RQF LEVEL 5 Solar Energy

TRADE: Solar Energy

MODULE CODE: SOLPP 501

TEACHER'S GUIDE

Module name: Operate Solar power plant

Table of content:

Contents

1. PREPARE SOLAR POWER PLANT OPERATION

- **1. Proper interpretation of solar power plant's manual based on different equipment**
- **2. Proper description of solar power plant components according to their schemes of connection**
- **3. Proper identification of PPE (Personal Protective Equipment) according to their use**

2. MONITOR SOLAR POWER PLANT EQUIPMENT

- **1. Proper checking of solar modules according to their types**
- **2. Proper monitoring of charge controllers according to their connections**
- **3. Proper control batteries according to manufacturer's information**
- **4. Proper control inverters according to their connection**

3. PERFORM THE ROUTINE MAINTENANCE

- **1 Proper planning of preventive maintenance of solar power plant components according to their types**
- **2. Proper inspection of solar power plant components according to their types**
- **3. Elaborate maintenance report**

ACRONYMS:

- ✓ **PV: PhotoVoltaic**
- ✓ **DC: Direct current**
- ✓ **AC: Alternative current**
- ✓ **PPE: Personal Protective Equipment**
- ✓ **BCS: Battery Charging Station**

Module Code and Title: SOLPP 501 Operate Solar power plant

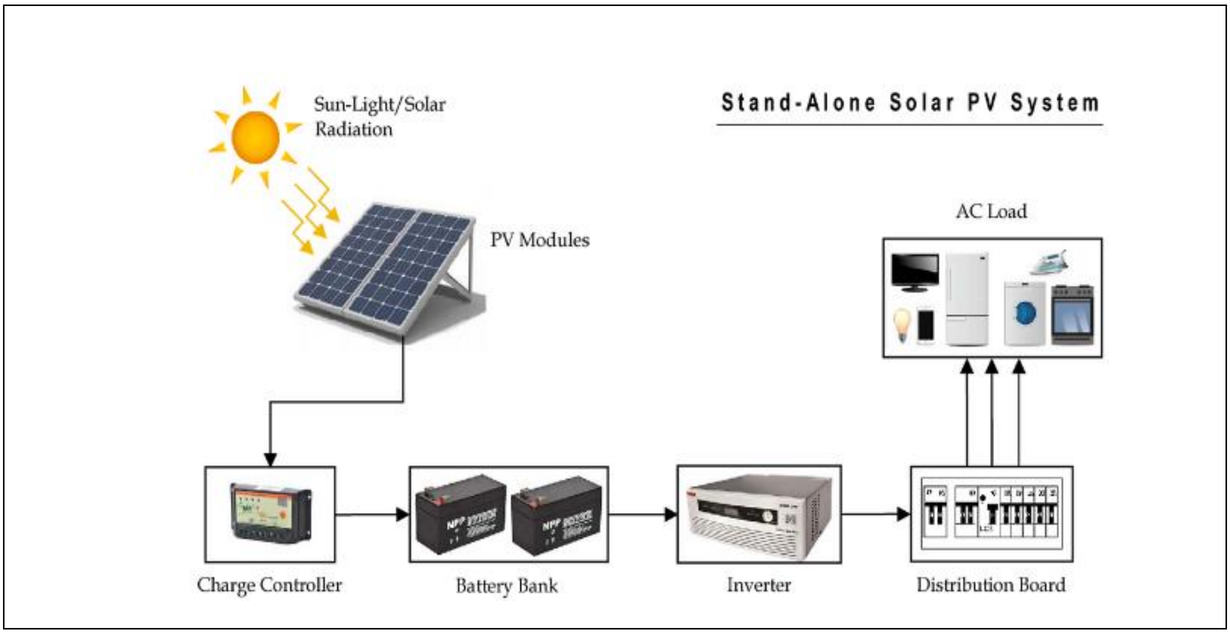
Learning units:

1. PREPARE SOLAR POWER PLANT OPERATION

2. MONITOR SOLAR POWER PLANT EQUIPMENT

3. PERFORM THE ROUTINE MAINTENANCE

Learning Unit 1: Prepare solar operation



STRUCTURE OF LEARNING UNIT

Learning outcomes:
➢ **1. Interpret solar manual** ➢ **2. Describe solar power plant components** ➢ **3. Identify PPE**

Learning Outcome1.1. Interpret solar manual

Duration: 7hrs

Learning outcome 1 objectives :

By the end of the learning outcome, the trainees will be able to:

1. Proper interpretation of solar power plant's manual based on different equipment

2. Proper description of solar power plant components according to their schemes of connection

3. Proper identification of PPE (Personal Protective Equipment) according to their use

Resources

Equipment	**Tools**	**Materials**
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

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Indicative content 1.1: Manual for Solar modules

Manual for solar modules

PV is emerging as a major power resource, steadily becoming more affordable and proving to be more reliable than utilities.

Photovoltaic power promises a brighter, cleaner future for our children.
The photovoltaic effect is the basic principal process by which a PV cell converts sunlight into electricity.

- ✓ When light shines on a PV cell, it may be reflected, absorbed, or pass right through.
- ✓ The absorbed light generates electricity.
- ✓ The solar energy conversion into electricity takes place in a semiconductor device that is called a solar cell.
- ✓ A solar cell is a unit that delivers only a certain amount of electrical power.
- ✓ In order to use solar electricity for practical devices, which require a particular voltage or current for their operation, a number of solar cells have to be connected together to form a solar panel, also called a PV module.
- ✓ For largescale generation of solar electricity, the solar panels are connected together into a solar array.
- ✓ The heart of a photovoltaic system is the solar module. Many photovoltaic cells are wired together by the manufacturer to produce a solar module.
- ✓ When installed at a site, solar modules are wired together in series to form strings.
- ✓ Strings of modules are connected in parallel to form an array The solar panels are only a part of a complete PV solar system.
- ✓ Solar modules are the heart of the system and are usually called the power generators.

The output of a PV module depends on sunlight intensity and cell temperature; therefore, components that condition the DC (direct current) output and deliver it to batteries, grid, and/or load are required for a smooth operation of the PV system.

These components are referred to as charge regulators.
For applications requiring AC (alternating current) the DC/AC inverters are implemented in PV systems.
These additional components form that part of a PV system that is called balance of system (BOS).

Finally, the household appliances, such as radio or TV set, lights and equipment being powered by the PV solar system are called electrical load.

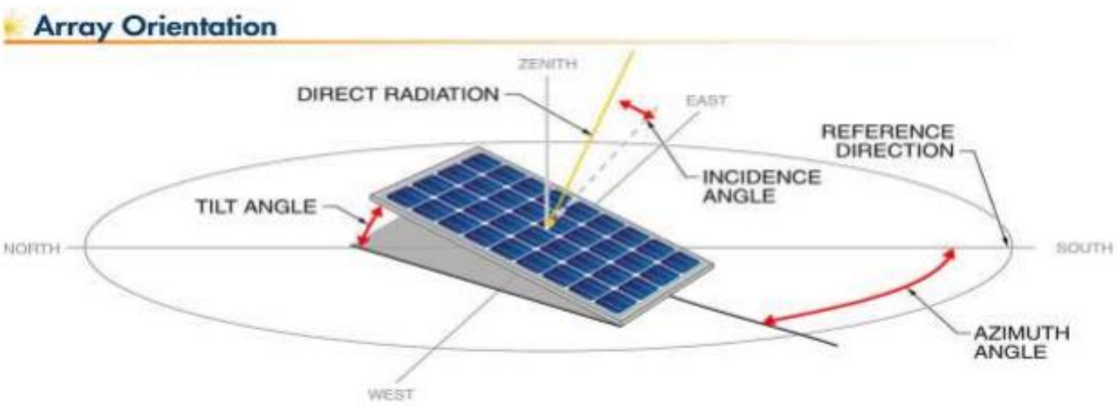
- Terms used in solar systems

  - Cells: Semiconductor device that converts sunlight into direct current (DC) electricity

- Modules: PV modules consist of PV cell circuits sealed in an environmentally protective laminate and are the fundamental building block of PV systems
- Panels: PV panels include one or more PV modules assembled as a pre-wired, field-installable unit
- Array: A PV array is the complete power-generating unit, consisting of any number of PV modules and panels
- **PV module:** Assembly of interconnected PV cells to form one unit called PV module.
- **PV cell:** basic PV device which can generate electricity when exposed to light such as solar radiation
- **Battery:** Storage device that store electrical energy in form of chemical energy
- **Battery bank:** Assembly of many batteries connected together to increase their energy are called battery bank.
- **Charger controller:** Device used to controller charging process and discharging process of batteries in solar system is called charger controller.
- **Inverter**: Device which converts DC voltage into AC voltage.
- **DC loads:** Electrical loads (appliance which works on presence of DC current)
- **AC loads:** Electrical loads (appliance which works on presence of DC current)
- **Insolation:** Quantity of solar radiation energy (energy). (unit is kWh/m2)
- **Irradiance:** Intensity of solar radiation energy(power). (unit is kW/m2)
- **Peak sun hour**: The value the averaged at 1kW/m2 irradiance. The unit is hour (the duration of 1kW/m2 irradiance)
- **PV string:** String is a circuit in which PV modules are connected in series, in order for a PV array to generate the required output voltage.
- **Solar Home System:** Small solar energy system used in home. Most are 12V system or 24V system
- **Pmax :** Maximum power that can be generated by a PV module. 8
- **Voc(stc), Open-circuit voltage:** voltage under standard test conditions across an unloaded (open) PV module, PV string, PV array, PV generator.
- **Isc (stc)Short-circuit current:** short-circuit current of a PV module, PV string, PV array or PV generator under standard test conditions
- **I array:** Output current from PV arrays.
- **Imp:** Maximum current of available PV module
- **Autonomy days:** Number of days on which battery bank can supply loads without being charged from PV arrays.
- **Depth Of Discharge (DOD) :** Maximum permissible level of battery discharge in percentage.
- **LVD**: Low Voltage Disconnect

- **HVD**: High Voltage Disconnect
- **HVR**: High Voltage Reconnect
- **LVR:** Low Voltage Reconnect

A solar PV cell converts solar radiation energy into DC electricity.



A Module's Main Parameters

Since a solar module is nothing but an interconnection of solar cells, similar parameters are defined such as module Efficiency, module Fill Factor, Maximum Power Point (MPP) Voltage and Current (Vmpp) and (Impp), Open Circuit Voltage (Voc), and Short Circuit Current (Isc).

Voltage and Current of a Module As we can see, the total voltage of a PV module is nothing but a scale version of the cell voltage (multiplied by a number of cells connected in series), while the total current is a scaled version of the cell current (multiplied by a number of strings of cells connected in parallel).

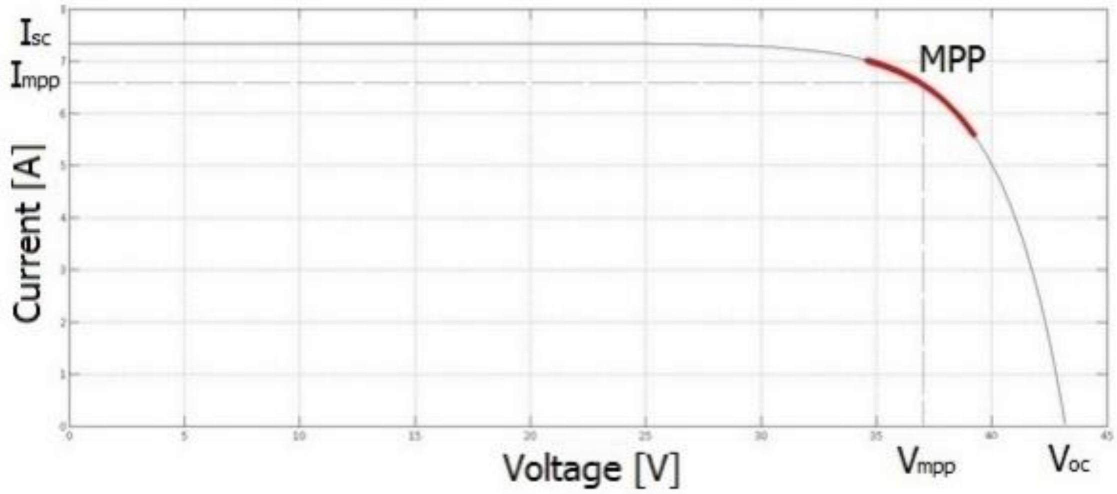
Module I-V Characteristics Previously, we learned about the I-V curve at the solar cell level.
However, in PV systems, we are more interested in the total current and voltage that the PV module can generate, so we define the Module I-V curve, or the current-voltage curve, as it is illustrated in Figure below

The curve indicates the voltage and current at different operating conditions.

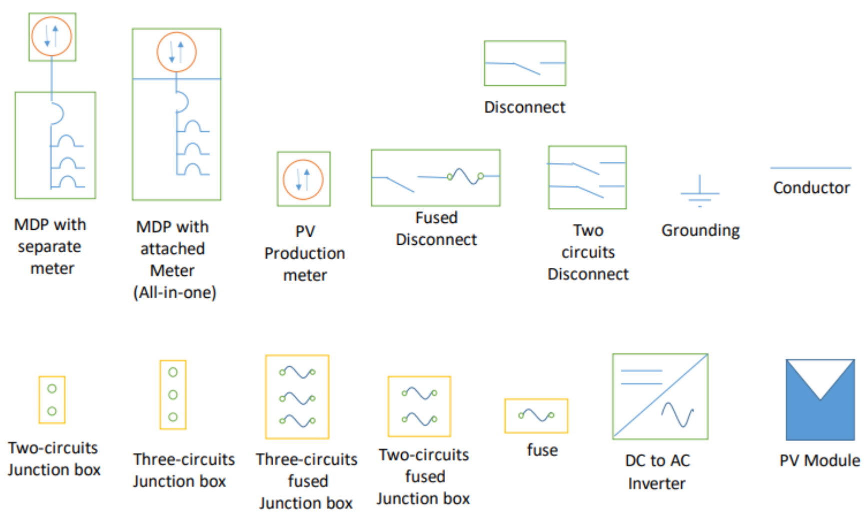
For example, the highest current corresponds to the short-circuit condition (when a PV module's positive and negative terminals are connected without load, causing very high current to pass), while the highest voltage occurs at open-circuit condition (when a PV module's positive and negative terminals are not connected to any load, causing no current to pass).

If we observe the current and voltage starting at the open-circuit condition (where voltage is maximum and current is zero), and as we increase the load of the circuit, the current starts increasing and the voltage falls down until it reaches the value of zero at short-circuit condition (where the current is maximum).

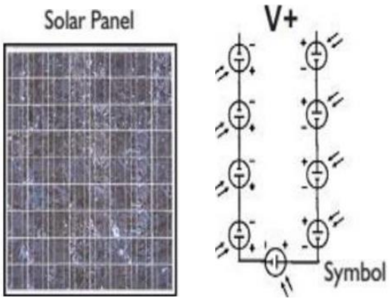
The knee of the curve indicates the operating condition in which current and voltage result in maximum power point (MPP). The voltage and current values at MPP are referred to as "Vmpp" and "Impp," respectively

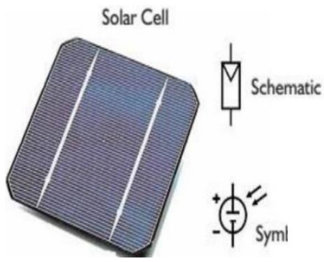


PV Module system parameters' symbols :



- **PV modules**





Identification of tools, material and equipment used in solar power plant operation:

Tools used in solar power plant:

Identification of types of equipment used in solar power plant

Electro-mechanical toolkit

Hand Electrical drilling machines

Instrument used in solar power plant

Material and used in solar power plant

✓ Solar panels

✓ Charge controllers

✓ Batteries

✓ Inverters

A major material used for PV cell is silicon semiconductor.

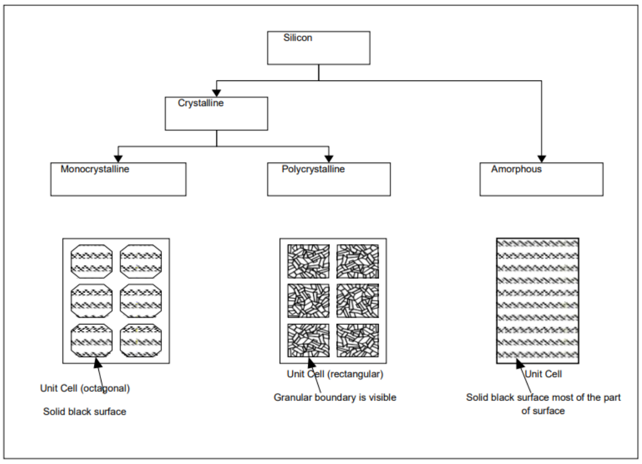


Figure 4: Types of PV module Silicon Crystalline Unit Cell (octagonal) Solid black surface Unit Cell (rectangular) Granular boundary is visible Unit Cell Solid black surface most of the part of surface Monocrystalline Polycrystalline Amorphous

Types of PV modules

There are three major types of silicon PV modules based on types of solar cell used. (monocrystalline, polycrystalline and Amorphous)

- Crystalline silicon

There are two types of crystalline cells:

- Monocrystalline and
- polycrystalline.

Monocrystalline cell has higher efficiency than polycrystalline cell.
However, there is no difference as you use it as a module.

But Monocrystalline module has slightly small dimensions compare to polycrystalline module.
Crystalline type is very reliable.

Normally performance of each PV module is not very different among manufacturers.
Lifetime is considered more than 20 years.

A solar cell itself has much longer lifetime, but the life is limited by the EVA (Ethylene Vinyl Acetate) resin used to sandwich cells and glass in modules.

- Amorphous silicon:
Amorphous is the thin film of silicon so that cost is relatively low for small size such as 10W.
However, efficiency is much lower than crystalline cells.

There are four common panel types on the market today, they are:

a) Monocrystalline panels
b) Polycrystalline panels
c) Thin film (amorphous silicon) panels
d) Hybrid panels (which are monocrystalline with an embedded layer of thin film)

Monocrystalline silicon solar cells:

Monocrystalline panels get their name from the fact that the silicon wafer used to make them is cut from a single crystal or 'boule' of silicon. Silicon is grown in a laboratory to achieve a high degree of purity and is then sliced very thinly to make wafers.

Benefits:

Monocrystalline cells have the highest efficiency of any cells on the market under standard operating conditions.

• Their high efficiency means they have the smallest footprint for their output, so you can maximize power output when roof space is limited.

Drawbacks:

• Due to higher production costs, monocrystalline cells are more expensive other cells.
• Monocrystalline cells don't perform as well as polycrystalline cells or thin film under higher temperatures (e.g. 25°C +). All cells are subject to 'de-rating' as the ambient temperature increases, and monocrystalline cells tend to produce less at higher temperatures than the other technologies.

Polycrystalline silicon cells:

These cells are cut from an ingot of melted and recrystallized silicon. In the manufacturing process, molten silicon is cast into ingots of polycrystalline silicon, then saw-cut into very thin wafers and assembled into complete cells. Polycrystalline cells (also known as multi-crystalline) are cheaper to produce than monocrystalline ones, due to the simpler manufacturing process. However, they tend to be slightly less efficient for the same size cell.

Benefits

• Polycrystalline cells typically offer a lower cost per watt of power produced.

• These cells have a better temperature de-rating co-efficient compared to monocrystalline, meaning

they produce more power in hotter weather, which usually more than offsets their slightly lower cell efficiency.

Disadvantages of polycrystalline cells

• Polycrystalline cells are slightly less efficient than monocrystalline cells, so
• they need more roof space to produce the same output capacity.

3.Thin film silicon

Thin film, or amorphous, silicon cells are made up of silicon atoms in a thin layer rather than a crystal structure. Amorphous silicon can absorb light more readily than crystalline silicon, so the cells can be thinner. For this reason, amorphous silicon is also known as ‘thin film’ photovoltaic (PV) technology.

Advantages

• Thin film offers the best shade tolerance of any solar technology.

• When compared with other types of panels, thin film performs best under hotter temperatures.

Disadvantages

• Thin film has the lowest conversion efficiency of all the panel types

• These panels need about twice the roof space to achieve the same power output as a similar crystalline panel.

As a result, the physical dimensions are almost twice as big as compared to crystalline modules.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment’s manuals

Points to Remember (Take home message)

- Module's Main Parameters
- PV Module system parameters’ symbols
- Types of PV modules
- A major material used for PV cell is silicon semiconductor.
- Identification of tools, material
  and equipment used in solar power plant operation

Indicative content 1.2: Manual for charges controllers

Charges controller:

It can be collected by human through photovoltaics systems. Photovoltaic systems composed of solar photovoltaic cells in modules, voltage control circuits and batteries for energy storage

Its purpose is “**to keep the batteries properly fed and safe for the long term”.**

The basic functions of a charge discharge controller are quite simple. Charge controllers block reverse current and prevent battery overcharge.

Some controllers also prevent battery over discharge, protect from electrical overload, and/or display battery status and the flow of the power. The main aim of doing this project is to develop cheap and better performance charge discharge controller.

We will first proceed with block diagram followed by circuit diagram and some experimental results.

CHARGE CONTROLLER

This essential piece of your solar system controls the Charge put into your battery, stops overcharging and prevents the solar panel pulling power from the battery at night.

DC electricity generated from solar a PV module flows to a charge controller if the system has any batteries. Charge controllers are often called as regulators.

This name of "regulator" often gives misunderstanding to many people as if it sounds voltage and current are regulated.

<u>Role of charge controller</u>

The role of charge controllers is to protect batteries since batteries are weak against over charge and over discharge.
Many people misunderstand that charge controllers regulate voltage and/or current.
However, charge controllers are sort of switching device that has two switches, one in between PV module terminal and battery terminal, the other is between load terminal and battery terminal.

<u>Types of Charge Controllers</u>

As described in the previous paragraph, a charge controller has over charge protection and over discharge protection.

There are two methods of overcharging protection

These are based on the method how to disconnect PV modules from the system to stop charging.

First method:
Is to use the switch A1 that is able to open the circuit line from PV module to battery.

The second method:
Is to use the switch A2 that is able to close the both end of PV module (make short circuit).
When PV module is shorted, no current goes to battery that means PV module is disconnected from the battery.
This method indicated the notable characteristic of PV modules because PV modules can be short circuited safely unlike other power generation devices.

The first one, is called series type charge controller and the latter one is called shunt type charge controller.

For small SHSs (Solar Home System), both types are fine.

For large systems, however, shunt type charge controller is recommended to avoid many PV modules become float (open).
Here, switching mechanisms has been shown as if those are mechanical on-off switches for easy understandings.

