 1000. To bypass the low-water probe (and activate the pump), connect a small wire between the probe terminals in the junction box. Restart the controller. If the pump runs, there is a fault at the probe or in the probe wiring. The wires may be shorted (touching each other) or open (broken) or the moving part on the probe may be stuck with debris, or the probe may be out of its normal, vertical position.

Test the full-tank float switch

If the controller indicates “Tank full” when the tank is not full, the float switch or pressure switch system may be at fault.

1. If the remote switch circuit is not being used, there must be a wire between the terminals.

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.

3. Most float switches are “normally open”. Disconnect a wire from the terminals, and the pump should run. Connect a wire between the terminal, and the pump should stop.

4. Most pressure switches (and some float switches) are “normally closed”. Connect a wire between the terminals, and the pump should run.

If the pump responds to the bypass tests above but not to the float switch, the wires may be shorted (touching each other) or open (broken), or the switch may be stuck

If the pump runs but flow is less than normal with debris, or out of its correct position.

1. Is the solar array receiving shadow-free light? (It only takes a small shadow to stop it.) Is it oriented properly toward the south, 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.

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

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.

1. Measure the pump current and compare it with the table in the previous section.
2. 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 much abrasive particles (sand or clay) in the water.

1. Is the AC motor current higher than normal? Does not start easily in low light?

This is likely to be related to dirt in the pump and/or pipe.

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

2. Run the pump in a bucket to observe.

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

4. If the check valve itself is clogged with dirt.

5. To help prevent dirt problems.

6. After years of use, it may be necessary to replace the pump end.

Electrical Testing

These tests are extremely helpful when trying to assess the performance of a system, or locate a fault.

Obtaining and using a multimeter Measuring current (amps) is easiest if you have a clamp-on ammeter.

Probe input. Some meters give a choice of probe sockets. The negative (black) probe always goes in the common socket. The + (red) probe input varies, and is specified below.

Part 1 – Testing the Solar Array (DC)

This test refers to a 48V solar array with a pump set. The system voltage may vary. The current is determined by both the array and the load (current draw of the pump system). If the pump is not under full load (like in a bucket), the current may be as little as 1 amp.

Range if the meter is "auto-ranging", this does not apply. Otherwise, use the range than the reading expected. For example, in Test1, "normal" voltage is around 80. The proper range may be 100V or 200V, depending on the meter design.

Access open the junction box for access to the terminals. The appearance of the wiring may vary.

Monitoring a Solar PV Pump System: Observe the output of the pump at the point of discharge? If not, it may not know if it malfunctions. Consider installing a water meter, or additional valves so that the flow can be directly observed.

Monitoring the water level in the storage tank: Will you be able to observe the level of water in the tank? If one cannot easily see into your storage tank, here are some methods of tank monitoring.

- Dipstick in the air vent
- Float with a visible rod that protrudes through the top of the tank
- Clear sight-tube alongside the tank
- Precision pressure gauge

Self-Check 3	Written Test

Directions Answer all the questions listed below and write your answer on the space provided

1. Describe what troubleshooting in solar system pumping? (4pts)
2. Explain what methods troubleshooting of solar pumping system? (4pts)

Answer Sheet

Score = 8pts
Rating: ____________

Name: _________________________ Date: _______________

Short Answer Questions

Q1.____
____
____

Q2.____
____
____
____
____

Operation Sheet #3	Troubleshooting

Directions:

- Implement solar equipment procedural troubleshooting performance in maintenance field, if appropriate. If not, just demonstrate at your learning workshop areas as appropriate.
- Identify and collect required equipment and tools for troubleshooting
- Follow and implement all safety rules and regulations Additional information for the Operator

The tasks to be implement are as follows:

1. Conduct troubleshooting activities on solar pumping system (apply it for single module and multiple module)

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions: Given necessary templates, tools and materials you are required to perform the following tasks within 3 hours.

1. Plan and prepare Solar pumping system installation and maintenance.
2. Demonstrate solar pumping system installation
3. Repair and maintain solar pumping system.
4. Troubleshoot for solar pumping system

List of Reference Materials

1. Training manual for Solar PV Pumping System (Prepared by: GRID Nepal in joint venture with Center for Energy Studies Institute of Engineering, TU September 2014)
2. Solar Pumping (by Practica foundation-Author: Erik van de Giessen MSc; co-authors and reviewers; Ebo Roek MSc ; Gertjan Bom MSc Stéphan Abric MSc; Robert Vuik MSc)
3. Installation, Operation and Maintenance Guide- 12, 24, and 48 Volt Systems (by Ventev Innovations (A Division of TESSCO Technologies**))**