Alliance for Mindanao Off-grid Renewable Energy Program

PV Technicians Training Module

RE Department
January 2006

Contents at a Glance

Preface

The Alliance for Mindanao Off-Grid Renewable Energy (AMORE) is being implemented by US-based non-profit organization Winrock International (WI) with funding from the United States Agency for International Cooperation (USAID) and in partnership with the Department of Energy (DOE), the Autonomous Region of Muslim Mindanao (ARMM) Government, and Mirant Philippines. AMORE seeks to improve quality of life and promote long-term peace in Mindanao by providing electrification in remote, conflict-affected villages with sustainable and clean renewable energy systems from indigenous resources such as solar and microhydro power systems.

Currently, AMORE II program through its partners, MIRANT Foundation, PNOC-Shell Solar Philippines, has installed 81 SHS in 27 barangays. These systems though highly reliable would still need to be maintained and operated within the design parameters.

Effective maintenance of the project which would include the collection of operational and maintenance funds for the possible replacement of batteries, the access to qualified personnel/technicians and the access to spare parts.

As part of developing an effective maintenance of RE systems, AMORE RE Program sees the need to capacitate the local technicians of the recently installed barangays. This training module would include the basic PV knowledge and the operation and maintenance of the system. Load management is also key topic in the sustainability of the system.

Acknowledgements

Most of the contents in this training module are derived from the training materials made by Mr. Herb Wade in his training manual entitled “Solar Photovoltaic Systems Technical Training Manual” – a UNESCO toolkit of learning and teaching material.

Also, some information was taken from JICA and Dr. Shiota Akio’s 2nd Edition “Solar Home System Handbook/JICA” and materials used during the implementation of AMORE 1 Program (manuals).

Distribution

This training module is solely for the use of AMORE II Program particularly RE Field Supervisors to serve as a training guide to all BRECDA local technicians.

References

AMORE 1 Field Manual and Training
Wade, H. (2003). “Solar Photovoltaic Systems Technical Training Manual”. UNESCO
Shirota, A. (2000) “2nd Edition Solar Home System Handbook”. JICA

PART I PV Technicians Training Module

I. Introduction

The Alliance for Mindanao Off-Grid Renewable Energy (AMORE) is being implemented by US-based non-profit organization Winrock International (WI) with funding from the United States Agency for International Cooperation (USAID) and in partnership with the Department of Energy (DOE), the Autonomous Region of Muslim Mindanao (ARMM) Government, and Mirant Philippines. AMORE seeks to improve quality of life and promote long-term peace in Mindanao by providing electrification in remote, conflict-affected villages with sustainable and clean renewable energy systems from indigenous resources such as solar and microhydro power systems.

Currently, AMORE II program through its partners, MIRANT Foundation, PNOC-Shell Solar Philippines, has installed 81 SHS in 27 barangays. These systems though highly reliable would still need to be maintained and operated within the design parameters.

Effective maintenance of the project which would include the collection of operational and maintenance funds for the possible replacement of batteries, the access to qualified personnel/technicians and the access to spare parts.

As part of developing an effective maintenance of RE systems, AMORE RE Program sees the need to capacitate the local technicians of the recently installed barangays. The training would include the basic PV knowledge and the operation and maintenance of the system. Load management is also key topic in the sustainability of the system.

The contents of the PV technicians training module is designed solely for approved two-day technicians training design. The training approach would be community-based and would require the support of our BRECDA. This approach would minimize training cost for AMORE and help the trainees adapt to actual field conditions.

II. Expected Output

The students are expected to know and understand the following:

- Basic DC electricity
- Different Components and Operation of PV Solar Home System (SHS)
- Installation and Maintenance of SHS
- Load Management
- AMORE Level 1 Monitoring of SHS

III. Activities

Classroom lecture, focal group discussion, hands-on practical works and exercises

IV. Time frame

Two days

V. Target Participants

BRECDA Technicians, (1) Community Development workers

VI. Training Methodology

The contents of the PV technicians training module is designed solely for approved two-day technicians training design. The training approach would be community-based and would require the support of our BRECDA. This approach would minimize training cost for AMORE and help the trainees adapt to actual field conditions.

The training shall be facilitated using easy to understand language and visuals. The methodologies to be used shall be in the form of lectures, hands-on training, workshop and actual field troubleshooting experiences. The field technician training will have a heavy emphasis on "hands-on" training though some theory will be necessary to fully understand the practical works. The training will have theory and would follow practical works every after lectures. The practical works should be given in consideration of good a weather conditions in the AREA.

For the SHS installations, the trainees should, in groups of no more than three, actual construct working PV systems with a post installation critique by the trainers and fault simulation of SHS and provision of solutions will be included.