These days, however, semiconductor devices are used as switching devices such as FET or power transistor.
Charge Controller Charge Controller
A: Series Type
B: Shunt Type

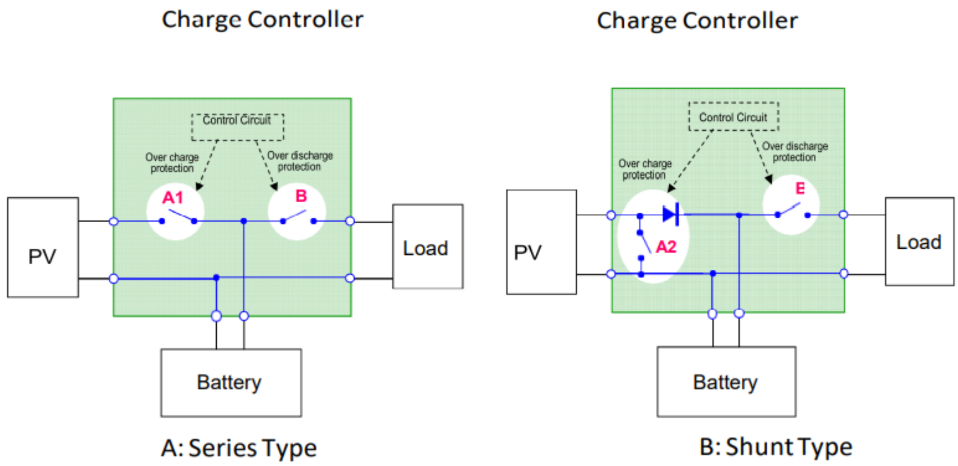


Figure 5: Types of Charge Controllers

This Figures related to types of Charge Controllers B Load Battery A2 Load Battery

Use regulators (Charge controller)

A solar charge controller is fundamentally a voltage or current controller to charge the battery and keep electric cells from overcharging. It directs the voltage and current hailing from the solar panels setting off to the electric cell. Generally, 12V boards/panels put out in the ballpark of 16 to 20V, so if there is no regulation the electric cells will damaged from overcharging. Generally, electric storage devices require around 14 to 14.5V to get completely charged. The solar charge controllers are available in all features, costs and sizes.
The range of charge controllers are from 4.5A and up to 60 to 80A.

Types of Solar Charger Controller:

There are three different types of solar charge controllers, they are:

1. Simple 1 or 2 stage controls
2. PWM (pulse width modulated)
3. Maximum power point tracking (MPPT)

Simple 1 or 2 Controls: It has shunt transistors to control the voltage in one or two steps. This controller basically just shorts the solar panel when a certain voltage is arrived at. Their main genuine fuel for keeping such a notorious reputation is their unwavering quality – they have so not many segments, there is very little to break.

PWM (Pulse Width Modulated): This is the traditional type charge controller, for instance anthrax, Blue Sky and so on. These are essentially the industry standard now.

Maximum power point tracking (MPPT): The MPPT solar charge controller is the sparkling star of today's solar systems. These controllers truly identify the best working voltage and amperage of the solar panel exhibit and match that with the electric cell bank. The outcome is extra 10-30% more power out of your sun oriented cluster versus a PWM controller. It is usually worth the speculation for any solar electric systems over 200 watts.

Applications:

In recent days, the process of generating electricity from sunlight is having more popularity than other alternative sources and the photovoltaic panels are absolutely pollution free and they don't require high maintenance. The following are some examples where solar energy is utilizing.

- Street lights use photovoltaic cells to convert sunlight into DC electric charge. This system uses solar charge controller to store DC in the batteries and uses in many areas.
- Home systems use PV module for house-hold applications.
- Hybrid solar system uses for multiple energy sources for providing full time backup supply to other sources.

Example of Solar Charge Controller:

From the below example, in this a solar panel is used to charge a battery. A set of operational amplifiers are used to monitor panel voltage and load current continuously. If the battery is fully charged, an indication will be provided by a green LED. To indicate under charging, over loading, and deep discharge condition a set of LEDs are used. A MOSFET is used as a power semiconductor switch by the solar charge controller to ensure the cut off load in low condition or over loading condition. The solar energy is bypassed using a transistor to a dummy load when the battery gets full charging. This will protect the battery from over charging.

Features of Solar Charge Controller:

- Protects the battery (12V) from over charging
- Reduces system maintenance and increases battery lifetime
- Auto charged indication
- Reliability is high
- 10amp to 40amp of charging current
- Monitors the reverse current flow

Function of Solar Charge Controller:

The most essential charge controller basically controls the device voltage and opens the circuit, halting the charging, when the battery voltage ascents to a certain level. More charge controllers utilized a mechanical relay to open or shut the circuit, halting or beginning power heading off to the electric storage devices.
Generally solar power systems utilize 12V of batteries. Solar panels can convey much more voltage than is obliged to charge the battery.

The charge voltage could be kept at a best level while the time needed to completely charge the electric storage devices is lessened.
This permits the solar systems to work optimally constantly.
“By running higher voltage in the wires from the solar panels to the charge controller, power dissipation in the wires is diminished fundamentally”.

The solar charge controllers can also control the reverse power flow. The charge controllers can distinguish when no power is originating from the solar panels and open the circuit separating the solar panels from the battery devices and halting the reverse current flow.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment’s manuals to charge controller for preventing the battery damaged

Points to Remember (Take home message)

- Role of charge controller and Function of Solar Charge Controller
- Features of Solar Charge Controller

Indicative content 1.3: Manual for batteries

Interpreting Battery Parameters and Specification Sheets

- BATTERY BANK

Battery capacity is measured in Amp Hours (e.g. 17AH). You need to convert this to Watt Hours by multiplying the AH figure by the battery voltage (e.g. 12V). this is just the simple calculation below

- X (Battery size in AH) x Y (Battery Voltage) = Z (Power available in watt hours
- For a 20AH, 12V battery the Watt Hours figure is 20(X) x 12(Y) = 240 WH (Z)

This means the battery could supply 240W for 1 hour, 120W for 2 hours or even 2w for 120 hours
i.e. the more energy you take, the faster the battery discharges.
However, you are never really able to take all the power from a battery as once the voltage drops below your equipment's requirements it will no longer be able to power it.

There is a simple rule of thumb for this but please check your battery's specifications to make sure.

PV module generates electricity during daytime only.
To use electricity during night time,

therefore, the storage of electricity is necessary;

- To store electricity, rechargeable battery is used.

There are several types of rechargeable battery.

- **Lead-acid battery is commonly used in solar PV systems**.

The reason is that lead-acid battery is economical and capacity.
If the PV systems are connected to grid, batteries are not necessary.

However, sometimes batteries are used to stabilize the output since the output is often fluctuated due to weather condition.

Role of Battery The solar PV system only can generate power during daytime.

Therefore,

- It is essential to store generated energy for the use at night.

  Rechargeable battery is used for this purpose. Change electricity into chemical form (Charging) Change chemical form into electricity (Discharge)

- Another role of battery is to stabilize fluctuated output from PV modules.

Types of solar battery

Lead Acid Deep-cycle, lead-acid batteries have been employed in renewable energy and reliably used in off-grid applications globally for decades.

Cost: Typical deep-cycle, lead-acid batteries cost significantly less than lithium-ion.

Cycling: Valve-regulated lead-acid (VRLA) batteries include absorbed glass mat (AGM) and gel models.
Many AGM batteries available in the market are primarily built for dual-purpose or standby

- **applications**; like emergency backup, but not deep cycling.

However, new deep-cycle AGM designs have increased performance and total energy output making them a good choice for renewable energy applications at a lower price point than gel batteries.
In fact, VRLA batteries with added Nano carbon are more resistant to sulfation, which can lead batteries to die over time.

The carbon slows sulfation and allows the battery to charge faster and cycle more than traditional lead acid.
This makes it a good choice for applications in which the battery is in a partial state of charge, such as energy arbitrage or off-grid

Lithium-ion

Li-ion battery's will give you around 80% of their rated power. (i.e. a 10Ah battery has 8Ah of usable power)
A common question that people ask regarding the battery's is,

QUESTION: Are car battery's just as good for solar as leisure battery's?

ANSWER: The answer to this is no they are not. The reason is because a leisure battery has been designed to be discharged and recharge, a Car battery is designed to provide a lot of power quickly but it's not able to cope with a low internal charge and recover fully.

We provide a wide range of sealed led acid batteries that are ideal for solar applications

According to a U.S. Solar Energy Monitor report, lithium-ion batteries are the most common storage technology, regardless of application.

There are three types:

pouches such as in smartphones and tablets, cylindrical such as in power tools, and prismatic (which come in various shapes) such as in electronic vehicles.

Prismatic types often have corrugated sides, which create air gaps between adjacent cells and can aid in cooling.
The prismatic can have applications in solar energy storage, specifically lithium iron phosphate (LFP) batteries.

2.3 Use solar storage devices

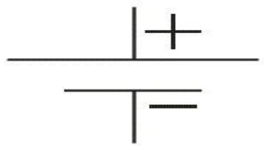
WORKING PRINCIPLE OF SOLAR STORAGE (BATTERIES)

A battery is a device that converts chemical energy to electrical energy.
In the modern era, electrical energy is normally converted from mechanical energy, solar energy, and chemical energy etc.

In the year 1836, John Frederic Daniel, a British chemist developed the Daniel cell as an improved version of the voltaic cell.
From that time until today, the battery has been the most popular source of electricity in many daily life applications.
In our daily life, we generally use two types of battery; one of them is which can be used once before it gets totally discharged. Another type of battery is rechargeable which means it can be used multiple times by recharging it externally.

The former is called primary battery and the later is called secondary battery. Batteries can be found in different sizes.

A battery may be as small as a shirt button or may be so big in size that a whole room will be required to install a battery bank. With this variation of sizes, the battery is used anywhere from small wrist watches to a large ship.



We often see this symbol in many diagrams of electrical and electronics network. This is the most popularly used symbol for battery. The bigger lines represent positive terminal of the cells and smaller lines represent negative terminal of the cells connected in the battery. We are often confused about the terms battery cell and battery.

We generally refer a battery as a single electro-chemical cell. But literally, battery does not mean that. Battery means a number of electro-chemical cells connected together to meet a certain voltage and current level. Although there may be a single cell battery, literally, battery and cell are different.

Types of solar storage(Batteries):

- ✓ **Lead acid batteries and**
- ✓ **Nickel-Cadmium batteries**

LEAD – ACID BATTERY

The lead-acid battery was invented in 1859 by French physicist Gaston Planté and is the oldest type of rechargeable battery. Despite having a very low energy-to-weight ratio and a low energy-to-volume ratio, its ability to supply high surge currents means that the cells have a relatively large power-to-weight ratio. This feature, along with their low cost, makes it attractive for use in motor vehicles to provide the high current required by automobile starter motors.

As they are inexpensive compared to newer technologies, lead-acid batteries are widely used even when surge current is not important and other designs could provide higher energy densities. Large-format lead-acid designs are widely used for storage in backup power supplies in cell phone towers, high-availability settings like hospitals, and stand-alone power systems.
For these roles, modified versions of the standard cell may be used to improve storage times and reduce maintenance requirements. Gel-cells and absorbed glass-mat batteries are common in these roles, collectively known as VRLA (valve-regulated lead-acid) batteries.

The nickel–cadmium battery (NiCd battery or NiCad battery) is a type of rechargeable battery using nickel oxide hydroxide and metallic cadmium as electrodes. The abbreviation NiCd is derived from the chemical symbols of nickel (Ni) and cadmium (Cd): the abbreviation NiCad is a registered trademark of SAFT Corporation, although this brand name is commonly used to describe all Ni–Cd batteries.

Wet-cell nickel-cadmium batteries were invented in 1899.

A NiCd battery has a terminal voltage during discharge of around 1.2 volts which decreases little until nearly the end of discharge.

NiCd batteries are made in a wide range of sizes and capacities, from portable sealed types interchangeable with carbon-zinc dry cells, to large ventilated cells used for standby power and motive power.

Compared with other types of rechargeable cells they offer good cycle life and performance at low temperatures with a fair capacity but their significant advantage is the ability to deliver practically their full rated capacity at high discharge rates (discharging in one hour or less).

However, the materials are more costly than that of the lead acid battery, and the cells have high self-discharge rates.

Sealed NiCd cells were at one time widely used in portable power tools, photography equipment, flashlights, emergency lighting, hobby R/C, and portable electronic devices.

The superior capacity of the Nickel-metal hydride batteries, and more recently their lower cost, has largely supplanted their use.

Further, the environmental impact of the disposal of the toxic metal cadmium has contributed considerably to the reduction in their use. Within the European Union, NiCd batteries can now only be supplied for replacement purposes or for certain types of new equipment such as medical devices.

Flow batteries:

Flow battery use in long duration storage is growing.
Most conventional flow batteries use two electrolyte liquids: one with a negatively charged cathode, and one with a positively charged anode.

The cathode and anode are separated into two tanks by a membrane,
because if they come into contact with each other the battery will short and require replacement.

This is often what happens with lithium-ion batteries; the membrane degrades over time.

But the exchange of negatively and positively charged fluids in flow batteries produces electrical current without degradation, providing a longer cycle life and quick response times.

CALCULATION OF CAPACITY AND ENERGY OF BATTERY

Step 0. A little tutorial on measurements of electronic charge. After all, it is electrons (really ions) that are stored in the battery. In phresh-man fisicks we all learned that the measure of charge is the coulomb and that a single electron has 1.602e-19 coulombs of charge. One amp flowing in a wire for one second will use one coulomb of charge, which is 6.24 x 10^18 electrons, $Q = I*t$

Where Q is the charge in coulombs, I, is the current in amps and t is the time in seconds.

The amount of charge passing through that wire (conducting 1.0 amps) in 60 seconds is 60 coulombs, and in one hour you would have had said “hello” and “good-bye” to 3600 coulombs of charge.

Batteries were evidently developed by engineers who subscribed to the “whatever’s easiest” system of measurement. They got tired of pulling out their slide rules to divide by 3600 every time they wanted to know how long 24000 coulombs would last them and came up with the unauthorized unit of amp-hours.

Later, when smaller batteries were used they came up with milliamp-hours.

Don’t be confused by the hyphen. Amp-hours means amps’ times hours. Divide by amps and you get hours, divide by hours and you get amps. So it isn’t amps, and it isn’t amps per hour, it is amp-hours. And, by the way, I have even used the term amp-seconds because when you say “coulombs” everybody goes glassy-eyed on you.

Don’t get me wrong, I love amp-hours for units, it is a handy rule of thumb. Amp hours is how much charge is stored in the battery. Since a battery changes voltage during the discharge, it isn’t a perfect measure of how much energy is stored, for this you would need watt-hours. Multiplying the average or nominal battery voltage times the battery capacity in amp-hours gives you an estimate of how many watt-hours the battery contains.

$E = C*Vavg$

Where **E** is the energy stored in watt-hours, **C** is the capacity in amp-hours, and **Vavg** is the average voltage during discharge.

Yes, watt-hour is a measure of energy, just like kilowatt-hours.

Multiply by 3600 and you get watt-seconds, which is also known as Joules.

As long as we are in the prelude, I might also mention that since the charge in a capacitor is Q=CV that a battery can be rated in farads as well. A 1.5 volt AA alkaline battery that stores 2 amp hours of charge (that’s 7200 coulombs) has the equivalent capacitance of 4800 Farads.

Of course a battery makes an awfully weird capacitor because the voltage doesn’t drop proportionally to the stored charge, it has a high equivalent resistance, and etc.

Also, I should mention that you don't always get all the amp-hours you expect out of a battery. This is explained in Part 3 below as the Peukart effect. This is why I called it a rule of thumb rather than a theorem. The biggest errors come when you discharge batteries fast.

Some batteries, such as Carbon-Zinc, Alkaline, or Lead Acid become less efficient when you discharge quickly.

A typical sealed lead acid battery will give only half of its rated capacity when discharged at the C/1 rate compared with the C/20 rate.

The following method assumes that you know how many amps you need for the gadget under power. If you know the watts go to Step A below.

Step 1. Back of the envelope

If the current drawn is x amps, the time is T hours then the capacity C in amp-hours is

$$C = xT$$

For example, if your pump is drawing 120 mA and you want it to run for 24 hours

$$C = 0.12 \text{ Amps} * 24 \text{ hours} = 2.88 \text{ amp hours}$$

Step 2. Cycle life considerations

It isn't good to run a battery all the way down to zero during each charge cycle. For example, if you want to use a lead acid battery for many cycles you shouldn't run it past 80% of its charge, leaving 20% left in the battery.

This not only extends the number of cycles you get, but lets the battery degrade by 20% before you start getting less run time than the design calls for $C' = C/0.8$

For the example above

$$C' = 2.88 \text{ AH} / 0.8 = 3.6 \text{ AH}$$

Step 3: Rate of discharge considerations

Some battery chemistries give much fewer amp hours if you discharge them fast.

This is called the Peukart effect.

This is a big effect in alkaline, carbon zinc, zinc-air and lead acid batteries. For example, if you draw at 1C on a lead acid battery you will only get half of the capacity that you would have if you had drawn at 0.05C.

It is a small effect in NiCad, Lithium Ion, Lithium Polymer, and NiMH batteries.

For lead acid batteries the rated capacity (i.e. the number of AH stamped on the side of the battery) is typically given for a 20 hours discharge rate. If you are discharging at a slow rate you will get the rated number of amp-hours out of them.

However, at high discharge rates the capacity falls steeply. A rule of thumb is that for a 1-hour discharge rate (i.e. drawing 10 amps from a 10-amp hour battery, or 1C) you will only get half of the rated capacity (or 5 amp-hours from a 10 amp-hour battery).

Charts that detail this effect for different discharge rate can be used for greater accuracy. For example the data sheets listed in /BB.htm

For example, if your portable guitar amplifier is drawing a steady 20 amps and you want it to last 1 hour you would start out with Step 1:

C=20 amps * 1 hour = 20 AH

Then proceed to Step 2 C' = 20 AH / 0.8 = 25 AH

Then take the high rate into account C''=25 /.5 = 50 AH

Thus you would need a 50 amps' hour sealed lead acid battery to run the amplifier for 1 hour at 20 amps' average draw.

Step 4. What if you don't have a constant load? The obvious thing to do is the thing to do. Figure out an average power drawn. Consider a repetitive cycle where each cycle is 1 hour. It consists of 20 amps for 1 second followed by 0.1 amps for the rest of the hour. The average current would be calculated as follows.

20*1/3600 + 0.1(3599)/3600 = 0.1044 amps' average current.

(3600 is the number of seconds in an hour).

In other words, figure out how many amps is drawn on average and use steps 1 and 2. Step 3 is very difficult to predict in the case where you have small periods of high current. The news is good, a steady draw of 1C will lower the capacity much more than short 1C pulses followed by a rest period.

So if the average current drawn is about a 20 hours' rate, then you will get closer to the capacity predicted by a 20-hours rate, even though you are drawing it in high current pulses. Actual test data is hard to come by without doing the test yourself.

If you know the watts instead of amps, follow the following procedure

Step A: Convert watts to amps

Actually, watts is the fundamental unit of power and watt-hours is the energy stored. The key is to use the watts you know to calculate the amps at the battery voltage . For example, say you want to run a 250 watt 110VAC light bulb from an inverter for 5 hours.
Watt-hours = watts * hours = 250 watts * 5 hours = 1250 watt hours

Account for the efficiency of the inverter, say 85% Watt-hours = watts * hours / efficiency = 1250 / 0.85 = 1470 watt-hours Since watts = amps * volts divide the watt hours by the voltage of the battery to get amp-hours of battery storage Amp-hours (at 12 volts) = watthours / 12 volts = 1470 / 12 = 122.5 amp-hours. If you are using a different voltage battery the amp-hours will change by dividing it by the battery voltage you are using.

Batteries are the final commercial product that are delivered to customers and that require some data provided from the manufacturers to allow customers to evaluate the performance of different battery types in terms of capacity rating, allowable DOD, and temperature operating ranges.

Most datasheets come with some curves that a PV designer should be able to perfectly interpret for best design practices.

In this section, we will discuss basic parameters of batteries and main factors that affect the performance of the battery.

The first important parameters are the voltage and capacity ratings of the battery.

Every battery comes with a certain voltage and capacity rating. As briefly discussed earlier, there are cells inside each battery that form the voltage level, and that battery rated voltage is the nominal voltage at which the battery is supposed to operate.

The capacity refers to the amount of charge that the battery can deliver at the rated voltage, which is directly proportional to the amount of electrode material in the battery.

The unit for measuring battery capacity is ampere-hour or amp-hour, denoted as (Ah).

The capacity can also be expressed in terms of energy capacity of the battery.

The energy capacity is the rated battery voltage in volts multiplied by battery capacity in amp-hours, giving total battery energy capacity in watt-hours (wh).

In general, it is the total amount of energy that the device can store. You must be wondering what is the significance of amp-hours as the unit of battery capacity? The unit itself gives us some important clues about battery properties.

A brand new battery with a 100 amp-hour capacity can theoretically deliver a 1 A current for 100 hours at room temperature.

In practice, this is not the case due to several factors, as we will see later.

C-rate Let's move to another important battery parameter, called the C-rate. C-rate is the discharge rate of the battery relative to its capacity.

The C-rate "number" is nothing but the discharge current, at which the battery is being discharged, over the nominal battery capacity.

It is calculated as the following:

"Number" C = $Idis\ Cnon$ Where "Idis " is the discharge current "Cnon " is the nominal battery capacity

The discharge rate is sometimes referred to as C/"number" and that number is the number of hours it takes the battery to be fully discharged. In other words, it is the inverse of the previous notation, and it is calculated as the following:

CI "Number" = $Cnon\ Idis$ For example, a C-rate of 1C for 100 Ah capacity battery would correspond to a discharge current of 100 A over 1 hour.

Or it can be represented as C/1. On the other hand, a C-rate of 2C for the same battery would correspond to a discharge current of 200 A over half an hour. Or it can be represented as C/0.5.

Similarly, a C-rate of 0.05C implies a discharge current of 5 A over 20 hours. Or it can be represented as C/20.

Finally, the same battery can be discharged at 1 A over 100 hours, and that corresponds to 0.01C or C/100. In general, C-rate depends on charging and discharging current.

Efficiency Since there is no energy conversion system that is 100% efficient, the term efficiency represents the system capability to transfer energy from the input of the system to the output.

Each battery type comes with different efficiency rating as discussed and usually we talk about efficiencies of both charge and discharge combined.

"Battery efficiency" is the ratio of total storage system input to the total storage system output.

For example, if 10 kWh is pumped into the battery while charging, and you can effectively retrieve only 8 kWh while discharging, then the round trip efficiency of the storage system is 80%. Let's discuss another important battery parameter, the state of charge or SOC.

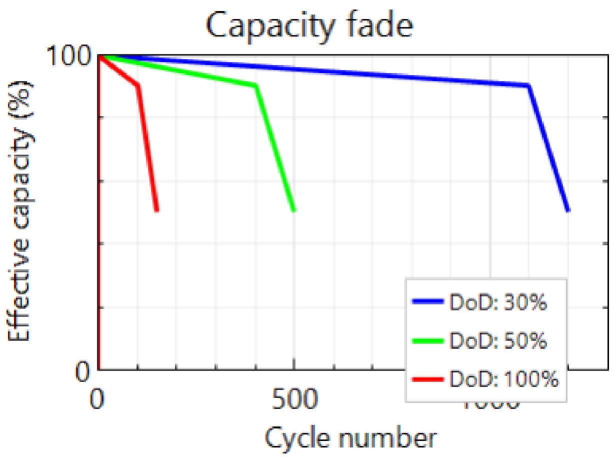
It is defined as the percentage of the battery capacity available for discharge, so thus, a 100 Ah rated battery that has been drained by 20 Ah had an SOC of 80%. Another parameter that complements the SOC is the depth of discharge or DOD, which is the percentage of the battery capacity that has been discharged. Thus, a 100 Ah battery that has been drained by 20 Ah has a DOD of 20%. In other words, the DOD and SOC are complementary to one another.

Now we come to a very important parameter: the cycle lifetime of the battery. Cycle lifetime is defined as the number of charging and discharging cycles after which the battery capacity drops below 80% of the nominal value. Usually, the cycle life is specified as an absolute number.

However, to be more precise, cycle life and other battery parameters are affected by changing ambient condition such (temperature in this case).

So what is the relationship between the battery parameters? The cycle life depends heavily on the depth of discharge. This can be seen in Figure 3.6 for a typical flooded lead-acid battery.

If we look at the effective capacity at different depth of discharge (DOD) rates for a lead-acid battery, we can see that the cycle number diminishes as the DOD increases.



Cycle lifetime also depends on the temperature.

The battery lasts longer under colder temperatures of operation. Furthermore, we can observe from Figure 3.6 that for a particular temperature, cycle lifetime depends non-linearly on the depth of discharge.

The smaller the DOD, the higher the cycle lifetime.

However, such a higher cycle life would also mean that those additional cycles you gain can only help you for a smaller depth of discharge. Thus, it could be said that the battery will last longer if the average DOD could be reduced over its normal operation.

Also, battery overheating should be strictly controlled. Overheating could occur due to overcharging and subsequent overvoltage of the lead-acid battery. We will learn more about voltage and charge control of the battery in the next section. While battery life is increased at lower temperatures, there is one more effect that needs to be considered.

The temperature affects battery capacity during regular use, too.

As seen in Figure 3.7, the lower the temperature, the lower the battery capacity. The Higher the temperature, the higher the battery capacity.

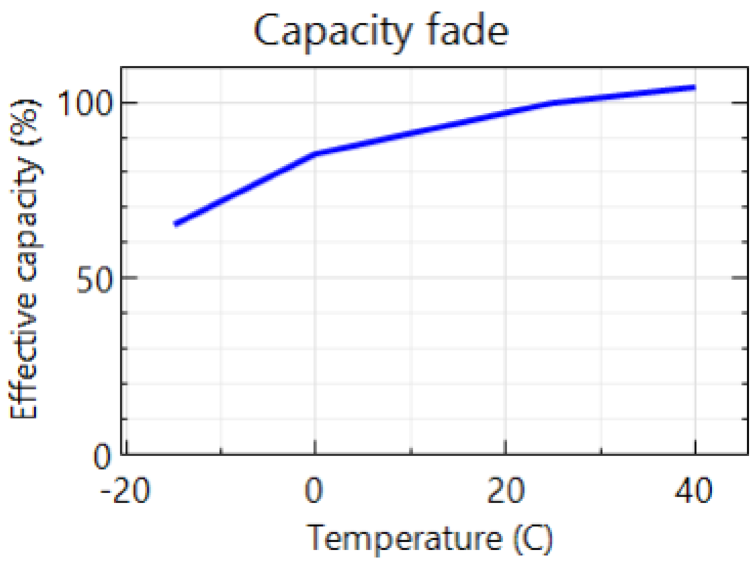


Figure 3.7: the effective capacity (%) vs temperature for a flooded lead-acid battery

Battery Aging Factors, It might not seem scientific, but it is even possible to reach an above rated capacity of the battery at high temperatures.

However, such high temperatures are severely detrimental to battery health. When we say that a battery has a limited cycle life, or that it has completely "run out of juice," what exactly does that mean? Is it related to the aging effect of the lead-acid battery? There are several factors that contribute to the aging of any battery.

Sulphation is one of the major causes of aging. And if the battery is not fully recharged after being heavily discharged, that causes sulphate crystals to grow, which cannot be completely transformed back into lead or lead oxide. As a result, the battery slowly loses the mass of active material and therefore discharge capacity will be lower.

Corrosion of lead grid at the electrode is another common aging factor. This leads to increased grid resistance due to high positive potentials. Moving further, when the battery loses moisture, it causes the electrolyte to dry out, which occurs at high charging voltages, resulting in loss of water.

It is referred to as gassing effect and may limit battery lifetime. This should be taken care of with routine maintenance by adding distilled water to the battery. Researchers have developed maintenance free lead-acid batteries for solar systems that exhibit very high lifetimes.

However, these are also high-end products and can be more expensive.

“Reflection How do we determine if the battery is preferred to be a maintenance-free type when designed for PV applications?”

Answer: After we covered all basic battery parameters and characteristic curves, a designer should be able to make the best selection for a product depending on the application.

But how do designers put these batteries in place? Is there only one size for all batteries, and it is scalable? Or do they make a custom design battery for each project? We will answer these questions in the next section.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment’s manuals to batteries’ polarities connections.

Points to Remember (Take home message)

- method assumes that you know how many amps you need for the gadget under power.
- Use solar storage devices

Indicative content 1.4: Manual for inverters

- **INVERTERS**

PV systems are basically DC systems since the output of PV modules and batteries use DC electricity.

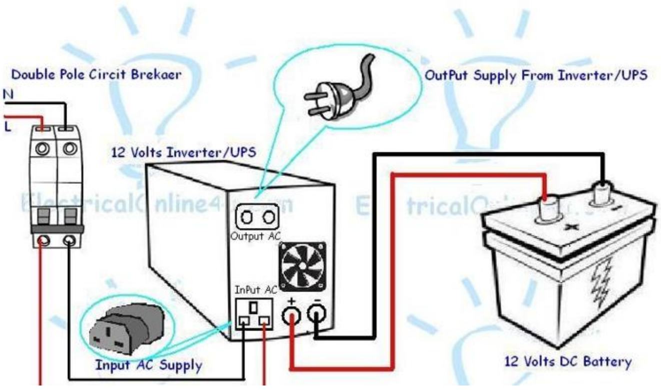
When AC electricity is required for load, DC-AC inverter is necessary to convert DC to AC.

Working principle of solar inverter

The inverters work by taking in power from a Direct Current (DC) Source, i.e., the solar panel.
The power is generated in the range of 250 Volts to 600 Volts.
DC power is converted into AC power by the inversion process taking place in the inverter.

This process of DC to AC Conversion is achieved by using a set of solid state devices like Insulated Gate Bipolar
Transistors (IGBT's.).

These devices when connected in a typical H-Bridge arrangement oscillate the DC power thereby creating AC power.



Inverters play a crucial role in any solar energy system and are often considered to be the brains of a project, whether it's a 2-kW residential system or a 5-MW utility power plant.

An inverter's basic function is to "invert" the direct current (DC) output into alternating current (AC).

Inverter technologies have advanced significantly, such that in addition to converting DC to AC,

- they provide a number of other capabilities and services in order to ensure that the inverter can operate at an optimal performance level, such as **data monitoring, advanced utility controls, applications and system design engineering.**

also provide post installation services that are integral to maintaining energy production

Introduction

The dc-ac converter, also known as the inverter, converts dc power to ac power at desired output voltage and frequency.

The dc power input to the inverter is obtained from an existing power supply network or from a rotating alternator through a rectifier or a battery, fuel cell, photovoltaic array or magneto hydrodynamic generator.

The filter capacitor across the input terminals of the inverter provides a constant dc link voltage. The inverter therefore is an adjustable-frequency voltage source.

The configuration of ac to dc converter and dc to ac inverter is called a dclink converter.

Inverters can be broadly classified into two types:

voltage source and current source inverters.

A voltage–fed inverter (VFI) or more generally a voltage–source inverter (VSI) is one in which the dc source has small or negligible impedance. The voltage at the input terminals is constant.

A current–source inverter (CSI) is fed with adjustable current from the dc source of high impedance that is from a constant dc source.

A voltage source inverter employing thyristors as switches, some type of forced commutation is required, while the VSIs made up of using GTOs, power transistors, power MOSFETs or IGBTs, self-commutation with base or gate drive signals for their controlled turn-on and turn-off. 16 A standard single-phase voltage or current source inverter can be in the halfbridge or full-bridge configuration.

The single-phase units can be joined to have three-phase or multiphase topologies. Some industrial applications of inverters are for adjustable-speed ac drives, induction heating, standby aircraft power supplies, UPS (uninterruptible power supplies) for computers, HVDC transmission lines, etc.

In this chapter single-phase inverters and their operating principles are analysed in detail.

The concept of Pulse Width Modulation (PWM) for inverters is described with analyses extended to different kinds of PWM strategies.

Finally, the simulation results for a single-phase inverter using the PWM strategies described are presented.

Voltage Control in Single - Phase Inverters The schematic of inverter system is as shown, in which the battery or rectifier provides the dc supply to the inverter.

The inverter is used to control the fundamental voltage magnitude and the frequency of the ac output voltage.

AC loads may require constant or adjustable voltage at their input terminals, when such loads are fed by inverters, it is essential that the output voltage of the inverters is so controlled as to fulfill the requirement of the loads.

For example, if the inverter supplies power to a magnetic circuit, such as a induction motor, the voltage to frequency ratio at the inverter output terminals must be kept constant. This avoids saturation in the magnetic circuit of the device fed by the inverter.

Battery or Rectifier Inverter Vd Cd AC Voltage Figure 2.1: Schematic for Inverter System The various methods for the control of output voltage of inverters can be classified as: (a) External control of ac output voltage (b) External control of dc input voltage (c) Internal control of the inverter.

The first two methods require the use of peripheral components whereas the third method requires no external components.

Mostly the internal control of the inverters is dealt, and so the third method of control is discussed in great detail in the following section. 2.2.1 Pulse Width Modulation Control The fundamental magnitude of the output voltage from an inverter can be controlled to be constant by exercising control within the inverter itself that is no external control circuitry is required.

The most efficient method of doing this is by Pulse Width Modulation (PWM) control used within the inverter.

In this scheme the inverter is fed by a fixed input voltage and a controlled ac voltage is obtained by 18 adjusting the on and the off periods of the inverter components.

The advantages of the PWM control scheme are [10]:

a) The output voltage control can be obtained without addition of any external components.

b) PWM minimizes the lower order harmonics, while the higher order harmonics can be eliminated using a filter.

The disadvantage possessed by this scheme is that the switching devices used in the inverter are expensive as they must possess low turn on and turn off times, nevertheless PWM operated are very popular in all industrial equipment. PWM techniques are characterized by constant amplitude pulses with different duty cycles for each period.

The figure shows the triangle and modulation signal with some arbitrary frequency and magnitude. In the inverter of Figure 2.2 the switches and are controlled based on the comparison of control signal and the triangular wave which are mixed in a comparator. When sinusoidal wave has magnitude higher than the triangular wave the comparator output is high, otherwise it is low.

Single-Phase Inverters

A single-phase inverter in the full bridge topology is as shown in, which consists of four switching devices, two of them on each leg. The full bridge inverter can produce an output power twice that of the half-bridge inverter with the same input voltage.

Three different PWM switching schemes are discussed in this section, which improve the characteristics of the inverter.

The objective is to add a zero sequence voltage to the modulation signals in such a way to ensure the clamping of the devices to either the positive or negative dc rail; in the process of which the voltage gain is improved, leading to an increased load fundamental voltage, reduction in total current distortion and increased load power factor.

the top devices are assigned to be S11 and S21 while the bottom devices as S12 and S22, the voltage equations for this converter are as given in the following equations.

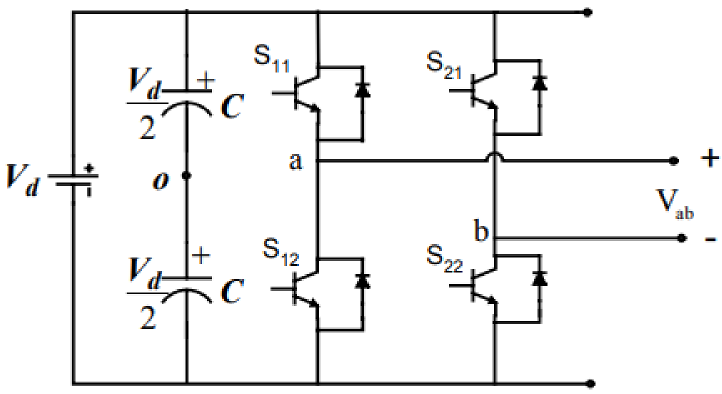


Figure 2.5: Schematic of a Single Phase Full-Bridge Inverter.

$$\frac{V_d}{2}(S_{11} - S_{12}) = V_{an} + V_{no} = V_{ao} \qquad (2.5)$$

$$\frac{V_d}{2}(S_{21} - S_{22}) = V_{bn} + V_{no} = V_{bo} \qquad (2.6)$$

$$V_{ab} = V_{an} - V_{bn} \qquad (2.7)$$

The voltages and V are the output voltages from phases A and B to an arbitrary point n, V is the neutral voltage between point n and the mid-point of the DC source.

The switching function of the devices can be approximated by the Fourier series to be equal to Van bn no (1+ M) 2 1 where M is the modulation signal which when compared with the triangular waveform yields the switching pulses.

Thus from Equations 2.4, 2.5, and 2.6, the expressions for the modulation signals are obtained as

$$M_{11} = \frac{2(V_{an} + V_{no})}{V_d}$$

$$M_{21} = \frac{2(V_{bn} + V_{no})}{V_d}.$$

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment's manuals to inverter for converting produce DC energy from PV modules.

Points to Remember (Take home message)

Working principle of solar inverter

Learning outcome 1 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) The photovoltaic effect is the basic principal process by which a PV cell converts sunlight into electricity.
b) The photovoltaic effect is emerging as a major power resource, steadily becoming more affordable and proving to be more reliable than utilities.
c) PV is emerging as a major power resource, steadily becoming more affordable and proving to be more reliable than utilities.
d) A PV string is a small solar energy system used in home. Most are 12V system or 24V system

Answer: a) True, b) False, c) True, d) False

Q2. Choose any three (3) Features of Solar Charge Controller;

i. Protects the battery (12V) from over charging

ii. Reduces system maintenance and increases battery lifetime

iii. Monocrystalline and
iv. polycrystalline.
v. Reliability is high

Answer:

i. Protects the battery (12V) from over charging

ii. Reduces system maintenance and increases battery lifetime

v. Reliability is high

⚠ **Please mix different assessment tools for triangulation and relevancy of assessment**

Practical assessment

- Assessment tools

In the district YYY is considered some category rooms which will be supplied by PV solar system so, as looked above

Tools, materials and equipment are: pliers, phase testers, multi-meter, screw drivers, and all PPEs

Install the room which contains 4 bulbs that are separated under two separation loads kind AC and DC loads

Checklist	Score	
	Yes	No
Interpretation of manual contents		
Application of manual information		
Observation		

References:

to EME 812 (4.5 Types of PV technology and recent innovation) [0].

https://www.e-education.psu.edu/ae868/node/518 Links [1]

https://www.e-education.psu.edu/eme812/node/534 [2]

https://www.e-education.psu.edu/eme812/node/606 [3]
https://www.eeducation.psu.edu/eme812/node/595 [4]

https://www.e-education.psu.edu/eme812/node/607 [5]

http://www.solaruk.com/pdf/DS%20-%20HIT235%20- %20HIT%20235%20SE10%20-%20datasheet.pdf [6]
https://www.e-education.psu.edu/eme812/node/60

Duration: 8hrs

Learning outcome 2 objectives :

By the end of the learning outcome, the trainees will be able to:

1. Proper interpretation of solar power plant's manual based on different equipment

2. Proper description of solar power plant components according to their schemes of connection

3. Proper identification of PPE (Personal Protective Equipment) according to their use

Resources

Equipment	**Tools**	**Materials**
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

Learning Outcome 1.2: Describe solar power plant components

Indicative content 1.2.1: Solar modules

- ✓ Parallel connection
- ✓ Series connection
- ✓ Series- parallel connection

Connection of photovoltaic modules: series or parallel

When connecting multiple solar panels in a 12-48 volt off-grid system, you have a few options: parallel, series, or a combination of the two.
In this article, we'll give you the basics on wiring solar panels in parallel and in series.
Let's start off with a quick comparison of parallel circuits and series circuits.

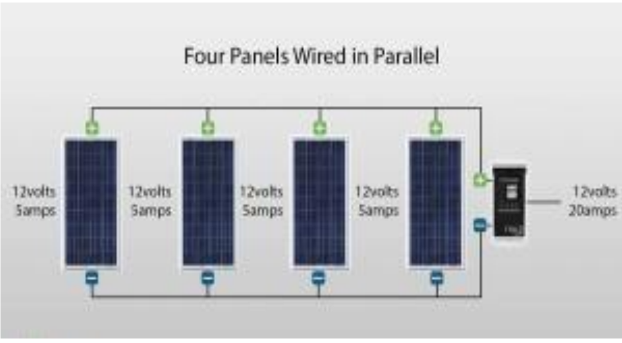
- ✓ **Parallel circuits**

Parallel connection circuits have multiple paths for the current to move along. If an item in the circuit is broken, current will continue to move along the other paths, while ignoring the broken one. This type of circuit is used for most household electrical wiring. For example: when you turn off your TV, it doesn't also turn off your lights.

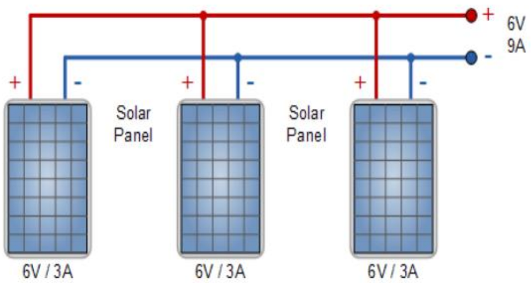
When wiring solar panels in parallel, the amperage (current) is additive, but the voltage remains the same.

Wiring Solar Panels in a Parallel Circuit

Connect all the positive terminals of all the solar panels together, and all the negative terminals of all the panels together.
E.g.: If you had 4 solar panels in parallel and each was rated at 12 volts and 5 amps, the entire array would be 12 volts at 20 amps



Circuit diagram of three solar PV modules (solar panels) connected in parallel



Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment's manuals to Connect under different connection system from PV modules in order to get output required voltage/ energy by parallel connection.

Points to Remember (Take home message)

Solar modules connection system at different features like in parallel, circuit connections

- ✓ **Series circuits**

Series connection circuits have only one path for current to travel along. Therefore, all the current in the circuit must flow through all the loads. A series circuit is a continuous, closed loop - breaking the circuit at any point stops the entire series from operating. An example of a series circuit is a string of old Christmas lights - if one bulb breaks, the whole string turns off. When wiring solar panels in a series, the voltage is additive, but the amperage remains the same.

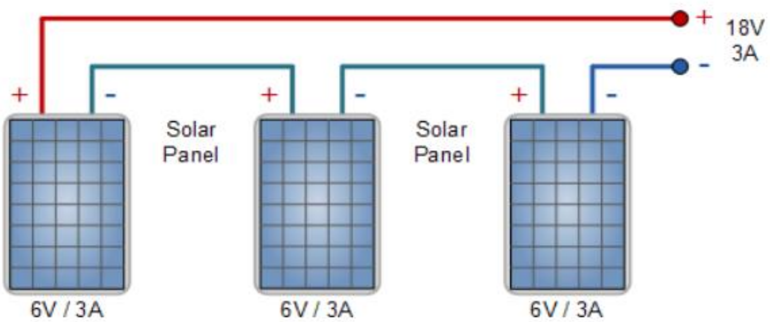
E.g.: If you had 4 solar panels in a series and each was rated at 12 volts and 5 amps, the entire array would be 48 volts and 5 amps.

Remember: just like batteries, solar panels have a negative terminal (-) and a positive terminal (+). Current flows from the negative terminal through a load (current consumed by a piece of equipment) to the positive terminal.

Wiring Solar Panels in a Series Circuit

- Connect the positive terminal of the first solar panel to the negative terminal of the next one.
- eg. If you had 4 solar panels in a series and each was rated at 12 volts and 5 amps, the entire array would be 48 volts at 5 amps.

Circuit diagram of three solar PV modules (solar panels) connected in series



Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment’s manuals to Connect under different connection system from PV modules in order to get output required voltage/ energy by parallel connection.

Points to Remember (Take home message)

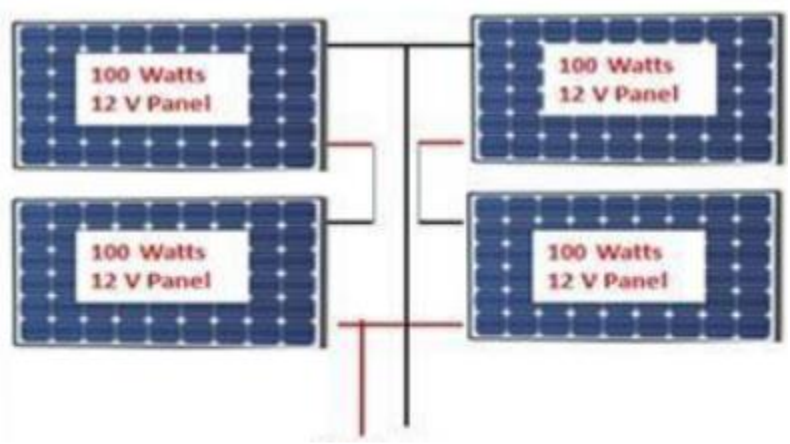
Solar modules connection system at different features like in series circuit connections

just like batteries, solar panels have a negative terminal (-) and a positive terminal (+). Current flows from the negative terminal through a load (current consumed by a piece of equipment) to the positive terminal.

- ✓ **Series- parallel connection**

Solar panels are said connected in parallel/series when the parts of the system are connected in series after those parts of system are connected in parallel.

For example, four solar panels are said connected in parallel / series when they are two systems of two solar panels connected in series then we connect those two systems in parallel.
The purpose of this connection is to increase the output voltage and output current at the sometime.



Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment's manuals to Connect under different connection system from PV modules in order to get output required voltage/ energy by improving the output voltage and current values.

Points to Remember (Take home message)

Solar modules connection system at different features like series-parallel circuit connections **Its version common purpose of this connection**

Indicative content 1.2.2: Charge controllers

- Connection of solar panels to charge controllers
- Connection of inverters to charge controllers
- Connection of batteries to charge controllers

  - ✓ WIRING OF WHOLE SOLAR SYSTEM (FROM SOLAR PANEL TO DC/AC)

INVERTER

AIM

This experiment will help students to be able to mount and to connect all solar quits in solar system in order to get 220V AC as output voltage obtained from solar sun chine with the help of solar quits. THEORY 41 The purpose of solar system is to use electricity converted from sun shine.

This will be possible when the components like:

- solar panel,
- charger controller,
- battery, and
- DC/AC Inverter are in place and well-connected as in DC, polarity must be respected.

The proper connection of one component to other must be respected in order to get 220V AC as the end output.

REQUIRED APPARATUS

✓ Multi-meter (digital)

✓ Clamp-on meter

REQUIRED TOOLS

✓ Pliers

• Combination pliers

• Stripping pliers

• Cutting pliers

✓ Screw driver

✓ Voltage tester

PROCEDURES / STEPS

✓ Select the materials and tools to be used

✓ Place solar panel secured

✓ Distinguish the terminals on the solar panel

✓ Distinguish the terminal also on battery

✓ Check the input and output of DC/AC Inverter and distinguish the terminal on the input. (DC input)

✓ Check the input on your charger controller for solar panel connection

✓ Check the output on charger controller. The outputs sometime are double. (One for battery other for load which inverter or DC loads). If output is one, it means is for the battery.

✓ Check the polarity on charger controller

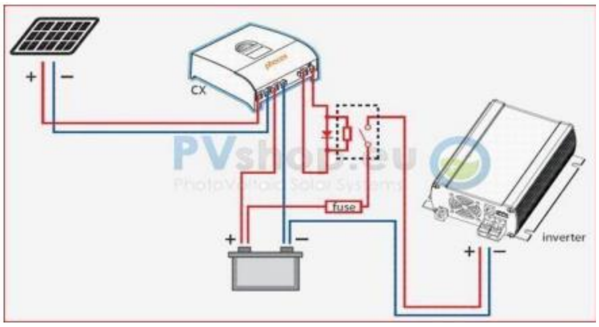
✓ Connect wires from solar panel to input on charger controller with polarity respect. (positive to positive and negative to negative)

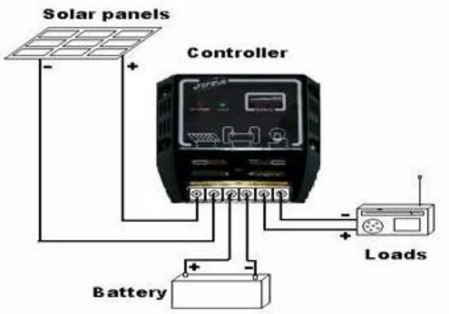
✓ Connect also wires from battery to the output to battery on charger controller with polarity respect. (positive to positive and negative to negative)

✓ Connect input of DC/AC Inverter to the loads output on charger controller if not possible connect direct input of DC/AC Inverter to the battery with polarity respect. Mean positive to positive and negative to negative).