VII. Course content

- VII.1 Basic DC Electricity
- VII.2 Introduction to Solar PV
- VII.3 Overview of PV Solar Home System
- VII.4 Basic Components of the Photovoltaic System
  - VII.4.1 Solar Photovoltaic (PV) Module
  - VII.4.2 Controllers
  - VII.4.3 Batteries
  - VII.4.4 Wiring and Appliances
- VII.5 Introduction to Tools and DC measurements
- VII.6 Installation and Maintenance
- VII.7 Load Management
- VII.8 Monitoring
- VII.9 Troubleshooting and Repair

BRECDA Technicians, (1) Community Development workers

VIII. Training Materials

RE Flipchart
Visual/Drawings
Pentel Pen
Manila paper / Craft paper
Chalk/blackboard eraser & blackboard

For group experiment and exercises, the following tools and materials are required per group:

At least (2) 1.5 V Battery
2 PV modules
Multimeter and Current meter
Cords / Wires of various lengths
Controllers
DC loads such as DC lamps or headlights
Flat Screw driver/Philips screw driver
Pliers
Compass
Electrical Tape

For battery activation exercise (optional):
 New 12 V Battery and battery solution
For battery discharge exercise and level 1 monitoring:
 Hydrometer

Required Documents reference:
 "Solar PV Photovoltaic System Technical Training Manual". Wade, H. (2003). UNESCO

IX. Training Effectiveness

Its is advised that prior to the start of the training proper the training facilitators (AMORE RE FS) will give a short pre-test to the participants for a quick run down on participants level of information about PV technology and electricity basics and to provide AMORE RE Department a baseline information of the participants prior training. After the training, a short post-test will be given to the participants using the same test/questionnaire. The result of which will be used to facilitate the evaluation of the trainors and the materials used.

PART II Main Module

I. Basic DC Electricity

In general, water systems and solar systems work in a very similar way. The ideas of pressure, flow rate, volume, resistance to flow, power and energy are almost the same for water system and electricity. Thus, we shall continue to use the "water analogy" to discuss further the basic DC electricity.

I.1 Key Terminologies

I.1.1 Pressure

Water pressure is a measure of the force that pushes water through a pipe. Usually, the unit of measurement used is kg/cm2 or lbs/in2 or pascals depending on the each country of preference. The electrical pressure is the force that pushes electricity and is measured in volts (V). A medium electrical pressure of 120V-240V is found at the electrical power points in the city homes. The PV system operates at 12 V or sometimes 24 V.

Simply, the voltage is the degree of strengths of electricity. The symbol E is commonly used.

I.1.2 Volume

Usually measured in liter or gallon, volume is the amount of water in a tank. A rainwater tank may hold 4,000 liters or 4 m3. For electrical volume, the unit of measurement is called Coulomb (C). However, the most commonly used unit of measurement is the ampere-hour (Ah). An electrical volume of 1 Ah is the same as the electrical volume of 3,600 C.

I.1.3 Flow rate

The flow rate is flow of a volume of water (gallons, liters or m3) through a pipe in a unit of time such as 1 second, 1 minute or 1 hour). Thus, it is often measured in liters per second or gallons per hour.

Compared to water which is called flow, the electricity that moves through the wire is usually said to have a Current rather than a flow rate and the unit of measurement is in amperes (A). So 1 A is a volume of 1C flowing through a wire over a time of 1 second. So an ampere is a one-coulomb per second flow rate.

Simply, current is the quantity of electricity flowing inside the wires. The symbol is I.

I.1.4 Resistance

The force that opposes the flow of water is called the flow resistance or just resistance. The resistance to the flow of water increases as the length of the liquid flow path increases. Also, the resistance increases in step with the decrease in the amount of space for the water to flow. The space for flow in a pipe is called cross-sectional area or cross-section and is usually measured in cm2 or in2. Diameter is different from a cross-sectional area. The diameter is the distance across the end of the pipe while the cross-sectional area is the total area available across the end of the pipe. If you double the diameter, the cross sectional area of the pipe is four times larger and not two times larger. This means that when one changes the diameter say from 20 mm diameter to 40 mm diameter, the resistance is four times smaller because the cross-sectional area of a 40 mm diameter pipe is four times larger than the cross-sectional area of a 20 mm pipe.

The same is true with the electricity flowing through a wire. The resistance of the wire is doubled if the wire length is doubled. Thus, it would be twice as hard to force electricity through the wire. If the wire size or the cross-sectional is cut in half, the resistance is doubled and it is twice as hard to push the electricity through the wire.

The unit of measurement used for electrical resistance is the ohm or the symbol Ω. Also, the above-mentioned relationship summarizes the Ohm's Law:

$$\text{Ohms law: } E = I \times \Omega$$

Example:

A resistance of 4Ω is measured to have a current of 3 A flowing through it. What voltage is there across the resistance?

$$V = 3\ A \times 4\Omega = 12\ V$$

I.1.5 Power

Power is the ability to do work. In flowing water, the power increases if one or both the flow rate and pressure are increased. The same way as with the electrical power, if one or both the pressure (volts) or E increases or the current (Ampere) or symbol I, the power increases. The Power Law is derived from voltage multiplied by current. The electrical power's symbol is usually P and the unit of measurement used is W (watt)

Power Law: P (W) = I (A) x E (V)

Example:

A light uses 2.5A at 12 V. Its power requirement is:

P (Watts) = 2.5 A x 12 V
= 30 Watts

I.1.6 Energy

While power is the ability to do work, the amount, energy is the total actual work that is done. The amount of energy used depends on both the power and the amount of time it is used. This is important because in the PV modules, energy is provided to the battery and energy that goes to the appliances from the battery. Thus, it is the flow of energy, not the power that determines how large the panels and batteries must be.

An electrical appliance that delivers a power of 7 W and is operated in 3 hours provides a 7 x 3 = 21 Watt-hr of energy. The unit of energy or the power consumption is called Watt-hour (Wh)

I.1.7 Circuits

In rainwater system, pipes are connected to reach the tap or appliance. The pipes and connection are commonly known as water circuit. Like water circuits, electrical circuits for PV systems can be very simple or complex with different appliances.

However, there is a difference between the water circuit and electrical PV circuits. The water circuit usually ends with a tap stand and when used the water will flow and away into a drain. For an electrical circuit, electricity cannot flow outside the wire, so there must be a wire to carry electricity away from the appliance as well as to carry to the appliance. Also, electricity must have a continuous path not only to the appliance but also from the appliance back to the source.

Open circuit -	continuous path does not exist
Closed circuit -	continuous path exist

A switch is a device that allows to do open or closed circuit.

I.1.7.1.1.1 Series circuits

When electrical elements are connected end to end, they are said to be connected in series. This is like connecting the short pipes to make one longer pipe.

All components in a series circuit have the same electrical current (A) flowing through them. In water system, if water tanks are stacked one over the other, the pressure from the bottom tank will increase. In a PV system, batteries and module are often connected in series. Just like in the water system the electrical pressure or (V) increases but the same amperes will flow everywhere in the wire.

I.1.7.1.1.2 Parallel circuits

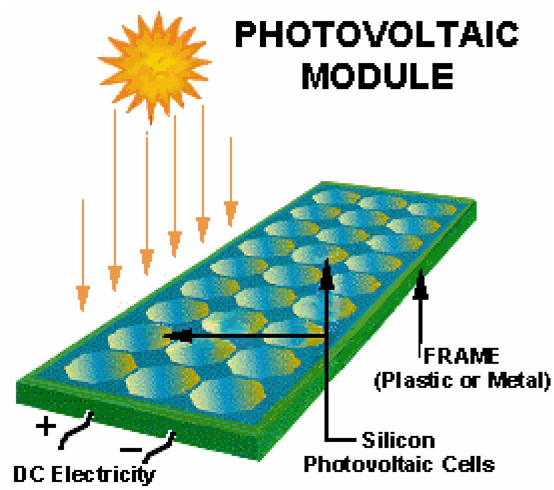
Parallel circuits are electrical components that are connected side by side. In water system, if two tanks are connected in parallel it will deliver twice the flow deliver at the same pressure. In PV system, say two batteries wired are in parallel, it will deliver twice the amperes at the same voltage. The amount of ampere produced is the sum of the individual currents.

I.1.8 Polarity

In water appliance, the inlet pipes have a distinctive mark which would identify the inlet from the outlet. These water appliances connected will not work if connected in reverse. The same is true with PV systems. The markings are distinct between each other and denotes a symbol of a + and –. The (+) side is called the positive pole and (-) side, the negative pole. Appliances have + pole connected to the + pole of the battery and their – pole to the – pole battery.

II. Introduction to Solar Photovoltaics

Comes from combining two words, the Greek word “PHOTOS” meaning light, and the word “VOLTAIC” which is a development of the name of the Italian scientist Alessandro Volta who studied electricity. Hence PHOTOVOLTAIC is the direct conversion of light (sunlight) into electricity.



Photovoltaic Effect - Sunlight to Electricity

A solar PV turns sunlight into electricity. Thus, the more sun there is, the more electricity is produced by the PV system. Electricity produced during day time is stored in a battery. The electricity can be drawn from the battery at any time to operate lights, radio and television.