✓ Test the AC voltage on the output of DC/AC Inverter using meter or multi-meter. Circuit diagram

- ✓ **CONNECTION OF SOLAR PANELS TO CHARGE CONTROLLERS**



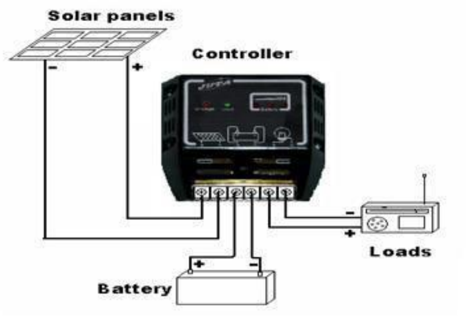


Features of Solar Charge Controller:

- Protects the battery (12V) from over charging
- Reduces system maintenance and increases battery lifetime
- Auto charged indication
- Reliability is high
- 10amp to 40amp of charging current
- Monitors the reverse current flow

Function of Solar Charge Controller:

The most essential charge controller basically controls the device voltage and opens the circuit, halting the charging, when the battery voltage ascents to a certain level. More charge controllers utilized a mechanical relay to open or shut the circuit, halting or beginning power heading off to the electric storage devices.
Generally solar power systems utilize 12V of batteries. Solar panels can convey much more voltage than is obliged to charge the battery. The charge voltage could be kept at a best level while the time needed to completely charge the electric storage devices is lessened. This permits the solar systems to work optimally constantly. By running higher voltage in the wires from the solar panels to the charge controller, power dissipation in the wires is diminished fundamentally.
The solar charge controllers can also control the reverse power flow. The charge controllers can distinguish when no power is originating from the solar panels and open the circuit separating the solar panels from the battery devices and halting the reverse current flow.



Solar Charge Controller Applications:

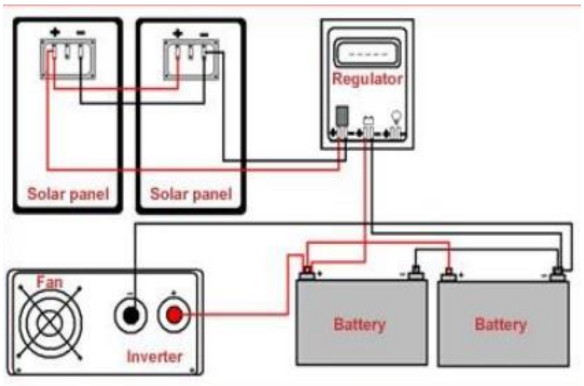
In recent days, the process of generating electricity from sunlight is having more popularity than other alternative sources and the photovoltaic panels are absolutely pollution free and they don't require high maintenance. The following are some examples where solar energy is utilizing.

- Street lights use photovoltaic cells to convert sunlight into DC electric charge. This system uses solar charge controller to store DC in the batteries and uses in many areas.
- Home systems use PV module for house-hold applications.
- Hybrid solar system uses for multiple energy sources for providing full time backup supply to other sources.

Example of Solar Charge Controller:

From the below example, in this a solar panel is used to charge a battery. A set of operational amplifiers are used to monitor panel voltage and load current continuously. If the battery is fully charged, an indication will be provided by a green LED. To indicate under charging, over loading, and deep discharge condition a set of LEDs are used. A MOSFET is used as a power semiconductor switch by the solar charge controller to ensure the cut off load in low condition or over loading condition. The solar energy is bypassed using a transistor to a dummy load when the battery gets full charging. This will protect the battery from over charging.

- ✓ **CONNECTION OF INVERTERS TO CHARGE CONTROLLERS**



Nowadays, in many rural areas they do not have electricity.

But they can use solar energy to enjoy the benefits of electricity like lighting, to power TV and Radio, charging phones and so on.

The above component con be connected together and convert solar energy which is sun rise into electricity to supply many home appliances the ones said above.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ to make the connection system PV modules in order to get output required voltage/ energy by preventing the storage bank damaged.

Points to Remember (Take home message)

solar energy is utilization and procedures / steps

Function of Solar Charge Controller

- ✓ **CONNECTION OF BATTERIES TO CHARGE CONTROLLERS**

PLACEMENT OF CHARGER CONTROLLER BETWEEN PV MODULE AND BATTERIES

AIM

This experiment will help the students to know and to understand how connected charge controller between solar panel and batteries in order to protect batteries during charging and discharging process of batteries.

The working principle of a solar charge controller is simple.

There is a circuit to measure the battery voltage, which operates a switch to divert power away from the battery when it is fully charged and to disconnect battery from the load when the battery reach to it maximum discharge. This means that the wires coming in batteries from solar panel must pass through the charger controller same as the wires coming from batteries to the load.

REQUIRED APPARATUS

✓ Multi-meter (digital)

✓ Clamp-on meter

REQUIRED TOOLS

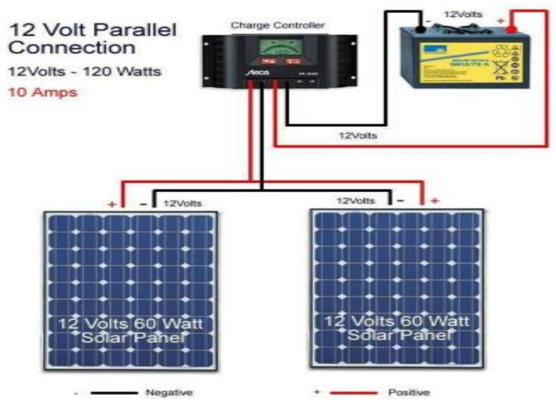
✓ Pliers

• Combination pliers

• Stripping pliers

• Cutting pliers

✓ Screw drivers



Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ to make the connection system PV modules in order to get output required voltage/ energy by preventing the blackout current.

Points to Remember (Take home message)

solar energy is utilization and procedures / steps

Function of Solar Charge Controller

Learning outcome 2 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) The photovoltaic effect is the basic principal process by which a PV cell converts sunlight into electricity.
b) The photovoltaic effect is emerging as a major power resource, steadily becoming more affordable and proving to be more reliable than utilities.
c) PV is emerging as a major power resource, steadily becoming more affordable and proving to be more reliable than utilities.
d) A PV string is a small solar energy system used in home. Most are 12V system or 24V system
Answer: a) True, b) False, c) True, d) False

Q2. Choose any three (3) Features of Solar Charge Controller;

i. Protects the battery (12V) from over charging

ii. Reduces system maintenance and increases battery lifetime

iii. Monocrystalline and
iv. polycrystalline.
v. Reliability is high

Answer:

i. Protects the battery (12V) from over charging

ii. Reduces system maintenance and increases battery lifetime

v. Reliability is high

Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

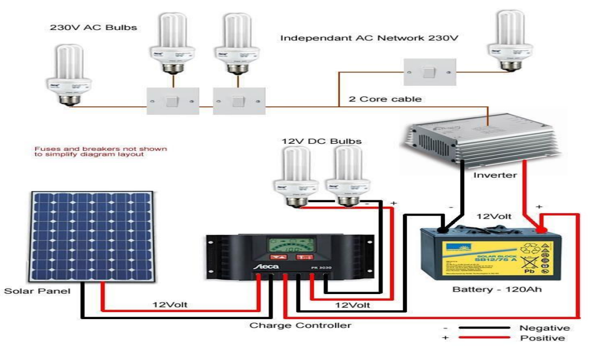
- Assessment tools

  In the district YYY is considered some category rooms which will be supplied by PV solar system so, as looked above

  Tools, materials and equipment are: pliers, phase testers, multi-meter, screw drivers, and all PPEs

  Install the room which contains 4 bulbs that are separated under two separation loads kind AC and DC loads

Answer:



Checklist	Score	
	Yes	No
Identification of different solar power plant components		
Function of different solar power plant components		
Observation		

✓ R.P.Raffaele, Current Trends in Photovoltaics, Santa Barbara Summit on Energy Efficiency (The Institute for Energy Efficiency, SantaBarbara,California,2011

✓ Geo Model Solars.r.o., (2014), solargis.info/doc/71. [102]

✓ E.A. dela Breteque, SolarEnergy83,1425 (2009). [103]

- ✓ P.Trinuruk,C. Sorapipatana, and D. Chenvidhya, Renewable Energy34,2515 (2009).
- ✓ www.ncsc.ncsu.edu.

Duration: 5hrs

Learning outcome 3 objectives :

By the end of the learning outcome, the trainees will be able to:

1. Proper interpretation of solar power plant's manual based on different equipment

2. Proper description of solar power plant components according to their schemes of connection

3. Proper identification of PPE (Personal Protective Equipment) according to their use

Resources

Equipment	Tools	Materials
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

Learning Outcome 1.3: Identify PPE

Indicative 1.3.1: Safety equipment used for solar power plant operation

SAFETY AND PRECAUTION ON WORKPLACE

Safety can define as the protection from a hazard.

It is widely known that the construction industry as a whole, of which plumbing is a part, accounts for many of the accident statistics recorded.

Selecting personal protective equipment(PPE)

Personal Protective Equipment is designed to protect employees from serious workplace injuries or illnesses resulting from contact with chemical, physical, mechanical, electrical or other workplace hazards. In addition to the commonly known PPE such as hard hats, safety glasses and steel toed shoes, PPE includes a variety of devices and garments such as goggles, coveralls, gloves, vests, earplugs and respirators.

Types of PPE

Protective clothing

- ✓ **Body protection**

Usually, body protection equipment is required in the following cases:

- ✓ For protection against weather conditions when working outdoors;
- ✓ Ensuring the high-visibility of users when they work in areas where there is a mixed vehicle (e.g. bikes, motors, cars and busses) and pedestrian traffic;
- ✓ For users' protection against extreme temperatures;
- ✓ Ensuring protection against entanglement, drowning, chemical contamination, etc.

Examples of body protection equipment: Life jackets; Clothing for specific weather conditions; Highvisibility clothing; Harnesses.

Fig.1.10: (a) Safety coverall (b) Safety jacket (c) safety trousers (d) reflective vest (e) Life jacket

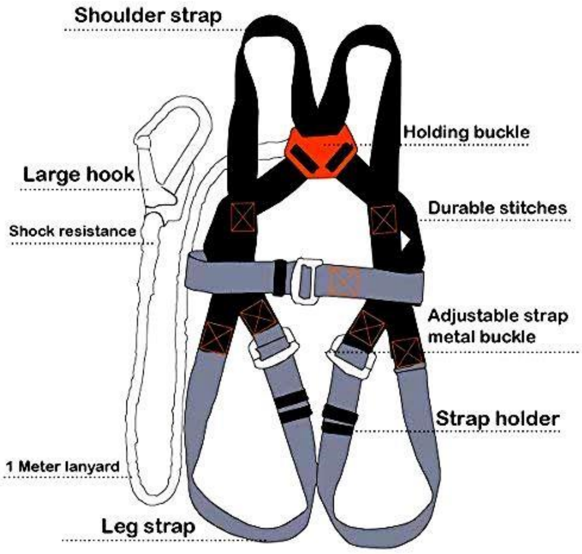


Fig.1.11: Safety body Harness

Fig.1.12: a worker falling and protected by a harness

 Clothing Materials

Materials used to make industrial clothing fall into two major categories, with several subcategories under each as follows: Non-flame-resistant materials; Flame-resistant materials. o **Non-flame-resistant materials.**

When these materials are treated with a flame-retardant chemical, they become flame resistant.

o Natural fibers such as **cotton** and **wool** o Synthetic
fibers such as **polyester**, **nylon**, and **rayon**

➢ **Cotton**

Cotton does not melt into the skin when heated; rather, it burns and disintegrates, falling away from the skin. Thick, heavy cotton material provides a minimal barrier from arc temperatures and ignites quickly. At best, cotton provides only minimal thermal protection.

General industrial practice and industry standards have rejected the use of cotton and wool even though they are permitted. The reason for this is that these natural fibers are not flame resistant. They will burn and, while they are not as bad as some synthetic fibers, they can aggravate the degree of injury.

➢ **Synthetic Materials**

Untreated synthetic clothing materials such as **polyester** and **nylon** provide extremely poor thermal protection and should never be used when working in areas where an electric arc may occur. Some synthetic materials actually increase the danger of exposure to an electric arc. They have a tendency to melt into the skin when exposed to high temperatures. This melting causes three major difficulties.

1. The melted material forms a thermal seal which holds in heat and increases the severity of the burn.

2. Circulation is severely limited or cut off completely under the melted material.

3. The removal of the melted material is extremely painful and may increase the systemic trauma already experienced by the burn victim. **Synthetic-Cotton Blends**

Synthetic-cotton blends such as polyester-cotton are used to make clothing that is easier to care for. Although slightly less vulnerable to melting than pure polyester, the blends are still extremely vulnerable to the heat of an electric arc and the subsequent plasma cloud.

o **Flame-resistant materials**

Chemically treated Materials; both natural and synthetic fibers can be chemically treated to render them flame resistant. Such materials are sometimes used in disposable, coverall-type clothing.

a. Non-flame-resistant materials that have been chemically treated to be made flame resistant

b. Inherently flame-resistant materials such as **PBI (Polybenzimidazole)**, **Kermel**, and **Nomex Work Clothing**

- Work clothing used for routine day-to-day electrical safety may be employed as secondary flash protection.

- Flame-retardant cotton, flame-retardant synthetic cotton blend, NOMEX, PBI, or other flame-retardant materials are preferred. The clothing should meet the following minimum requirements: (a) Long sleeves to provide full arm protection (b) Sufficient weight for both thermal and mechanical protection

Fig.1.13: a person complete with PPE

The safety equipment is defined as all equipment that are designed to be worn or held to protect against risks to health and /or safety. Personal protective equipment includes most types of protective clothing and equipment, such as eye, hand, foot and head protection

Eye protection

- ✓ **Eye and face protection**

Eye injuries can be avoided simply by wearing the proper eye and face protection equipment. As examples of such PPE can be mentioned the following ones: Safety glasses and goggles; Eye and face shields; Visors.

Fig.1.5: (a) Safety glasses (b) Safety goggles (c) face shield (d) welding helmet

Your eyes are two of your most precious possessions. You need them for learning and for earning, because without your eyesight you probably cannot perform your present job.Your eyes are extremely vulnerable to injury at work.

There are many types of eye protection equipment available:

- Safety glasses
- Safety goggles
- Full face masks/shields (is used even to protect nose and mouth)

Foot protection

- ✓ **Foot protection**

The foot protection equipment is designed to protect the feet and legs against various hazards, such as extreme temperatures, crushing, piercing, slipping, cutting, chemicals and electricity. It is typically required when users are involved in construction activities, working in very cold or hot environments, working with chemicals and forestry, or when manually handling heavy objects. As examples of foot protection equipment can be pointed out the following ones: Safety boots and shoes; Anti-static and conductive footwear.

Fig.1.8: Safety shoes

Fig.1.9: safety boots

The basic universal form of foot protection is the safety shoe which will usually include some kind of metallic toe protection, rubber soles and boots.

- ✓ **Hand protection**

Arms, hands and fingers are often injured and, therefore, it is vital to wear hand protection equipment when it is required. The hand protection equipment can ensure protection against heat, cold, vibrations, burns, cuts by sharp objects, bacteriological risks and chemical contamination. Hand protection equipment are work gloves.

Fig.1.4: Leather gloves

Your hands, which you use for almost everything including working, playing, driving, eating…. Unfortunately, hands are often injuried. Almost one in four work-related injuries happens to the hands and fingers.

One of the most common problems other than cutting, crushing or puncture wounds to the hand is dermatitis. Dermatitis is an inflammation of the skin normally caused by contact with irritant substances.

The irritation of the skin may be indicated in several ways, sores, blisters, redness or dry cracked skin, which easily become infected. To protect your hands from irritating substances, you need to keep them clean by regular washing using approved cleaners. Make good use of barrier creams where provided, and wear appropriate personal protection (usually a strong pair of gloves).

- ✓ **Head protection**

Wearing PPE for head protection will help you avoid any harm that may come to you from falling materials or swinging objects. Examples of head protection equipment: Helmets; Hard hats; Bump Caps; Guards

Fig.1.3: Safety Helmet

This is another important form of personal protective equipment and is especially important to plumbers who need to spend time on rooftops and up ladders.

A hammer accidentally dropped from a roof location could cause serious injury or death if it landed on someone's unprotected head.

Hard hats constructed from high-density polystyrene, will provide some protection from falling objects and accidental head knocks.

Head protection is extremely important because it guards your most vital organ (your brain).

As we have previously said, a head injury can physically disable a person for life and can even result in death.

Head protection can help prevent such injuries. Approximately 80% of industrial head injuries are a result of people not **wearing hard hat** protection. You need to wear your safety helmet whenever it is required and should ensure that it is worn correctly,

The following are types of personal protective equipment critical for the defense of users against hazards.

- ✓ **Hearing protection**

The hearing protection equipment is vital when working in an environment with high-sound levels. The type of hearing protection should not only be suitable for the working environment but also provide a level of hygiene and comfort to the users. Examples of hearing protection equipment: Earplugs, Ear defenders or earmuffs, Acoustic foam.

Fig.1.6: Earplugs

Fig. 1.7: Earmuffs

Handling of safety equipment needed for solar power

✓ Ensure the operator is trained and qualified to operate the equipment.

✓ ensure the correct equipment is used for the job.

✓ provide personal protective equipment for employees.

✓ plan any work to minimise risks identified.

✓ use appropriate warning signs.

✓ provide appropriate training and guidelines to employees.

✓ maintain and check equipment regularly.

Use of safety equipment used for solar power plant:

The Importance of Personal Protective Equipment. ... PPE is equipment that will protect workers against health or safety risks on the job.

The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

It also includes respiratory protective equipment (RPE).

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment's manuals

Points to Remember (Take home message)

- Handling of safety equipment needed for solar power
- Safety equipment used for solar power plant operation

Learning outcome 3 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) The hand protection equipment can ensure protection against heat, cold, vibrations, burns, cuts by sharp objects, bacteriological risks and chemical contamination.

b) The foot protection equipment is designed to protect the feet and legs against various hazards

c) the hands injuries can be avoided simply by wearing the proper eye and face

d) Eye injuries can be avoided simply by wearing the proper eye and face protection equipment.

Answer: a) True, b) True, c) False, d) True

Q2. Choose any three (3) Handling of safety equipment needed for solar power

i. provide personal protective equipment for employees.

ii. Non-flame-resistant materials that have been chemically treated to be made flame resistant

iii. Inherently flame-resistant materials such as PBI (Polybenzimidazole), Kermel, and Nomex Work Clothing

iv. plan any work to minimise risks identified.

v. use appropriate warning signs.

Answer:

i. provides personal protective equipment for employees.

iv. plan any work to minimise risks identified.

v. use appropriate warning signs.

Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

- Assessment tools

  How will be completely wearer at field standard work properly for avoiding any risks at workplace.

Answer:

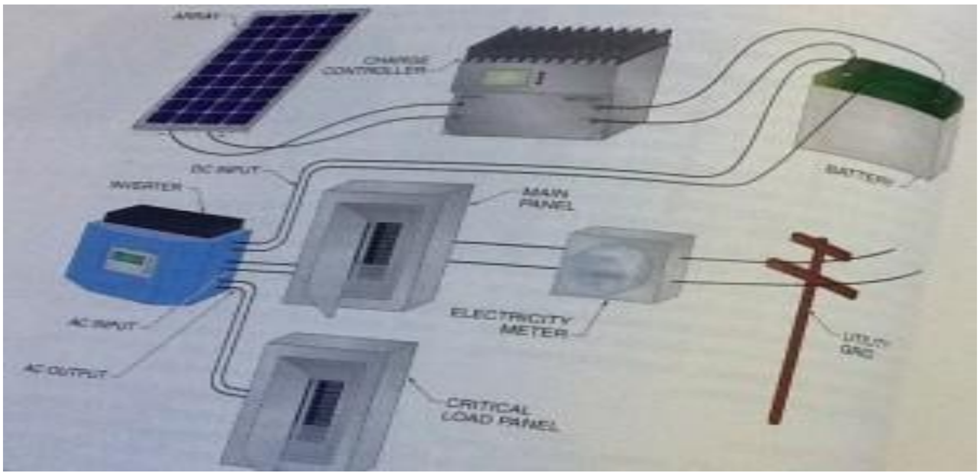
Checklist	Score	
	Yes	No
Identification of PPE		
Use of PPE		
Observation		

References:

1. Principles of power system, V.K MEHTA , ROHIT MEHTA, S.CHAND &COMPANY, NEW DELHI 2004

2. http://www.ebay.com/bhp/high-voltage-tester

LEARNING UNIT 2: Monitor Solar power plant equipment



STRUCTURE OF LEARNING UNIT

Learning outcomes:

1. Check solar modules

2. Monitor Charge controllers

3. Control batteries

Duration: 10hrs

Learning outcome 1 objectives :

By the end of the learning outcome, the trainees will be able to:

1 Proper checking of solar modules according to their types

2. Proper monitoring of charge controllers according to their connection

3. Proper control batteries according to manufacturer’s information

4. Proper control inverters according to their connection

Resources

Equipment	Tools	Materials
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

Learning Outcome 2.1: Check solar modules

Check solar rays striking solar panels

Light striking crystals such as silicon or germanium, in which electrons are usually not free to move from atom to atom within the crystal, provides the energy needed to free some electrons from their bound condition.

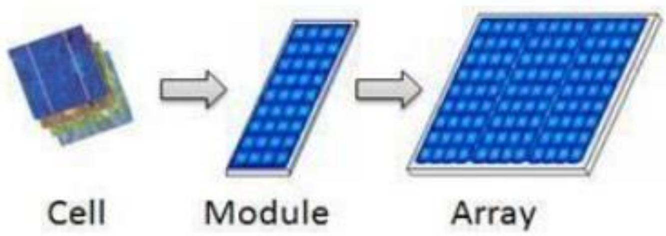
Free electrons cross the junction between two dissimilar crystals more easily in one direction than in the other, giving one side of the junction a negative charge and another of positive charge, therefore, a negative voltage with respect to the other side of positive, just as one electrode of a battery has a negative voltage with respect to the other of positive, thus solar cell produce d.c electricity.

The photovoltaic effect can continue to provide voltage and current as long as light continues to fall on the two materials.

Combination of more solar pv cells for increasing output voltage or current result a device called solar pv module (solar panel), whereas the combination of solar pv modules is array. solar cell configuration

iii. Irradiance & Insolation In electricity, we use power (W) and energy (Wh). Similar to this, solar radiation energy also has power and energy.

Here, power is recognized as intensity of sun light. The intensity of solar energy is called irradiance and the energy is called insolation. Do not mix them up Irradiance starts to increase from dawn and reaches its maximum at noon. Then it reduces till dusk.



It very important that you understand the flow of energy from input to output and the role of each device Cleary as follow:

✓ To obtain electricity PV module is used. PV module is a power generation.

✓ To store electricity, rechargeable battery is used since power generation is during day time only.

✓ To use rechargeable battery from controller is necessary to protect battery from overcharge and over discharge.

✓ When loads require AC electricity, DC-AC inverter is necessary to convert DC into AC since solar PV system use DC internally.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment's manuals

Points to Remember (Take home message)

- Handling of safety equipment needed for solar power
- Safety equipment used for solar power plant operation

Indicative content 2.1.2. Check the connections between solar panels

Check the connections between solar panels

Connection of photovoltaic modules: series or parallel

When connecting multiple solar panels in a 12-48 volt off-grid system, you have a few options: parallel, series, or a combination of the two.
In this article, we'll give you the basics on wiring solar panels in parallel and in series.
Let's start off with a quick comparison of parallel circuits and series circuits.

Parallel circuits

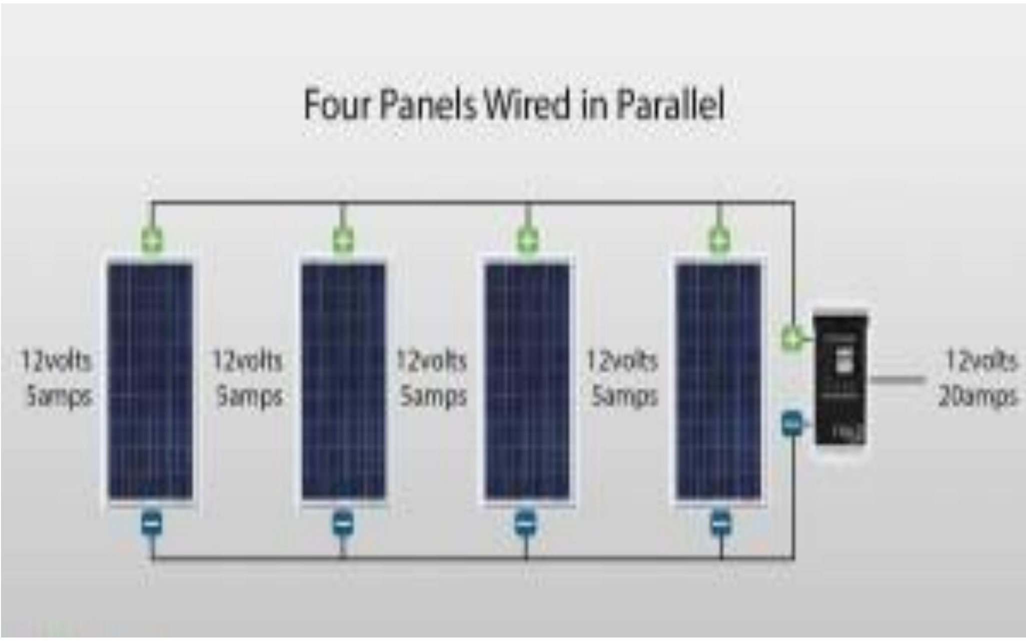
Parallel connection circuits have multiple paths for the current to move along. If an item in the circuit is broken, current will continue to move along the other

paths, while ignoring the broken one. This type of circuit is used for most household electrical wiring. For example:
when you turn off your TV, it doesn't also turn off your lights.

When wiring solar panels in parallel, the amperage (current) is additive, but the voltage remains the same.

- ✓ **Wiring Solar Panels in a Parallel Circuit**

Connect all the positive terminals of all the solar panels together, and all the negative terminals of all the panels together.E
Eg : If you had 4 solar panels in parallel and each was rated at 12 volts and 5 amps, the entire array would be 12 volts at 20 amps

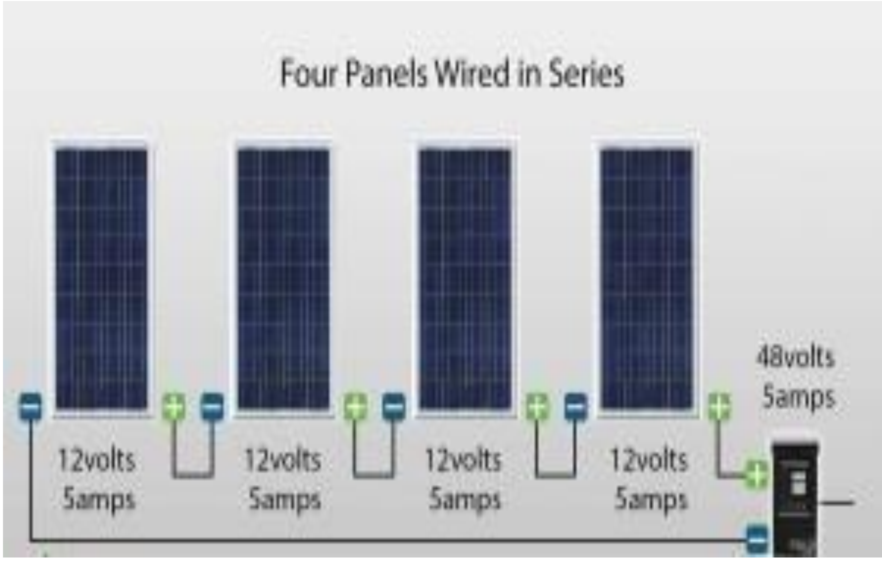


- ✓ **Series circuits**

Series connection circuits have only one path for current to travel along. Therefore, all the current in the circuit must flow through all the loads. A series circuit is a continuous, closed loop - breaking the circuit at any point stops the entire series from operating. An example of a series circuit is a string of old Christmas lights - if one bulb breaks, the whole string turns off. When wiring solar panels in a series, the voltage is additive, but the amperage remains the same. eg. If you had 4 solar panels in a series and each was rated at 12 volts and 5 amps, the entire array would be 48 volts and 5 amps.

Remember: just like batteries, solar panels have a negative terminal (-) and a positive terminal (+). Current flows from the negative terminal through a load (current consumed by a piece of equipment) to the positive terminal.
Wiring Solar Panels in a Series Circuit

- Connect the positive terminal of the first solar panel to the negative terminal of the next one.
- eg. If you had 4 solar panels in a series and each was rated at 12 volts and 5 amps, the entire array would be 48 volts at 5 amps.



Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment's manuals to inverter for converting produce DC energy from PV modules.

Points to Remember (Take home message)

Working principle of solar inverter

Indicative content 2.1.3. Check the output voltage at solar panels

Check the output voltage at solar panels

Wiring at PV Array and Shading Effect Connections at the Module Level Now that we have covered the basics of series and parallel connections of PV cells when we discussed the I-V characteristics, it is time to understand the bigger picture by investigating the connections at the module level.

In this lesson, we will define a new commonly used term in the solar PV industry, which is the PV string. We will look at how the total voltage and current characteristics change as a result of these formations. In addition, we will discuss how characteristics are affected by the pattern of shading applied to the PV system.

A PV string is formed when multiple modules are connected in series. In this case, the string I-V curve is the same as the individual I-V curve of each module, but it is scaled in voltage by the number of modules connected in series while the current stays similar to the individual module's current.

PV strings can be as small as one module, or can have multiple numbers of modules in series.

When strings are combined in parallel form, that leads to a scaled current by the number of strings, while voltage equals the individual string's voltage. A PV system can consist of a single string or multiple strings, depending on the size of the system. Blocking Diode Moving to the shading effect on PV systems, similar to the modules level effect, when one module is shaded within the string, the entire string can lose power by the restriction of current flowing through the string.

As the modules solution suggested, the bypass diodes will clear the shading effect by bypassing the shaded module. As a result, that will have a voltage drop impact on the total string voltage that may interfere with the other parallel strings within the system, since equivalent array voltage is dictated by the string with the lowest voltage.

Reflection

What about the scenario when we have a row of shading that covers the same number of modules on each string? Click for answer... For that reason, some designers choose to add a blocking diode to prevent the current from flowing back to the weak string, and that will eliminate fire hazards as well. Illustrates the bypass and blocking diodes at the system level and how the total voltage is affected by it. We can see nine PV modules wired to form a PV array.

Each group of three modules is connected in series to form a string, for a total of three strings.

Each module uses a dedicated bypass diode that only actives when the module is shaded. For example, there is a green colored triangular shape that represents the bypass diode.

That is associated with the shaded module illustrated in dark blue in the bottom left corner. We can also see red coloured triangles that represent the blocking diodes in series with each group to protect the entire string. Assuming each module generates 1V, the unshaded strings generate a total of 3V while the shaded string can only generate 2V (due to the bypass diode effect). In this case, the blocking diode will protect the shaded string from draining current from the unshaded strings.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant equipment’s manuals to inverter for converting produce DC energy from PV modules.

Points to Remember (Take home message)

Working principle of solar inverter

Learning outcome 1 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) The hand protection equipment can ensure protection against heat, cold, vibrations, burns, cuts by sharp objects, bacteriological risks and chemical contamination.
b) The foot protection equipment is designed to protect the feet and legs against various hazards

c) the hands injuries can be avoided simply by wearing the proper eye and face
d) Eye injuries can be avoided simply by wearing the proper eye and face protection equipment.

Answer: a) True, b) True, c) False, d) True

Q2. Choose any three (3) Handling of safety equipment needed for solar power

i. provide personal protective equipment for employees.

ii. Non-flame-resistant materials that have been chemically treated to be made flame resistant

iii. Inherently flame-resistant materials such as PBI (Polybenzimidazole), Kermel, and Nomex Work Clothing

iv. plan any work to minimise risks identified.

v. use appropriate warning signs.

Answer:

i. provides personal protective equipment for employees.

iv. plan any work to minimise risks identified.

v. use appropriate warning signs.

Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

- Assessment tools

Construct the Wiring Solar Panels in a Parallel Circuit

Answer:

Checklist	Score	
	Yes	No
Output voltage		
Connection of solar modules		
Observation		

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LEARNING OUTCOME 2.2. Monitor Charge controllers

Duration: 12hrs

Learning outcome 2 objectives :

By the end of the learning outcome, the trainees will be able to:

1 Proper checking of solar modules according to their types

2. Proper monitoring of charge controllers according to their connection

3. Proper control batteries according to manufacturer's information

4. Proper control inverters according to their connection

Resources

Equipment	**Tools**	**Materials**
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

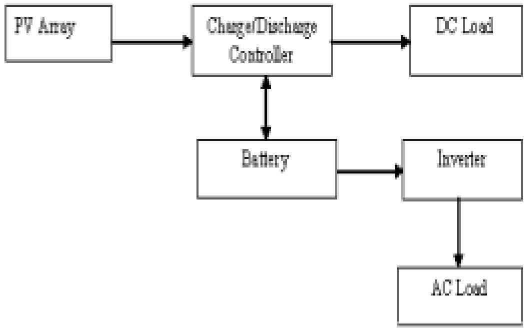
. Hand out notes

. Internet

. Expert who is qualified in that field location

2. 2 .1: Connection of charge controller to the panels

BLOCK DIAGRAM



OPERATION OF CHARGE /DISCHARGE CONTROLLER

There are different types of charge and discharge controller exists

But here we are developing the charge discharge controller using MOSFET. The input of charge/discharge controller varies from (13-14) V to 20V and the standard battery voltage is 20V (lead-acid maintenance free battery).

The voltage level of this battery is maintained between 11.5V and 14.5V for longevity of battery life i.e. maximum of 14.5V and the charge should not go below 11.5 V.

In worst case, the battery should never be discharged below 10.8V.

Therefore, it is necessary to design a suitable battery charge and discharge controller for solar compatible equipment.

Example: solar inverter, solar lighting system, solar water pump, etc.

Indicative content 2.2.1. Connection of charge controller to the panels

Connection of charge controller to the panels

What is the behavior of the two solar charge controllers technologies?

And now we see two photos we took to show the behavior of the current in the pwm charge controller PR3030 and mppt charge controller Solarix. As we used a panel solar panel 100W monocrystalline silicon. The angle of the panel was not exactly perpendicular to the sun's rays needed for a "photographic". The battery is a 12V Lead-acid Fiamm battery.

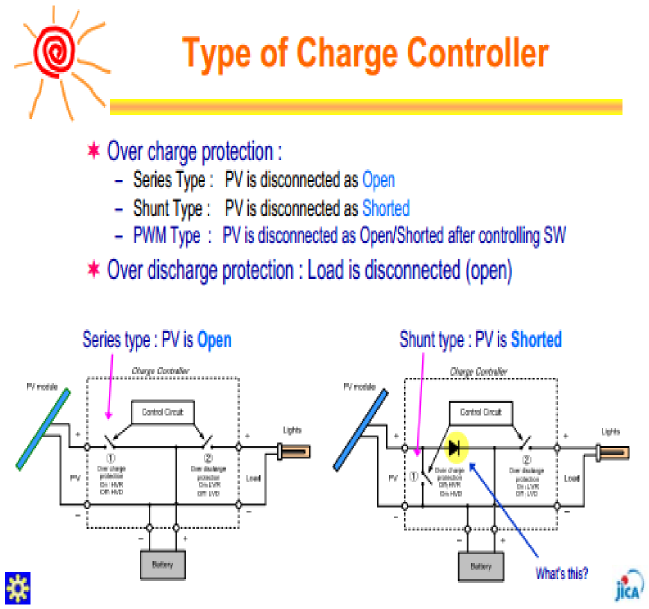
1) Pwm solar charge controller PR3030

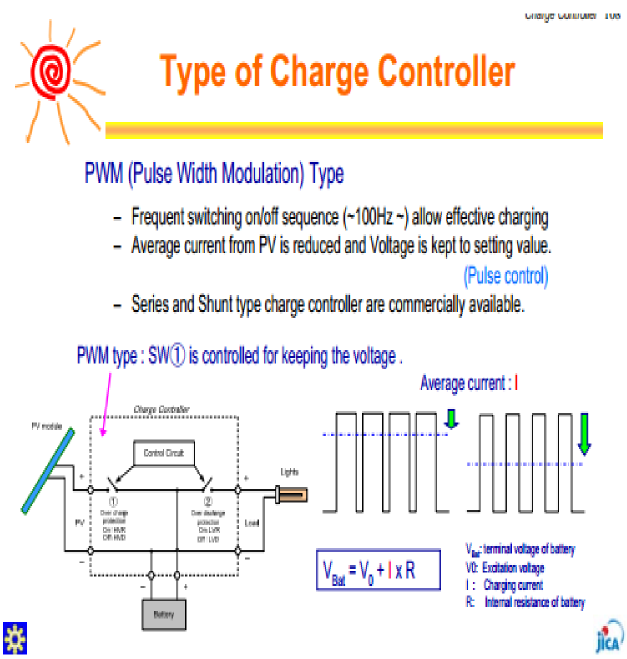
As can be seen from the picture, leaving the panel we have a current of 1.60 A, which is used almost entirely by the controller pwm (1.57 A) to charge the 12V battery. The solar charge controller PR3030 can withstand currents of up to 30A and also presents the display function of the percentage of battery charge. In this case, informs us that the battery is charged to 76%.

2) Mppt solar charge controller Solarix

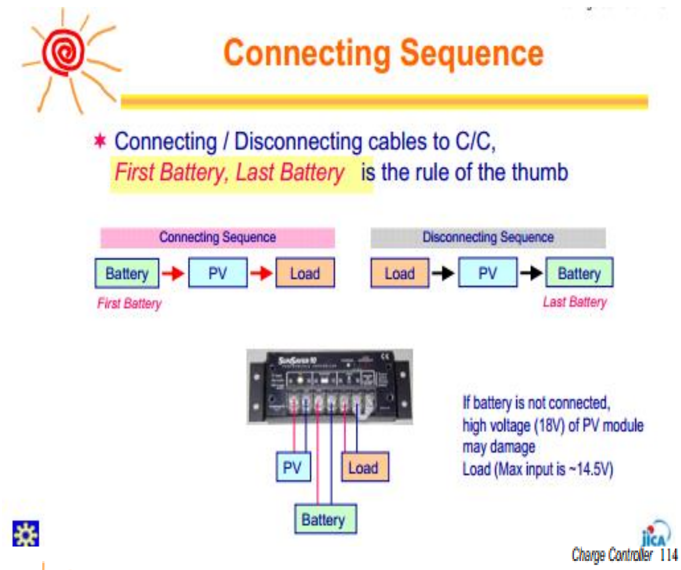
Unlike the regulator pwm which considers only the current to the end of charging, **the regulator mppt Solarix considers all the power** of the photovoltaic panel (then voltage and current). In fact the difference between the voltage delivered by the panel (example 36V) and the necessary voltage to the battery at that moment (example 14V) is not lost but is transformed by the current regulator mppt useful to the process of charging. From the picture it is seen that the output current from the panel is of 1.68 A, but the current that goes to the battery is even of 2.07 A. With the mppt solar charge controller Solarix use all the power of the panel!

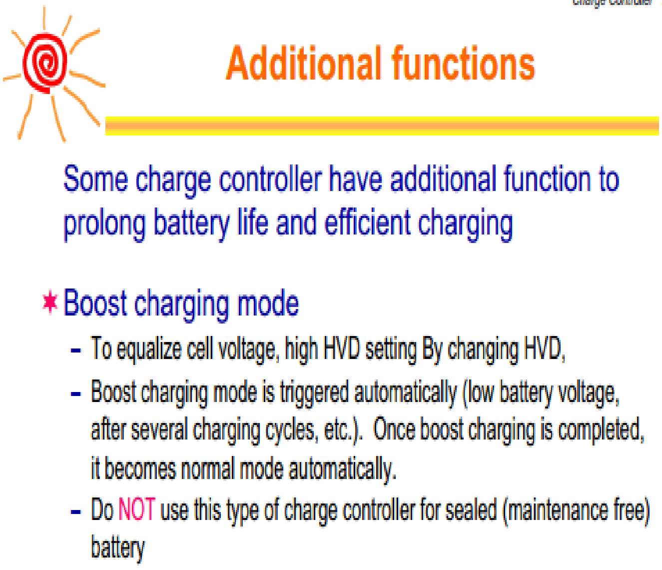
- **Charge controllers**





- ✓ Connection of solar panels to charge controllers
- ✓ Connection of inverters to charge controllers





In other words, the battery offers higher energy per unit of weight. On the "y" axis, the volumetric energy density increases as we go up. In other words, the amount of energy in higher per unit of volume. ,

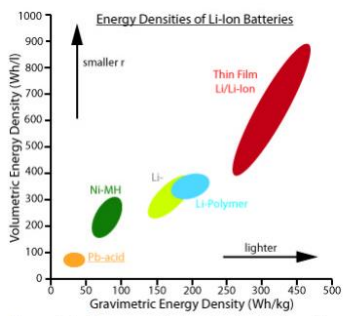


Figure 3.3: Ragone plot showing the Volumetric energy vs Gravimetric energy of different battery types
Credit: Ragone Plot for diff Li batteries [2] / Chem511grpThinLiBat / CC BY-SA 4.0 [3]

Volumetric energy density is the amount of energy stored per unit volume of battery. The typical unit of measurement is Wh/l.

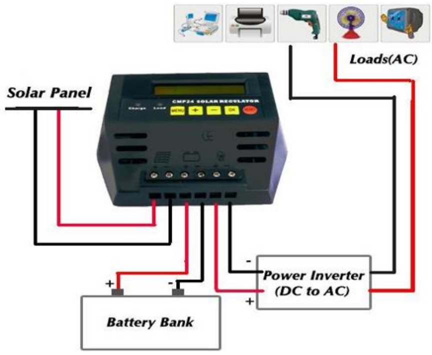
We can observe that the higher the volumetric energy density, the smaller the battery size. Gravimetric energy density is the amount of energy stored per unit mass of the battery.

The typical unit of measurement is Wh/kg. We can also observe that the greater the gravimetric energy density, the lighter the battery.

As shown in Figure 3.3, lead-acid shows the lowest volumetric and gravimetric energy densities among the batteries, while Li-ion exhibits the best combination.

Reflection Since Lithium-ion batteries have the best properties in terms of energy and power density, why isn't it the most widely spread technology for PV applications?

That said, let's look a little bit more closely at the lead-acid battery. Similar to most batteries, **the lead-acid battery consists of several individual cells, each of which has a nominal voltage of around 2 V.**



The switch at PV module side is used for over charge protection. the switch at load side is used for over discharge protection.

<u>- Over charge protection</u>

The basic mechanism of over charge protection is simple.

When the battery is fully charged, the PV module is disconnected from the battery so that further charging (over charging) can be stopped.

Therefore, there is a switch (A) between the terminals of PV module and the terminals of battery. This switch (A) is normally ON.

This switch (A) is OFF only when the battery voltage reached the certain voltage which is recognized that beyond this voltage is over charge.

<u>Over discharge protection</u>

The basic mechanism of over discharge protection is simple.

Before the battery is discharged to empty status, the load is disconnected from battery so that further discharging (over discharging) can be stopped.

Therefore, there is a switch (B) between the terminals of load and the terminals of battery. This switch (B) is normally ON.

This switch (B) is OFF only when the voltage of battery decreased to the certain voltage which is recognized that beyond this voltage is over discharge.

Under normal operation,

The switch (B) is always ON since the voltage of battery does not go low as solar PV systems are designed in that way.
There are two cases that switch (B) is OFF.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Proper checking of solar modules according to their types.

Points to Remember (Take home message)

The connection behaviour of solar charge controller

Indicative content 2.2.2. Connection of charge controller to batteries

Connection of charge controller to batteries

The entire system is designed with a conventional feedback regulator with a p-channel MOSFET as the series element and a quad operational amplifier IC LM-324. The op-amp U3C is used as a reference voltage generator.

This amplifier with the reference diode D12(LM-385- 2.5V) is a band gap regulator situated in the feedback loop of this IC. It generates a constant 5V reference voltage for all the other op-amps which are used as comparators.

Op-amp U1A is used as a charge controller which controls the series pass regulator MOSFET and maintain its output voltage constant at a set level by comparing its output voltage with the reference voltage.

The charging limit (14.5V) is set by the pre-set R11 so that the battery receives a float change of 14.2V after a drop of nearly 0.3V across the diode D2.

SELECTION OF Charge controller

As we said, the choice of technology of the charge depends on the type of panels that have or want to install both the battery bank. The controller pwm normally costs less than an MPPT controller, but the controller mppt is able to take full advantage of a solar panel with **voltage higher** than the batteries bank one and therefore enables the production of more energy compared to a regulator pwm. If the voltage of the panel is slightly greater than that of the battery (typical case of a panel to 12V and 12V battery 30 cells), the controller pwm is recommended because it has a daily yield in this case similar all'mppt. Below so we made a very simple **table** where you will find the technology of the charge controller to use based on:

1) Number of cells that make up your panels

2) Voltage of the battery bank that you want to charge

Panels + Batteries	Type of Controller
36 cells Panels + 12V Batteries	MPPT
48 cells Panels + 12V/24V Batteries	MPPT
54 cells Panels + 12V/24V Batteries	MPPT
72 cells Panels + 12V/24V Batteries	MPPT
144 cells Panels + 48V Batteries	MPPT
30 cells Panels + 12V Batteries	PWM
60 cells Panels + 24V Batteries	PWM
120 cells Panels + 48V Batteries	PWM

One is overuse the other is end of battery life.

Overuse is the situation that the user consumes energy more than power generation every day. The shortfall of power generation is drained from the stored energy in the battery.

Therefore, after several days of overuse, the voltage of battery decreased to low level.

It is an important component because it plays a few different roles.

- It monitors the working of the batteries and it regulates the charging of the batteries.

▪ If batteries are not connected with a charge controller, they can get overcharged easily.

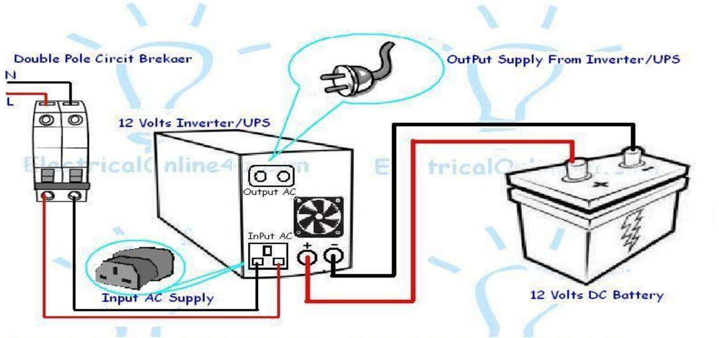
- The charge controller changes the rate of charging at a fixed voltage which is called set point.
- To determine the set point, the pattern of usage and the type of battery used is considered.

Some charge controllers have set points that can be easily adjusted whereas others do not.

▪ If a charge controller is not used it is difficult to discontinue the process of charging when the batteries are fully charged.

If you have a wind turbine at your home, a charge controller is a must for your house.

The charge controller also helps in redirecting excess energy.



▪ When the charging process is complete, the charge controller diverts the extra energy to some other work such as heating water.

In modern charge controllers, a pulse width modulation system is used.

In this system, the amount of energy transferred to a battery reduces slowly when the battery reaches near the maximum charge point.

▪ It reduces the stress on the battery and enhances its life. There is less power loss and power generated from the solar panels is used efficiently for various purposes in your home.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Proper checking of solar modules according to their types.

Points to Remember (Take home message)

- **important component**
- **Connection of charge controller to batteries**

Indicative content 2.2.3. Status of charging of the batteries

Status of charging of the batteries

There are three main things to consider choosing a Solar panel or creating a Solar system.

1: How much energy can your battery store?

2: How much energy will your appliance(s) use over a period of time?

3: How much energy can a Solar panel generate over a period of time?

Firstly, you need to know how much energy your battery can store and then select a Solar panel that can replenish your 'stock' of energy in the battery in line with your pattern of use.

Battery Charging Station (BCS)

There is a type of solar PV system that shares PV array by users.

Each user bring their battery to the battery charging station.

Users bring their battery to charging station when battery is empty, normally twice a month.

If the user do not have money for charging, they will leave battery uncharged over months.

This usage style develops sulfation of battery that cause short life of battery. Therefore, running cost in total is more than SHS due to short cycle of battery replacement.

The initial system cost of BCS itself is cheaper than SHSs since it does not inclue the cost of components at each household. On the other hand, the cost per available power is more than SHS.

Therefore, BCS is not economical compare to SHS.

<u>This system has following disadvantages.</u>

✓ Heavy battery has to be carried to the charging station from user‟s house. This work tends to be burden for wemen or children.

✓ Acid is spilt during carrying battery, and it is hazardous for skin.

✓ Battery life is short compare to SHS. Because battery is always deep discharged so that sulfation is developped rapidly.

✓ Available power is much less than SHS.

✓ For long term cost versas available electricity, SHS is much economical.

1: How much energy can your battery store?

Battery capacity is measured in Amp Hours (e.g. 17AH). You need to convert this to Watt Hours by multiplying the AH figure by the battery voltage (e.g. 12V). this is just the simple calculation below

- X (Battery size in AH) x Y (Battery Voltage) = Z (Power available in watt hours
- For a 20AH, 12V battery the Watt Hours figure is 20(X) x 12(Y) = 240 WH (Z)

This means the battery could supply 240W for 1 hour, 120W for 2 hours or even 2w for 120 hours i.e. the more energy you take, the faster the battery discharges.
However, you are never really able to take all the power from a battery as once the voltage drops below your equipment's requirements it will no longer be able to power it. There is a simple rule of thumb for this but please check your battery's specifications to make sure.
Lead acid batteries will give you around 50% of their rated power. (I.e. a 10Ah battery has 5Ah of usable power)
Li-ion battery's will give you around 80% of their rated power. (i.e. a 10Ah battery has 8Ah of usable power)
A common question that people ask regarding the battery's is,

QUESTION: Are car battery's just as good for solar as leisure battery's?

ANSWER: The answer to this is no they are not. The reason is because a leisure battery has been designed to be discharged and recharge, a Car battery is designed to provide a lot of power quickly but it's not able to cope with a low internal charge and recover fully.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Proper checking of solar modules according to their types.

Points to Remember (Take home message)

- Battery Charging Station (BCS)

Learning out come 2 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) To determine the set point, the pattern of usage and the type of battery used is considered.
b) Are car battery's just as good for solar as leisure battery's?
c) If batteries are not connected with a charge controller, they can get overcharged easily.
d) The charge controller changes the rate of charging at a fixed voltage which is called set point.

Answer: a) True, b) False, c) True, d) True

Q2. Choose any three (3) three main things to consider choosing a Solar panel or creating a Solar system.

a. How much energy can your battery store

b. How much energy will your appliance(s) use over a period of time

c. How much energy can a Solar panel generate over a period of time

d. Available power is much less than SHS.

e. For long term cost verse as available electricity, SHS is much economical.

Answer:

a. How much energy can your battery store

b. How much energy will your appliance(s) use over a period of time

c. How much energy can a Solar panel generate over a period of time

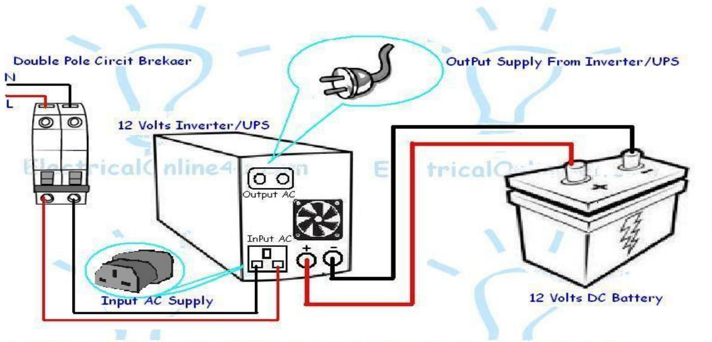
Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

- Assessment tools

Construct the Connection of charge controller to batteries

Answer:



Checklist	Score	
	Yes	No
Connection of Batteries, inverters and or load		
State of charging of the batteries		
Observation		

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LEARNING OUTCOME 2.3: Control batteries

Duration: 10hrs

Learning outcome 3 objectives :

By the end of the learning outcome, the trainees will be able to:

1 Proper checking of solar modules according to their types

2. Proper monitoring of charge controllers according to their connection

3. Proper control batteries according to manufacturer's information

4. Proper control inverters according to their connection

Resources

Equipment	Tools	Materials
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

Indicative content 2.3.1. Connection of the batteries (Their terminals)

Connection of the batteries (Their terminals)

Batteries should be regularly and carefully maintained to extend their useful life. These activities include:

1. Inspecting and cleaning regularly
2. Checking the electrolyte level (not required for Gel Batteries)
3. Keeping in a high state

Battery Inspection and Cleaning   A visual inspection should be done to assess the general condition of the system's batteries.   Check for any electrolyte leak, cracks in the batteries, or corrosion at the terminals or connectors

Effects of poor maintenance techniques are shown in the pictures below

free of electrolyte and corrosion residue. Corrosion at battery terminals is seen as a white coating around the battery terminals. Cleaning should be done once monthly

PRECAUTIONS

To minimize hazards, the following precautions should be taken prior to carrying out battery maintenance:

- Safety goggles must be worn when performing battery maintenance
- Protective gloves and chemical-resistant rubber gloves must be worn to prevent contact with battery acid.
- If there is acid spillage, neutralize the acid with a water and bi-carbonate soda solution. Metal files should not be used to remove corrosion.

• Use tools with insulated handles to carry out any maintenance.

- Do not smoke or light
- Do not smoke or light fire near batteries.
- Batteries produce hydrogen gas which is highly flammable

Before maintenance is carried out, each component of the system should be isolated.

This would involve switching off circuit breakers to and from the battery bank and the solar panels.

BATTERY CLEANING PROCEDURES ARE AS FOLLOWS:

1. Switch off/disconnect all loads on the system. Turn off or disconnect the solar charge. Then turn off the circuit breaker to and from the battery bank.
2. Ensure that the caps on the batteries are sealed tight to keep any dirt from entering the battery. Wipe the top and outside of the battery with a (damp) cloth. If corrosion is present at the terminals, mix baking soda with fresh water and apply the solution to the affected area. Stubborn areas should be scrubbed with a metal brush. After cleaning, rinse the terminals with water. If available, apply petroleum jelly or grease to the connected terminal to prevent future corrosion.
3. Maintenance of gel cell and AGM batteries relates only to the battery terminals and connections. The terminals and posts should be wiped until they are shiny, and if corroded, clean them properly with Bi-carbonate soda and water. If available, apply petroleum jelly or grease to the connected terminals.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant Proper control batteries according to manufacturer's information

Points to Remember (Take home message)

- Connection of the batteries
- BATTERY CLEANING PROCEDURES

Indicative content 2.3.2. Input/output voltage of the batteries

Input/output voltage of the batteries

Calculation of total watt-hours per day Multiply the total appliances Watt-hours per day (E4) times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels. Ep = E4 x 1.3 Calculation of depth of discharge DOD a measure of how deeply a battery is discharged. When a battery is 100% full, the DOD is 0%. Ampere hours removed from a fully charged cell or battery, is expressed as a percentage of rated capacity.

For example, if 25 Ah are removed from a 100 Ah battery, it's depth of discharge is 25% and the battery is at a 75% state of charge. OK, with the definition taken care of, why is DOD an important part of calculating battery capacity? First another definition: A Cycle is a period of discharge and recharge is called one cycle.

A battery cycle is one complete discharge and recharge cycle. It is usually considered to be discharging from 100% to 20% DOD, and then back to 100%. One of a Battery's performance indicators is the measure of the expected number of cycles it may deliver. The greater the average depth-of-discharge, the shorter the cycle life. Be careful when looking at ratings that list how many cycles a battery is rated for unless it also states how far down it is being discharged.

A battery that is rated for a 20 years life expectancy if discharged by only 15% may have a 5 years life expectancy if discharged to 50%. Typically, batteries ratings are in AHr are published to 100% discharge.

A discharge level that you should avoid. (Careful again some companies name their batteries based on 100 hours to discharge! The longer the discharge time

e.g. 100 hr the more Ampere hours that can be squeezed from a battery. Battery ratings should be compared at 20 hr discharge rate for off-grid purposes.)

Calculation of battery nominal voltage

While calculating load in Ah, it is very critical to define which voltage was used to convert Wh into Ah.

The nominal voltage of a power module (modules that are used for charging 12 V batteries) is taken as 12 V, though it may operate in any voltage range from 0 to Voc. The solar PV system voltage may be different than the nominal module voltage.

For example, if large AC loads are to be used, the large capacity inverter is required.

The nominal DC input voltage for large capacity inverters are no more 12 V, they are rather 48 V or higher.

Higher system voltage is selected in order to reduce the size of cable. With higher voltage, the same power can be delivered at lower current.

And since the required size of the cable depends upon the magnitude of the current, usually high voltage-low current configuration is used.

In this case the module/array voltage should match the system nominal voltage. And all the DC loads are to be selected to operate from the nominal system voltage. For a small home system 12 V could be selected as the system voltage. The DC input of a low capacity inverter is also 12 V.

Therefore, there should be no problem in using 12 V DC loads and smaller AC loads operated through the inverter.

But if the AC load is large (in the range of few kVA), the input DC voltage required may be even 120 or 240 V DC. In this case the array is wired to produce 120 or 240 V as system voltage.

Now there should be no question of using 12 V DC operated appliances in the system under consideration, unless separate module/array is wired to produce a system voltage of 12 V.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant Proper control batteries according to manufacturer's information

Points to Remember (Take home message)

- Input/output voltage of the batteries
- Calculation of battery nominal voltage

Indicative content 2.3.3. Acid level

Acid level

Lead-acid batteries could have different types of assembly. For example, the common lead-acid battery pack voltage is 12 V, which means 6 cells are connected in series.

When the battery is recharged, the flow of electrons is reversed, as the external circuit doesn't have a load, but a source that has a higher voltage than the battery can enable the reverse reaction.

In a PV system, this source is nothing but the PV module or array providing solar power and can charge the battery when the sun is available. As we learned previously in Lesson 1, the PV array when the sun is not available. In other words, the loads are at the mercy of the availability of the sun. In that case, an energy storage option such as batteries can be very useful.

As an example, a typical daily solar irradiance profile is shown in Figure 3.4. If we observe the orange curve that represents the daily solar irradiance, we can see that a significant amount of energy is generated during the daytime while no energy is generated during the night-time.

On the other hand, the daily energy demand represented in the blue curve shows that energy is needed all day long, with higher demands at certain time periods.

When we put the daily load demand curve (aka daily load profile) on the same figure, we see that a significant energy demand exists when there is no sun.

use of storage is more common in the stand-alone PV systems, because there is no other source of power to support

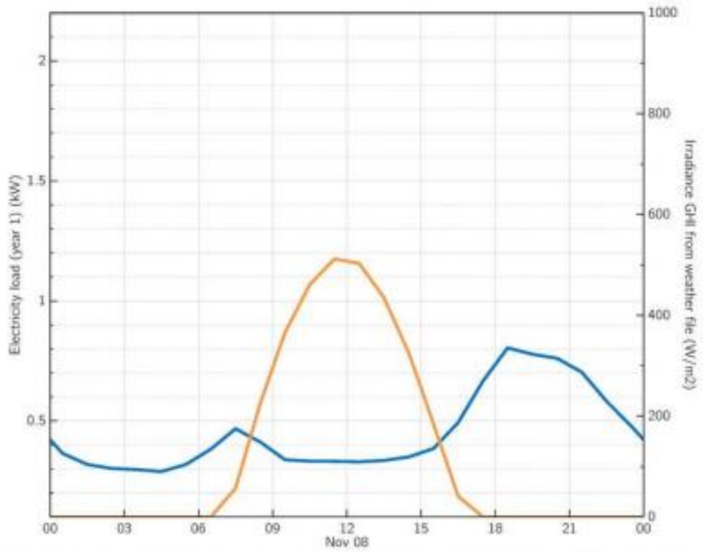


Figure 3.4: Daily solar irradiance (Orange) and daily load profile (Blue) for State College, PA.
Credit: Developed using SAM

For utility-interactive systems, the excess energy is fed back to the grid while the load demand can be supplied from the grid when the sun is not available.

As for a stand-alone system without storage, even though the sun has more than enough power during the day, the system fails to utilize this excess energy to power the loads when the sun is not available.

With the introduction of battery storage, the excess energy from the sun during the day can be stored in a battery and then used later to meet the load demand when the sun is not available.

This is represented in highlighted areas A1 and A2 in Figure 3.5, below, for excess solar power and evening load demand respectively.

The perfect match occurs when area A1 equals to area A2 and that can be accomplished by perfectly sizing the solar PV system to meet the average daily load energy demand. Furthermore, excess solar energy can be stored using Battery systems.

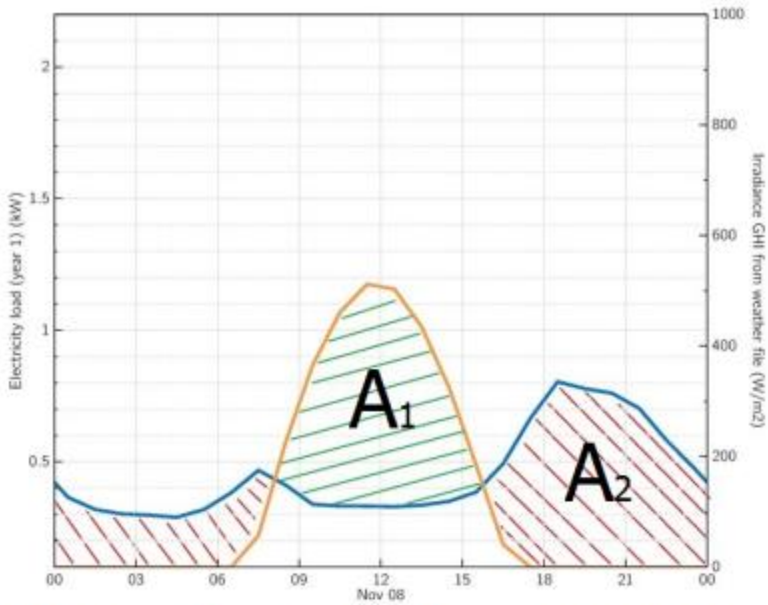


Figure 3.5: Excess solar energy highlighted (green) and daily load highlighted (red) for State College, PA.
Credit: Developed using SAM

In summary, we have seen different types of battery technologies and discussed why lead-acid is the battery of choice for most current PV systems.

We will talk in detail about battery parameters in the next topic. We will also see how managing battery parameters is a whole new optimization challenge on its own.

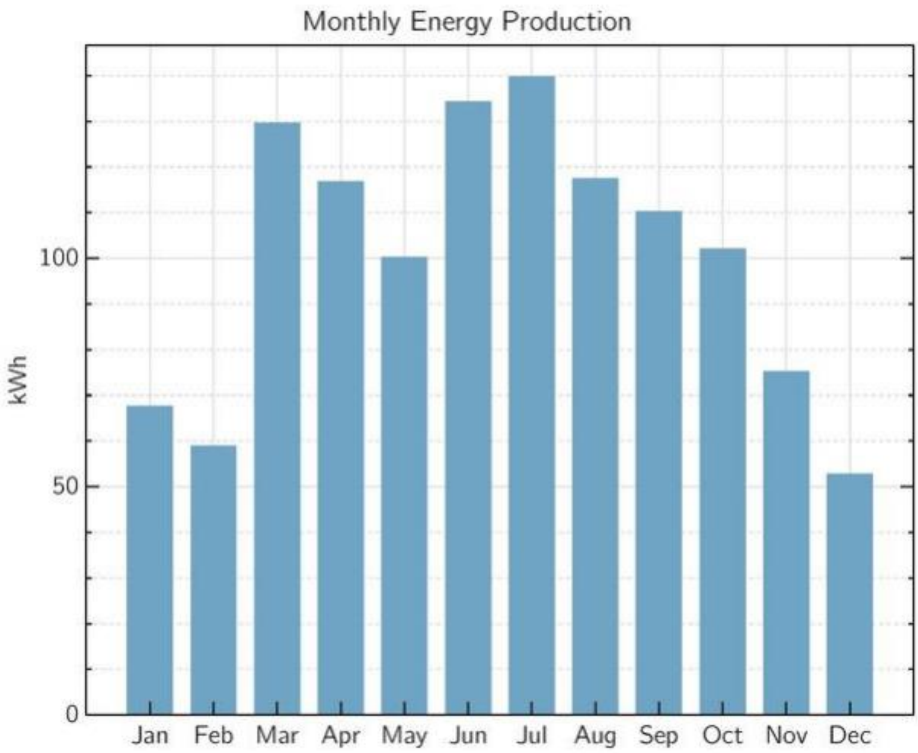
Source

Storage is needed in PV systems to overcome the intermittency of the energy generated.

These variations could be caused due to daily or monthly solar irradiance fluctuations. Daily fluctuation occurs as a result of the change of solar irradiance within the 24-hour period; while the seasonal (or monthly) fluctuations occur due to the change of solar irradiance across the summer and winter as seen in Figure 3.1. If we observe the monthly energy production of a 1 kW PV system installed in State College, PA, we can see that the generation increases during the summer months while the energy generation drops during the winter months.

We can see that the PV system will not generate the same amount of energy each month.

This means we need another complementary system to help even out the energy difference throughout the year.



In addition to solving the critical intermittency generations issue of solar PV, storage systems provide:

1. A potential resource for shifting energy from one time to another

2. A local source of energy to supply peak demand and potential enhancement for better reliability and resiliency.

3. A method to enable load shifting to improve asset utilization and defer other capital investment How do we make an optimal choice of a storage system?

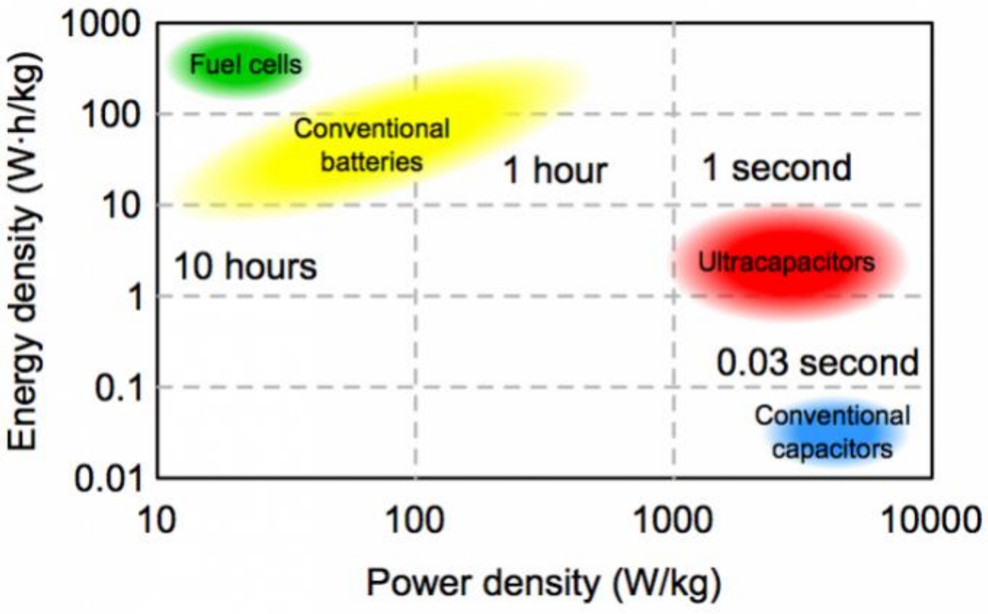
Depending on the desired application intended for a storage system, there are many factors that affect the selection decision. In general, each application requires either more power from the storage system or it may require more energy.

In Figure 3.2, the Ragone plot illustrates the power/energy density of various storage technologies.

It can be seen that some technologies, such as fuel cells, can generate higher energy density (in wh/kg) than technologies with lower energy density such as capacitors.

In other words, fuel cells can supply energy for longer time periods than can capacitors. In contrast, capacitors have higher power density (W/kg) than fuel cells, which means capacitors supply higher power for short periods than do fuel cells.

For example, a capacitor is a good choice for high power density requirements, but it is not the optimal choice for high energy density, as we can see in Figure 3.2.



Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant Proper control batteries according to manufacturer's information

Points to Remember (Take home message)

- Battery Charging Station (BCS)

Indicative content 2.3.4. Water level

- **Water level**

2. CHECKING THE ELECTROLYTE LEVEL

Battery maintenance involves checking the cell electrolyte level for correct acid volume once a month. The cells should be watered back to the original acid level which is ¼ - ½" below the bottom of the vent well (the tube inside

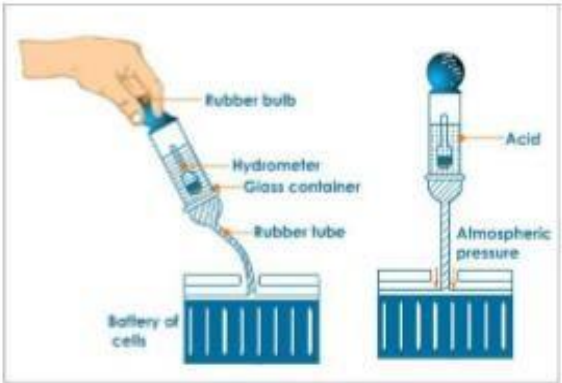
Attention!!!!!

Use only distilled water to top up the batteries.

Testing for the specific gravity of electrolyte in the battery is an accurate way to measure and compare the state of charge of each individual cell.

The process of checking the electrolyte specific gravity for a "Deep Cycle Flooded" Lead Acid battery is given below:

1. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.
2. Draw liquid into the hydrometer and avoid bumping the hydrometer. The float should not be flooded or sticking to the sides of the glass tube.
3. Obtain a reading by looking at the float which corresponds to a level on the tube. The acid level in the batteries should be within two centimeters of the top of the battery. A visual inspection could also be made to check the condition of the plates. Record the cell number and the results.
4. Do not replace liquid from one cell to another.



The table below shows typical battery state -of-charge at various levels of specific gravity.

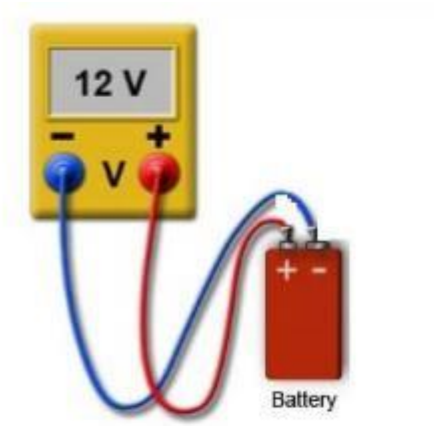
The voltages mentioned below are for 12v and 6V batteries

State of Charge	Specific Gravity	Voltage - 12V	Voltage - 6V
100%	1.265	12.7	6.3
75%	1.225	12.4	6.2
50%	1.190	12.2	6.1
25%	1.155	12.0	6.0
Discharged	1.120	11.90	6.0

Note that the table above gives only indicative values; specific gravity will vary somewhat depending on the battery type and brand, and on the battery's temperature.

The specific gravity readings of each cell should be recorded and maintained in a log sheet.

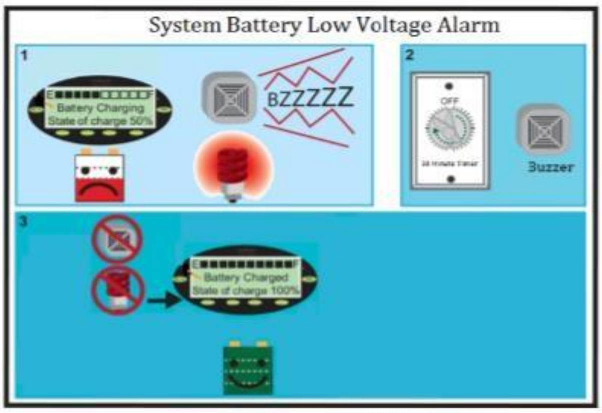
3. Check the battery voltage



Another important measure in determining the battery state of charge is the battery voltage. A volt meter is used to measure this quantity. The positive lead of the volt meter should be connected to the battery's positive terminal and the negative lead of the volt meter should be connected to the negative terminal of the battery. The table above shows the corresponding battery voltages and the corresponding state of charge of the battery**.**

Battery Alerts

The solar system has an alarm to produce a visual and audible indication to alert a low battery state of charge. When the battery state of charge falls to 50% the alarm will trigger and buzzer will sound for 10 minutes. The buzzer will be automatically turned off, but will start again every 10 minutes. Turn off lights connected to the solar system to avoid deterioration of the battery.



Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant Proper control batteries according to manufacturer's information

Points to Remember (Take home message)

- CHECKING THE ELECTROLYTE LEVEL
- The process of checking the electrolyte specific gravity

Learning outcome 3 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) To determine the set point, the pattern of usage and the type of battery used is considered.
b) Are car battery's just as good for solar as leisure battery's?
c) If batteries are not connected with a charge controller, they can get overcharged easily.
d) The charge controller changes the rate of charging at a fixed voltage which is called set point.

Answer: a) True, b) False, c) True, d) True

Q2. Choose the correct answer respectively, the process of checking the electrolyte specific gravity

a. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.

b. Do not smoke or light fire near batteries.
c. Draw liquid into the hydrometer and avoid bumping the hydrometer. The float should not be flooded or sticking to the sides of the glass tube.

d. Do not smoke or light

e. Obtain a reading by looking at the float which corresponds to a level on the tube. The acid level in the batteries should be within two centimeters of the top of the battery. A visual inspection could also be made to check the condition of the plates.

f. Batteries produce hydrogen gas which is highly flammable

Answer:

a. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.

c. Draw liquid into the hydrometer and avoid bumping the hydrometer. The float should not be flooded or sticking to the sides of the glass tube.

e. Obtain a reading by looking at the float which corresponds to a level on the tube. The acid level in the batteries should be within two centimeters of the top of the battery. A visual inspection could also be made to check the condition of the plates.

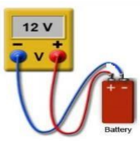
Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

- Assessment tools

Implement illustrate correctively Checking the battery voltage due to test

Answer:



Checklist	Score	
	Yes	No
Terminals of the batteries		
Acid and water level		
Observation		

References:

URL:https://www.e-education.psu.edu/ae868/node/895 Links [1] https://www.e-education.psu.edu/eme812/node/705 [2]
https://commons.wikimedia.org/wiki/File:Ragone_Plot_for_diff_Li_batteries.jpg [3]
http://creativecommons.org/licenses/by sa/4.0

Learning Outcome 2.4: Control inverters

Duration: 8hrs

Learning outcome 4 objectives :

By the end of the learning outcome, the trainees will be able to:

1. Proper checking of solar modules according to their types

2. Proper monitoring of charge controllers according to their connection

3. Proper control batteries according to manufacturer’s information

4. Proper control inverters according to their connection

Resources

Equipment	Tools	Materials
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

2.4.1: Connection of the input/output cables

Inverter stringing tool as it seems, the math can get very tedious, so most Inverter manufacturers create their own sizing tools that are available online for free, where you can choose:

1. PV module brand and model

2. The desired inverter model

3. The average highest ambient temperature and lowest (record) ambient temperature ranges (some tools allow user to choose the location and these temperature values will be already available).

The tool will then give all possible configurations (series and parallel) and the capacity factor.

An example of inverter stringing will be available in the Lesson Activity, where you can apply the knowledge to a real world example.

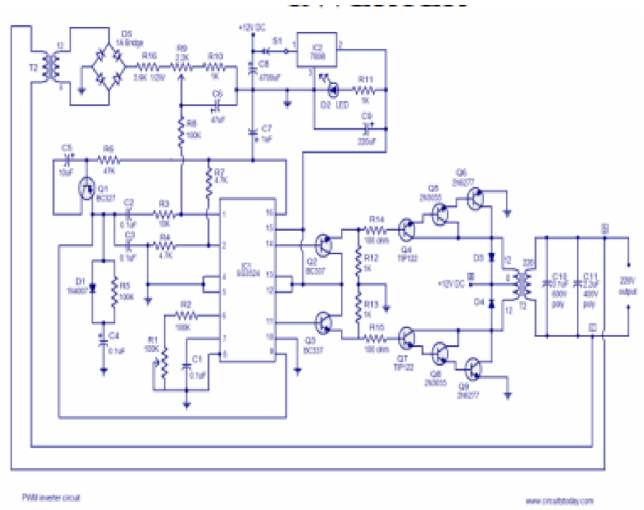
DC to AC ratio and inverter design as a rule of thumb, designers choose DC to AC ratio (AKA capacity factor) range not to be less than 80% and not to exceed 125% depending on the location and the irradiance and type of inverter used.

For example, for a system in Seattle, WA, it is recommended to oversize the PV array since it is very unlikely to overload the inverter since radiation is less than the STC power rating of the modules.

In contrast, in Miami, FL you cannot exceed 110% since radiation there reaches the STC level and may exceed it.

For best stringing choices, use the manufacturer's datasheet to determine the maximum and minimum allowed PV array sizes.

IV. CIRCUIT DIAGRAM OF PWM INVERTER



OPERATION OF PWM INVERTER A PWM inverter circuit using IC SG3524 is shown here.

This IC is an integrated switching regulator circuit that has all essential circuit required for making a switching regulator in Push-pull mode.

This circuit consists of pulse width modulator, oscillator, voltage reference, error amplifier, overload protection circuit, output drivers etc., SG3524 plays main role in PWM inverter circuit which can change its output voltage against the variations in the output voltage. In this circuit resistor R2 and Capacitor C1 sets the frequency of the ICs internal oscillator.

The pre-set switch R1 is used for fine tuning of the oscillator frequency.

Pin 14 and Pin 11 are the emitter terminals of the internal driver transistor of the IC.

The collector terminals (Pin 13 and Pin 12) of the driver transistors are connected to the +8V output pin of the IC 7808.

Two 50 Hz pulse trains which are 180 degrees out of phase are available at pin 14 and pin 15 of the IC 7808.

These are the signals driving the subsequent transistor stages.

When signal is high at pin 14, transistor Q2 is switched ON which turn makes transistor Q4, Q5, Q6 ON and the current flows from the +12V source(battery) connected at point a through the transistors Q4, Q5 and Q6.

As a result, a voltage is induced in the transformer secondary and this voltage contributes to the upper half cycle of the 220V output waveform. The working of voltage regulation section is as follows.

The inverter output (output of T2) is tapped from point's labelled b, c and supplied to the primary of the transformer T2.

The transformer T2 steps down this high voltage bridge D5 rectifies it and this voltage is supplied to the pin1 through R8, R9, R16 and this voltage is compared with the internal reference voltage.

This error voltage will be proportional to the variation of the output voltage from the desired value and the IC adjust the duty cycle of the drive signals in order to bring back the output voltage to the desired value.

Pre-set R9 can be used for adjusting the inverters output voltage as it directly controls the amount of voltage feedback from the inverter output to the error amplifier section.

IC2 and its associated components produce an 8V supply from the 12V source for powering the IC and its related circuitries.

Diode D3 and D4 are freewheeling diodes which protect the driver stage transistor from voltage spikes which are produced when the transformer primaries are switched. R14 and R15 limit the base current of Q4 and Q7 respectively.

R12 and R13 are pull down resistors for Q4 and Q7 prevents their accidental switch ON.

C10 and C11 are meant for bypassing noise from the inverter output. C8 is a filter capacitor for the voltage regulator IC 7808. R11 limits the current through the indicator LED D2.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret solar power plant Proper inspection of solar power plant components according to their types.

Points to Remember (Take home message)

- Connection of the input/output cables

2.4.2: Input/output voltage

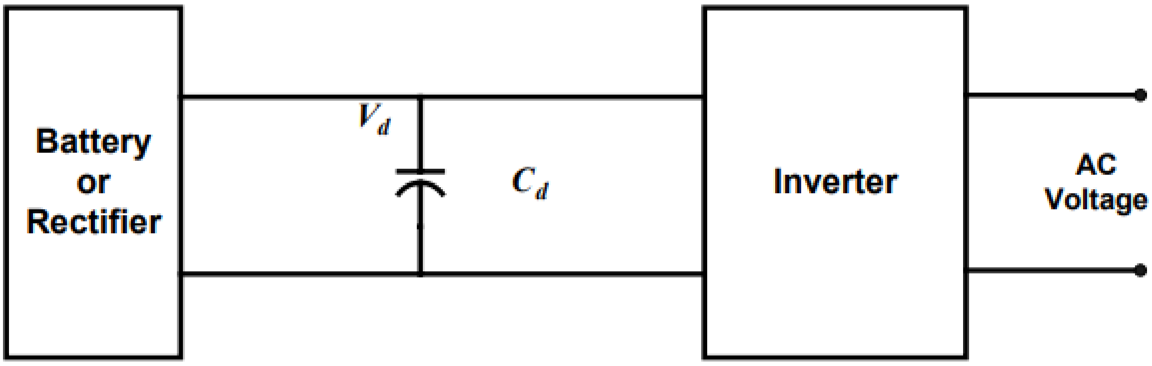


Figure 2.1: Schematic for Inverter System

The various methods for the control of output voltage of inverters can be classified as: (a) External control of ac output voltage (b) External control of dc input voltage (c) Internal control of the inverter. The first two methods require the use of peripheral components whereas the third method requires no external components. Mostly the internal control of the inverters is dealt, and so the third method of control is discussed in great detail in the following section.

Pulse Width Modulation Control

The fundamental magnitude of the output voltage from an inverter can be controlled to be constant by exercising control within the inverter itself that is no external control circuitry is required.

The most efficient method of doing this is by Pulse Width Modulation (PWM) control used within the inverter.

In this scheme the inverter is fed by a fixed input voltage and a controlled ac voltage is obtained by 18 adjusting the on and the off periods of the inverter components.

The advantages of the PWM control scheme are [10]:

a) The output voltage control can be obtained without addition of any external components.
b) PWM minimizes the lower order harmonics, while the higher order harmonics can be eliminated using a filter.

The disadvantage possessed by this scheme

- ✓ is that the switching devices used in the inverter are expensive
- ✓ they must possess low turn on and turn off times,
- ✓ nevertheless, PWM operated are very popular in all industrial equipment.

PWM techniques are characterized by constant amplitude pulses with different duty cycles for each period.

The width of these pulses are modulated to obtain inverter output voltage control and to reduce its harmonic content.

There are different PWM techniques which essentially differ in

- ✓ the harmonic content of their respective output voltages,
- ✓ thus the choice of a particular PWM technique depends on the permissible harmonic content in the inverter output voltage.

The advantages of the PWM control scheme are [10]:

a) The output voltage control can be obtained without addition of any external components.

b) PWM minimizes the lower order harmonics, while the higher order harmonics can be eliminated using a filter.

PWM techniques are characterized by constant amplitude pulses with different duty cycles for each period.

The figure shows the triangle and modulation signal with some arbitrary frequency and magnitude.

the switches and are controlled based on the comparison of control signal and the triangular wave which are mixed in a comparator.

When sinusoidal wave has magnitude higher than the triangular wave the comparator output is high, otherwise it is low.

Single-Phase Inverters

A single-phase inverter in the full bridge topology is as shown in, which consists of four switching devices, two of them on each leg.

The full bridge inverter can produce an output power twice that of the half-bridge inverter with the same input voltage.

Three different PWM switching schemes are discussed in this section, which improve the characteristics of the inverter.

The objective is to add a zero sequence voltage to the modulation signals in such a way to ensure the clamping of the devices to either the positive or negative dc rail; in the process of which the voltage gain is improved, leading to an increased load fundamental voltage, reduction in total current distortion and increased load power factor.

the top devices are assigned to be S11 and S21 while the bottom devices as S12 and S22, the voltage equations for this converter are as given in the following equations.

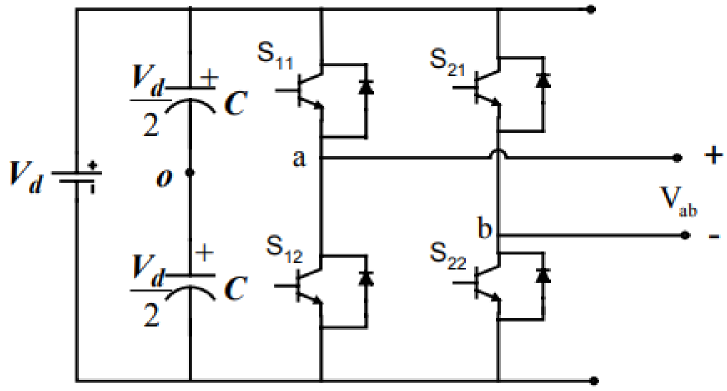


Figure 2.5: Schematic of a Single Phase Full-Bridge Inverter.

$$\frac{V_d}{2}(S_{11} - S_{12}) = V_{an} + V_{no} = V_{ao} \tag{2.5}$$

$$\frac{V_d}{2}(S_{21} - S_{22}) = V_{bn} + V_{no} = V_{bo} \tag{2.6}$$

$$V_{ab} = V_{an} - V_{bn} \tag{2.7}$$

The voltages and V are the output voltages from phases A and B to an arbitrary point n, V is the neutral voltage between point n and the mid-point of the DC source.

The switching function of the devices can be approximated by the Fourier series to be equal to Van (1+ M) 2 1 where M is the modulation signal which when compared with the triangular waveform yields the switching pulses.

Thus from Equations 2.4, 2.5, and 2.6, the expressions for the modulation signals are obtained as

$$M_{11} = \frac{2(V_{an} + V_{no})}{V_d}$$

$$M_{21} = \frac{2(V_{bn} + V_{no})}{V_d}.$$

INVERTER CIRCUIT

The output of charge discharge controller is 12V which is given to solar PWM inverter converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into an alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network.

Standalone inverters used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

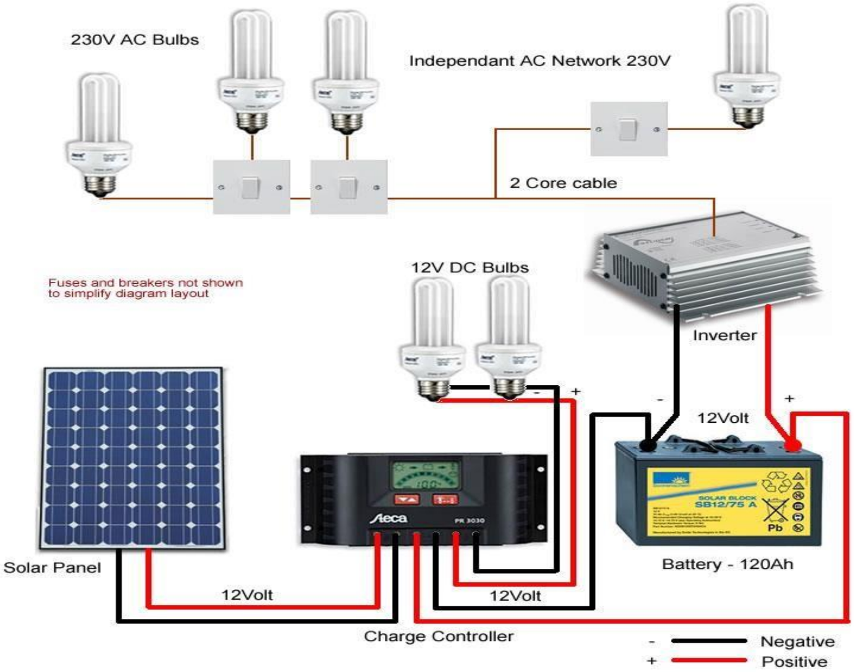
Practical learning Activity

- ✓ Practical exercises of Proper control inverters according to their connection.

Points to Remember (Take home message)

- Pulse Width Modulation Control
- Three different PWM switching schemes are discussed in this section, which improve the characteristics of the inverter

2.4.3: Signalling lamps



The Basics of Electric Load Evaluation

If your home is connected to the utility grid, your energy usage has already been calculated for you in kilowatt-hours per month on your electric bill. If not, or if you are building a home and would like a renewable energy system to power it, you may be asked to complete a load evaluation form analysis.

In order to size a photovoltaic system, you must be able to calculate the average daily electrical energy consumption in watt-hours as well as the total connected watts.

There exist different variables when calculating a load evaluation analysis.

Some important details to consider are:

1. Always use the correct load estimate numbers
2. Don't forget the phantom loads (loads that draw power when devices are turned off)

3. The refrigerator is one of the single largest energy loads in a home (try an energy efficient model)
4. Some equipment/appliances cycle on and off ("Duty Cycle")
5. Examine all opportunities for energy conservation and load shifting
6. Future loads may change
7. Refer to manufacturer's numbers, not just generalized sources

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret Proper control inverters according to their connection

Points to Remember (Take home message)

• The Basics of Electric Load Evaluation

Learning outcome 4 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false; the advantages of the PWM control scheme

a) The output voltage control can be obtained without addition of any external components.

b) PWM minimizes the lower order harmonics, while the higher order harmonics can be eliminated using a filter.

c) is that the switching devices used in the inverter are expensive

d) they must possess low turn on and turn off times,

e) nevertheless, PWM operated are very popular in all industrial equipment.

Answer: a) True, b) True, c) False, d) False, e) False

Q2. Choose any four (4) important details to consider when calculating a load evaluation analysis;

1. Some equipment/appliances cycle on and off ("Duty Cycle")
2. the harmonic content of their respective output voltages,
3. Examine all opportunities for energy conservation and load shifting
4. Future loads may change
5. thus the choice of a particular PWM technique depends on the permissible harmonic content in the inverter output voltage.
6. Refer to manufacturer's numbers, not just generalized sources

Answer:

1. Some equipment/appliances cycle on and off ("Duty Cycle")
2. Examine all opportunities for energy conservation and load shifting
3. Future loads may change
4. Refer to manufacturer's numbers, not just generalized sources

Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

The consider to the process of which the voltage gain is improved, leading to an increased load fundamental voltage, reduction in total current.

Mentioned the circuit output of charge discharge controller is 12V which is given to solar PWM inverter converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into an alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network.

Answer:

Checklist	Score	
	Yes	No
Input/output cables		
Signalling lamp		
Observation		

References

https://www.thomasnet.com/articles/electrical-power-generation/types-of-switches/ October2020 https://www.lisc.org/charter-schools/understanding-your-needs/site-selection/determinecriteria-site-selection/ October2020 https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved= 2ahUKEwio9Zmt4-nsAhU2ShUIHYnaAyMQFjACegQIBhAC&url=https%3A%2F%2Fwww.cleanenergyauthority.com% 2Fsolar-energy-resources%2Fcomponents-of-a-residential-solar-electricsystem&usg=AOvVaw3qZDazOYko6U3hxzxQIoas October2020

LEARNING UNIT 3: PERFORM THE ROUTINE MAINTENANCE

STRUCTURE OF LEARNING UNIT

Learning outcomes:

- **Plan for preventive maintenance**
- **Inspect solar power plant components**
- **Elaborate maintenance report**

Duration: 10hrs

Learning outcome 1objectives :

By the end of the learning outcome, the trainees will be able to:

1. Proper planning of preventive maintenance of solar power plant components according to their types

2. Proper inspection of solar power plant components according to their types

3. Elaborate maintenance report

Resources

Equipment	Tools	Materials
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

Learning Outcome 3.1: Plan for preventive maintenance

Indicative content 3.1.1: Planned activities for different components of solar power plant

3.1.1: Planned activities for different components of solar power plant

- ✓ **Weekly**
- ✓ **Monthly**
- ✓ **Annually**

Preventive maintenance activities are the core element of the maintenance services to a solar power plant.

It comprises regular visual and physical inspections as well as verification activities conducted with specific frequencies of all components which are necessary to comply with the operating manuals.

It must also maintain the equipment and component warranties in place and reduce the probability of failure or degradation.

Daily activities

Maintenance daily schedule is a means for coordination between maintenance and production to accomplish the required daily maintenance work.

Also, it is a means to allocate the required maintenance resources to the required work in a planned manner to cover the required maintenance work according to priority.

The daily schedule will include also work that was planned to be done during this week and other work that has been carried over from previous weeks.

Weekly activities

Weekly maintenance activity is a maintenance that is done once a week.

A weekly schedule is a way to keep track of your activities and tasks for the weeks.

A weekly schedule includes everything you have to get done and helps you plan out when you can get things done.

It also helps you to see how much time you have available.

Monthly activities

Monthly maintenance activity is a maintenance which is done once a month.

Annual activities

Annual maintenance activity is a maintenance that is done once a year.

Topic 2: Elaboration of convenient maintenance

A short definition of maintenance planning and scheduling:

Planning decides what, how and time for a job.
Scheduling decides when and who will do a job
Planning of a job should be done before scheduling a job

A dated maintenance plan must include as a minimum, the following data:

- Description of equipment tested
- Description of test
- Test results with all fields completed
- Summary of project findings and recommendation if required for additional work
- Documentation of the conditions at which the tests were performed
- Name and address of the testing firm along with contact information of the individual doing the testing

1.2 Appropriate identification of tools and measurement instruments used in solar power plant **systems maintenance** A. Tools:

- Electro-mechanical toolkit
- Plumber toolkit
- Blower machine

B. Types of measurement instruments:

- Pressure switch
- Flow sensors
- Thermometer

1.3 Identification of personal protective equipment (PPE) used in solar water heater systems maintenance

Topic 1: Types of PPE used in maintenance of solar power plant systems

- **Overcoat and overall**: Are usually used as protective clothing while working. It is designed for the purpose of keeping the wearer clearly in view, they make abundant use of colors that can always be seen and glow in the dark.
- **Gloves**: A covering for the hand worn for protection against cold or dirt and typically having separate parts for each finger and the thumb.
- **Safety shoes**: A shoe with a reinforced toe cap to minimize foot injuries caused by dropped articles.
- **Helmet**: Are one of the most frequently used forms of PPE safety helmets will protect the user’s head against impact from objects falling from above by resisting and deflecting blows to the head.
- **Earmuff:** Are objects designed to cover a person’s ears for hearing protection or warmth. They consist of a thermoplastic or metal head band that fits over the top or back of the head and a cushion or cup at each end to cover the external ears.

- **Goggles:** Are forms of protective eyewear that usually enclose or protect the area surrounding the eye in order to prevent particulates, water or chemicals from striking the eyes.
- **Nose protection mask:** Are loose fitting masks that cover the nose and mouth. And have ear loops or tie or bands at the head.

Topic 2: Use of safety equipment used for solar power plant maintenance

The importance of personal protective equipment is to protect workers against health or safety risks on the job. The purpose is to reduce employee exposure to hazards when engineering and administrative controls are not feasible or effective to reduce these risks to acceptable levels.

Topic 3: Handling of safety equipment needed for solar water heater maintenance

Ensure the operator is trained and qualified to operate the equipment

Ensure the correct equipment is used for job

Provide personal protective equipment for employees

Plan any work to minimize risks identified

Provide appropriate training and guidelines to employees

Maintain and check equipment regularly

Overarching O&M Approaches PV O&M approaches are typically broken out into three main categories, each with different cost-benefit t trade off and risk profiles:

• Preventative maintenance (PM) encompasses routine inspection and servicing of equipment

- ✓ at frequencies determined by equipment type, environmental conditions, and warranty terms in an O&M services agreement
- ✓ to prevent breakdowns and unnecessary production losses. There is approach is becoming increasingly popular because of its perceived ability to lower the probability of unplanned PV system downtime.
- ✓ However, the upfront costs associated with PM programs are moderate and the underlying structure of PM can engender superfluous labour activity if not optimally designed.

• Corrective or reactive maintenance addresses equipment repair needs and breakdowns after their occurrence and, as such, is instituted to mitigate unplanned downtime.

- ✓ The historical industry standard, this “break-fi x” method allows for low upfront costs, but also brings with it a higher risk of component failure and accompanying higher costs on the backend (perhaps placing a premium on negotiating extended warranty terms).
- ✓ Though a certain amount of reactive maintenance will likely be necessary over the course of a plant’s 20-year lifetime, it can be lessened through more proactive PM and condition-based maintenance (CBM) strategies.8

• Condition-based maintenance (CBM) uses real-time data to anticipate failures and prioritize maintenance activities and resources.

- ✓ A rising number of third party integrators and turnkey providers are instituting CBM regimes to off greater O&M efficiency.
- ✓ The increased efficiency, however, comes with a high upfront price tag given communication and monitoring software and hardware requirements.
- ✓ Moreover, the relative novelty of CBM can produce maintenance process challenges caused in part by monitoring equipment malfunction and/or erratic data connection.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of Proper inspection of solar power plant components according to their types.

Points to Remember (Take home message)

- Preventive maintenance activities are the core element of the maintenance services to a solar power plant.
- Use of safety equipment used for solar power plant maintenance

Learning outcome 1 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) To determine the set point, the pattern of usage and the type of battery used is considered.
b) Are car battery's just as good for solar as leisure battery's?
c) If batteries are not connected with a charge controller, they can get overcharged easily.
d) The charge controller changes the rate of charging at a fixed voltage which is called set point.

Answer: a) True, b) False, c) True, d) True

Q2. Choose the correct answer respectively, the process of checking the electrolyte specific gravity

a. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.

b. Do not smoke or light fire near batteries.
c. Do not smoke or light
d. Batteries produce hydrogen gas which is highly flammable

Answer:

a. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.

d. Batteries produce hydrogen gas which is highly flammable plates.

Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

- Assessment tools

Implement Preventative maintenance (PM) encompasses routine inspection and servicing of equipment

Answer:

- ✓ at frequencies determined by equipment type, environmental conditions, and warranty terms in an O&M services agreement
- ✓ to prevent breakdowns and unnecessary production losses. There is approach is becoming increasingly popular because of its perceived ability to lower the probability of unplanned PV system downtime.
- ✓ However, the upfront costs associated with PM programs are moderate and the underlying structure of PM can engender superfluous labour activity if not optimally designed.

Checklist	Score	
	Yes	No
Plan preventive maintenance		
Identification of planned activities		
Inspection of different parts of solar power plant		
Application of inspection techniques		
Observation		

References:

1. R.S.Naagarazan 2006, Professional Ethics and Human Values, NEW AGE INTERNATIONAL PUBLISHERS, India

2. GordanaDodig-Crnkovic 2004, Professional Ethics in Science and Engineering,DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERINGMÄLARDALEN UNIVERSITY

3. Vee, C. and Skitmore, R.M. (2003) Professional ethics in the construction industry. Engineering Construction and Architectural Management 10(2):pp. 117-127. Copyright 2003 Emerald.

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Duration: 12hrs

Learning outcome 2 objectives :

By the end of the learning outcome, the trainees will be able to:

1. Proper planning of preventive maintenance of solar power plant components according to their types

2. Proper inspection of solar power plant components according to their types

3. Elaborate maintenance report

Resources

Equipment	Tools	Materials
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

Learning Outcome 3.2: Inspect solar power plant components

Indicative content 3.2.1: Inspection of different parts of solar power plant

- ✓ **Solar panel (Connection and output voltage)**
- ✓ **Batteries (voltage, acid level, water)**

Operation and Maintenance Guidelines of Grid Connected PV Plants

1. For the optimal operation of a PV plant, maintenance must be carried out on a regular basis.
2. All the components should be kept clean. It should be ensured that all the components are fastened well at their due place.
3. During mandatory O&M period of 5 years, the rooftop solar PV plant has to be maintained by the vendor for the activity assigned to electrician/technician.

The user shall be suitably guided by the vendor for all tasks lying in scope of the user and the user shall also be provided with appropriate documents for such guidance. Maintenance guidelines for various components viz. solar panels, inverter, wiring etc. are discussed below:

SOLAR PANELS Although the cleaning frequency for the panels will vary from site to site depending on soiling, it is recommended that

i. The panels are cleaned at least once every fifteen days.
ii. Any bird droppings or spots should be cleaned immediately.
iii. Use water and a soft sponge or cloth for cleaning.
iv. Do not use detergent or any abrasive material for panel cleaning.
v. Iso-propyl alcohol may be used to remove oil or grease stains.
vi. Do not spray water on the panel if the panel glass is cracked or the back side is perforated.
vii. Wipe water from module as soon as possible.
viii. Use proper safety belts while cleaning modules at inclined roofs etc.
ix. The modules should not be cleaned when they are excessively hot. Early morning is particularly good time for module cleaning.
x. Check 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.
xi. Ensure that the module terminal connections are not exposed while cleaning; this poses a risk of electric shock.
xii. Never use panels for any unintended use, e. g. drying clothes, chips etc.
xiii. Ensure that monkeys or other animals do not damage the panels.

CABLES AND CONNECTION BOXES

i. Check the connections for corrosion and tightness.
ii. Check the connection box to make sure that the wires are tight, and the water seals are not damaged.

iii. There should be no vermin inside the box.
iv. Check the cable insulating sheath for cracks, breaks or burns. If the insulation is damaged, replace the wire
v. If the wire is outside the building, use wire with weather-resistant insulation.
vi. Make sure that the wire is clamped properly and that it should not rub against any sharp edges or corners.
vii. If some wire needs to be changed, make sure it is of proper rating and type.

INVERTER

i. The inverter should be installed in a clean, dry, and ventilated area which is separated from, and not directly above, the battery bank (if applicable).

ii. Remove any excess dust in heat sinks and ventilations. This should only be done with a dry cloth or brush.

iii. Check that vermin have not infested the inverter. Typical signs of this include

iv. Spider webs on ventilation grills or wasps' nests in heat sinks.

v. Check functionality, e.g. automatic disconnection upon loss of grid power supply, at least once a month.

vi. Verify the state of DC/AC surge arrestors, cable connections, and circuit breakers.

SHUTTING DOWN THE SYSTEM

i. Disconnect system from all power sources in accordance with instructions for all other components used in the system.

ii. Completely cover system modules with an opaque material to prevent electricity from being generated while disconnecting conductors.

iii. To the extent possible, system shutdown will not be done during daytime or peak generation.

INSPECTION AND MAINTENANCE SCHEDULE:

Component Activity Description Interval by PV Module Cleaning Clean any bird droppings/ dark spots on module Immediately Beneficiary Cleaning Clean PV modules with plain water or mild dishwashing detergent.

Do not use brushes, any types of solvents, abrasives, or harsh detergents.

Fortnightly or as per the site conditions Beneficiary Inspection (for plants > 100 kWp) Use infrared camera to inspect for hot spots; bypass diode failure Annual Technician Component Activity Description Interval by PV Array Inspection Check the PV modules and rack for any damage.

Note down location and serial number of damaged modules.

Annual User/Technician Inspection Determine if any new objects, such as vegetation growth, are causing shading of the, array and move them if possible.

Annual User/Technician Vermin Removal Remove bird nests or Vermin from array and rack area.
Need basis User/Technician Junction Boxes Inspection Inspect electrical boxes for corrosion or intrusion of water or insects. Seal boxes if required.
Check position of switches and breakers.

Check operation of all protection devices.

Annual User/Technician Wiring Inspection Inspect cabling for signs of cracks, defects, loose connections, overheating, arcing, short or open circuits, and ground faults.

Annual User/Technician Inverter Inspection Observe Quarterly Electrician Component Activity Description Interval by Instantaneous operational indicators on the faceplate of the inverter to ensure that the amount of power being generated is typical of the conditions.

Inspect Inverter housing or shelter for physical maintenance, if required.

Inverter Service Clean or replace any air filters.

As needed Instruments Validation Spot-check monitoring instruments pyrano-meter etc.) with standard instruments to ensure that they are operational and within specifications.

Annual PV Specialist Transformer Inspection Inspect transformer oil level, temperature gauges, breather, silica gel, meter, connections etc.

Annual Electrician Tracker (if present) Inspection Inspect gears, gear boxes, bearings as required. Annual Technician Service Lubricate tracker mounting bearings, gearbox as required.

Bi-annual Technician Plant Monitoring Daily Operation and Performance Monitoring Daily Beneficiary Inverter Inspection Observe instantaneous operational indicators on the faceplate of the inverter to ensure that the amount of power being generated is typical of the conditions.

Inspect Inverter housing or shelter for physical maintenance, if required. Quarterly Electrician Inverter Service Clean or replace any air filters.
As needed Electrician Instruments Validation Spot – check monitoring instruments (pyrano-meter etc.) with standard instruments to ensure that they are operational and within specifications.

Annual PV Specialist Transformer Inspection Inspect transformer oil level, temperature gauges, breather, silica gel, meter, connections etc.

Annual Electrician Tracker (if present) Inspection Inspect gears, gear boxes, bearings as required. Annual Technician Service Lubricate tracker mounting bearings, gearbox as required.

Bi-annual Technician Plant Monitoring Daily Operation and Performance Monitoring Daily Beneficiary Spare Parts Management Manage inventory of spare parts.

As needed Site in charge Logbook Documentation Document all O&M activities in a workbook available to all service personnel Continuous Site in charge Operation and Maintenance Guidelines of Grid Connected PV Plants

i. Periodic cleaning of solar modules, preferably once every fortnight or as per site conditions. As this task has to be done by the beneficiary, the vendors shall apprise the beneficiary on the importance and proper technique for cleaning.

ii. O&M of Solar Power Plant shall be compliant with grid requirements to achieve committed energy generation.
iii. Periodic checks of the Modules, PCUs and BoS shall be carried out as a part of routine preventive and breakdown maintenance.

iv. Immediate replacement of defective Modules, Invertors/PCUs and other equipment as and when required.

v. Supply of all spares, consumables and fixtures as required. Such stock shall be maintained for all associated equipment and materials as per manufacturer/ supplier's recommendations.

vi. All the equipment testing instrument required for Testing, Commissioning and O&M for the healthy operation of the Plant shall be maintained by the Bidder. The testing equipment must be calibrated once every 2 years from NABL accredited labs and the certificate of calibration must be kept for reference as required.

vii. If negligence/ mal operation on part of the Bidder's operator results in failure of equipment, such equipment should be repaired/ replaced by the Bidder free of cost

Table 3 – Major Elements of PV Operations and Maintenance

Preventative Maintenance (PM)	
Panel Cleaning	Water Drainage
Vegetation Management	Retro-Commissioning†
Wildlife Prevention	Upkeep of Data Acquisition and Monitoring Systems (e.g., electronics, sensors)
Upkeep of Power Generation System (e.g., Inverter Servicing, BOS Inspection, Tracker Maintenance	Site maintenance (e.g., security, road/fence repair, environmental compliance, snow removal, etc.).
Corrective/Reactive Maintenance	
On-Site Monitoring	Non-Critical Reactive Repair**
Critical Reactive Repair* (high priority)	Warranty Enforcement
Condition-Based Maintenance (CBM)	
Active Monitoring—Remote and On-Site Options	Equipment Replacement (Planned and Unplanned)
Warranty Enforcement (Planned and Unplanned)	

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of interpret Proper inspection of solar power plant components according to their types.

Points to Remember (Take home message)

- INSPECTION AND MAINTENANCE SCHEDULE
- Operation and Maintenance Guidelines of Grid Connected PV Plants

Learning outcome 2 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) To determine the set point, the pattern of usage and the type of battery used is considered.
b) Are car battery's just as good for solar as leisure battery's?
c) If batteries are not connected with a charge controller, they can get overcharged easily.
d) The charge controller changes the rate of charging at a fixed voltage which is called set point.

Answer: a) True, b) False, c) True, d) True

Q2. Choose the correct answer respectively, the process of checking the electrolyte specific gravity

a. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.

b. Do not smoke or light fire near batteries.
c. Draw liquid into the hydrometer and avoid bumping the hydrometer. The float should not be flooded or sticking to the sides of the glass tube.

Answer:

a. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.

c. Draw liquid into the hydrometer and avoid bumping the hydrometer. The float should not be flooded or sticking to the sides of the glass tube.

the battery. A visual inspection could also be made to check the condition of the plates.

Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

- Assessment tools

Implement illustrate correctively Checking consideration shutting down the system
Answer:

i. Disconnect system from all power sources in accordance with instructions for all other components used in the system.

ii. Completely cover system modules with an opaque material to prevent electricity from being generated while disconnecting conductors.

iii. To the extent possible, system shutdown will not be done during daytime or peak generation.

Checklist	Score	
	Yes	No
Plan preventive maintenance		
Identification of planned activities		
Inspection of different parts of solar power plant		
Application of inspection techniques		
Observation		

References:

1. R.S.Naagarazan 2006, Professional Ethics and Human Values, NEW AGE INTERNATIONAL PUBLISHERS, India

2. GordanaDodig-Crnkovic 2004, Professional Ethics in Science and Engineering,DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERINGMÄLARDALEN UNIVERSITY

3. Vee, C. and Skitmore, R.M. (2003) Professional ethics in the construction industry. Engineering Construction and Architectural Management 10(2):pp. 117-127. Copyright 2003 Emerald.

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Duration: 8hrs

Learning outcome 3 objectives :

By the end of the learning outcome, the trainees will be able to:

1. Proper planning of preventive maintenance of solar power plant components according to their types

2. Proper inspection of solar power plant components according to their types

3. Elaborate maintenance report

Resources

Equipment	**Tools**	**Materials**
- Electro-mechanical toolkit - Hand Electrical drilling machines - PPEs	- Screw drivers - Pliers - Allen keys whole types - Electrical knife	- Nails - Bolts - Nuts - Electrical tape - Cables - Manuals and - Books

Advance preparation:

. Hand out notes

. Internet

. Expert who is qualified in that field location

Learning Outcome 3.3: Elaborate maintenance report

- Format of the maintenance report

- Contents of the maintenance report
- Methods for reporting

Indicative content 3.3.1: FORMAT OF THE MAINTENANCE REPORT

FORMAT OF THE MAINTENANCE REPORT

Maintenance report format sample

<table>
<tr><td colspan="7">COMPANY NAME</td></tr>
<tr><td colspan="7">NAME OF SOLAR POWER PLANT OPERATION</td></tr>
<tr><td colspan="7">PREVENTIVE MAINTENANCE</td></tr>
<tr><td colspan="7">DAILY CHECKS</td></tr>
<tr><td colspan="7">DATE</td></tr>
<tr><td>COMPONENTS TYPES</td><td>NO. OF FACILITIES</td><td>MAINTENANCE TASK</td><td>PLANNED</td><td>ACTUAL</td><td>EXCEPTION FROM PLANNED</td><td>NOTES</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3" rowspan="2">Names and Signature of Team in charge</td><td colspan="4"></td></tr>
<tr><td colspan="4"></td></tr>
</table>

3. Keeping records of maintenance activities

Maintenance records are written notes that provide documentation about the upkeep of a certain piece of equipment.

Most of the time when people talk about these sorts of records in an industrial setting, they're referring to the formalized reports and files kept by fleet owners, industrial plant operators, or other business people engaged in some sort of work with machines.

Keeping an adequate log of mechanical service and repairs in these scenarios is usually considered good business practice, and may also be required by law.

Records are particularly useful in maintenance management because they help businesses ensure that their equipment is kept in good condition, and they also offer a way to manage and track repair and preventative upkeep expenses

Here we list the benefits of keeping a maintenance record.

Prevent expensive repair works from happening

Helps you create specialized maintenance programs

Prevent problems regarding warranty claims

It increases the safety of operators

Helps you track who is accountable for a piece of equipment

It increases the resale value of the equipment

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of Proper inspection of solar power plant components according to their types
- ✓ Elaborate maintenance report

Points to Remember (Take home message)

- Format of the maintenance report
- Contents of the maintenance report
- Methods for reporting

Indicative content 3.3.2: Contents of the maintenance report

3.3.2: Contents of the maintenance report

A maintenance report shows maintenance details of each event in the time range, including the Setup/Takedown Time,

Instructions,

Event Time,

Facility,

Event,

ID (Rental, Contract or Event),

Service, and

customer.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment’s manuals
- ✓ Group discussion on solar power plant equipment’s manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Practical exercises of Proper inspection of solar power plant components according to their types

Points to Remember (Take home message)

- Contents of the maintenance report

3.3.3: Methods for reporting

3 Ways to Keep a Maintenance record

1. Start a Paper Trail

Whether you use a pen to jot down on paper the dates and details of every Equipment maintenance service that your Equipment undergoes, or you type the information in your computer, print it, and put it in a file folder, having an easily-accessible paper trail is still a very common and practical way to keep a car maintenance log.

This option is particularly convenient if you want to sell your Equipment at a dealership or privately; having an easy to-read, tangible folder of documents detailing how you've maintained your Equipment can help to increase its market value.

2. Download an App

A great way to keep track of all thing's equipment related, equipment is an all-in-one, easy to-use, highly customizable FREE app for Android 2.1+ equipment.

Once you've entered your equipment's make, model, and year in the app, it can provide tons of helpful statistics, graphical charts, and interesting reports about your Equipment. (Yes, you can use if for more than one equipment).

3. Use Microsoft Excel

Use equipment maintenance log template to keep track of your auto repairs and maintenance upkeep. Vertex42 offers spreadsheet templates for Microsoft® Excel®, OpenOffice.org, and Google Docs.

With their template of columns, you'll be able to keep track of the dates you have your equipment serviced, what was done, and how much it was.

In addition to providing a detailed equipment maintenance log, you can also use the template to create a vehicle maintenance schedule so that you know exactly what your equipment (really) routinely needs and when it needs it.

4. Analysis of the maintenance report

Report analysis is the process of exploring data and reports in order to extract meaningful insights, which can be used to better understand and improve business performance.

How do you Analyse a report? Draw out the findings that are most important and directly align with your analysis goals. Summarize your findings in a memo, report or email.

Start with an executive summary that describes your analysis and highlights the key findings. Include the appropriate level of detail and your recommendations for next steps.

Theoretical learning Activity

- ✓ Brainstorming on solar power plant equipment's manuals
- ✓ Group discussion on solar power plant equipment's manuals
- ✓ Documentary Research

Practical learning Activity

- ✓ Proper planning of preventive maintenance of solar power plant components according to their types
- ✓ Proper inspection of solar power plant components according to their types
- ✓ Elaborate maintenance report

Points to Remember (Take home message)

• **Ways to Keep a Maintenance record**

Learning outcome 3 formative assessment

Written assessment

- Assessment tools

Q1. Answer by true or false

a) To determine the set point, the pattern of usage and the type of battery used is considered.
b) Are car battery's just as good for solar as leisure battery's?
c) If batteries are not connected with a charge controller, they can get overcharged easily.
d) The charge controller changes the rate of charging at a fixed voltage which is called set point.

Answer: a) True, b) False, c) True, d) True

Q2. Choose the correct answer respectively, the process of checking the electrolyte specific gravity

a. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.

b. Do not smoke or light fire near batteries.
c. Draw liquid into the hydrometer and avoid bumping the hydrometer. The float should not be flooded or sticking to the sides of the glass tube.

d. Do not smoke or light
e. Obtain a reading by looking at the float which corresponds to a level on the tube. The acid level in the batteries should be within two centimeters of the top of the battery. A visual inspection could also be made to check the condition of the plates.
f. Batteries produce hydrogen gas which is highly flammable

Answer:

a. First, remove the caps from each cell one at a time. Carefully insert the hydrometer into the cell.

c. Draw liquid into the hydrometer and avoid bumping the hydrometer. The float should not be flooded or sticking to the sides of the glass tube.

e. Obtain a reading by looking at the float which corresponds to a level on the tube. The acid level in the batteries should be within two centimeters of the top of the battery. A visual inspection could also be made to check the condition of the plates.

Please mix different assessment tools for triangulation and relevancy of assessment

Practical assessment

- Assessment tools

Make the that show how can complete the standard maintenance report format.

Answer:

Maintenance report format sample

COMPANY NAME						
NAME OF SOLAR POWER PLANT OPERATION						
PREVENTIVE MAINTENANCE						
DAILY CHECKS						
DATE						
COMPONENTS TYPES	NO. OF FACILITIES	MAINTENANCE TASK	PLANNED	ACTUAL	EXCEPTION FROM PLANNED	NOTES
Names and Signature of Team in charge						

Checklist	Score	
	Yes	No
Format of maintenance report		
Contents of the report		
Observation		

References:

1. R.S.Naagarazan 2006, Professional Ethics and Human Values, NEW AGE INTERNATIONAL PUBLISHERS, India

2. GordanaDodig-Crnkovic 2004, Professional Ethics in Science and Engineering,DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERINGMÄLARDALEN UNIVERSITY

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