PV systems and water systems: A Similar Idea (use visual aid)

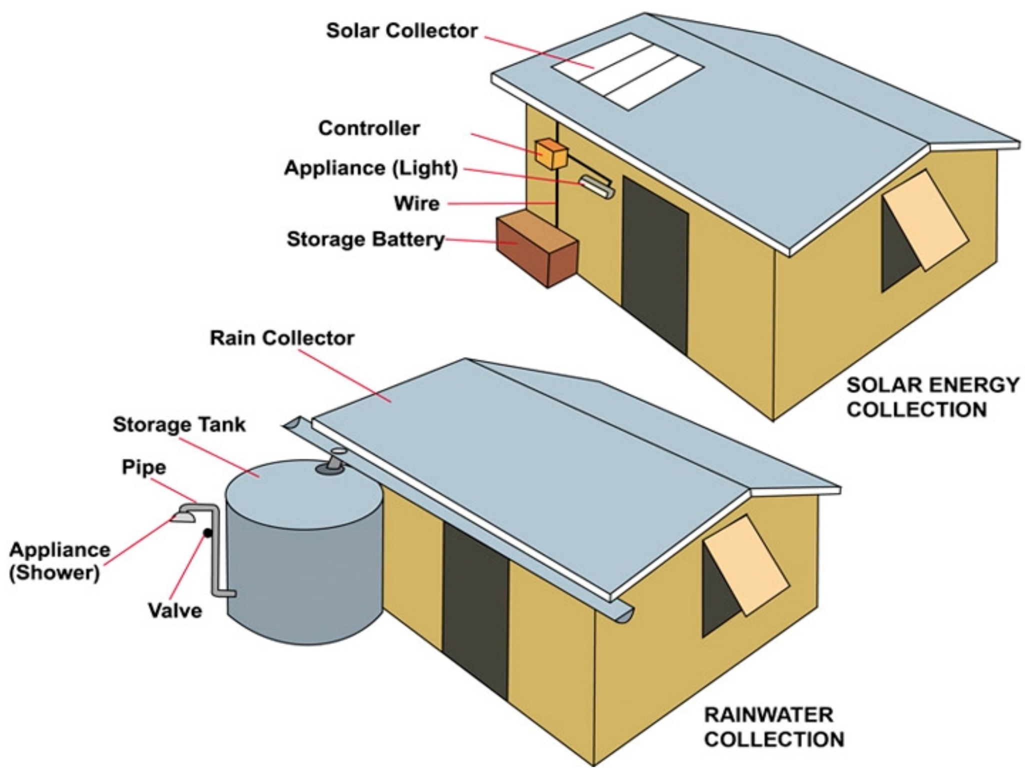
To understand further the PV system and its electricity, the concept of the “water analogy” will form the basis of teaching non-technical people to easily understand the topic.

The water system that acts most likely as a PV system is a rainwater collection system. Like most rainwater collection system, the amount of water collected is depended on the weather. There are with a lot of rain and days with none, so some days a lot of water is collected and others none is collected. In the same way, the amount of electricity collected by a PV system changes according to weather. There are days with bright sun making more electricity and other when its cloudy and little electricity is made. So the output of both rainwater collection systems and PV systems depends on the weather patterns.

In fact, not only do PV systems and rainwater collection systems act much the same, they have similar parts as well.

Rainwater Collection System	**Photovoltaic System**
▪ The roof collection area	▪ The PV panel
▪ A storage tank	▪ A storage battery
▪ Pipes to carry water to and from the tank	▪ Wires to carry the electricity to and from the battery
▪ Valves on the pipes to control the flow of water	▪ A controller to control the flow of electricity
▪ Appliances (shower) to use the water	▪ Appliances (lights) to use the electricity

Each part of the rainwater collection system does a similar job to a part in the PV system.



II.1 Discussion of main parts

II.1.1 Collection

The PV panel collects sunlight and converts it into electricity. These PV panels are usually mounted on a roof but not necessarily as long as it can be placed anywhere there is sun. On the part of the rainwater collection system, the house roof does a similar job. The roof collects rainwater so it can be stored for later use. The bigger the roof or the PV panel the more collection of water or electricity. If it rains hard, a lot of water is collected in a short time and if it rains lightly, only a little is collected in the same time. If the sun shines brightly, a lot of electricity is collected in the short time and if it is cloudy, only a little is collected in the same time. If it does not rain, no water is collected. At night, no solar energy is collected.

II.1.2 Storage

Both solar PV systems and rainwater collection system must have storage. This is necessary when water is needed and the rain stops or electricity is used for some time after the sun goes down. For the PV system, the battery acts as the storage and for water system it is the storage tank. If it rains a lot, the storage tank will be filled up to its capacity. The same way with PV system, if the sun shines and there is little use of electricity then the battery becomes fully charge.

If people use water when there is little rain, the storage water level will gradually fall and will be eventually be empty. The same is true for PV systems. When people use electricity when there is little sun shine, the amount of electricity in the battery will gradually fall and soon there will be no electricity.

II.1.3 Flow control

For rain water collection system, the valves on their outlet pipes would serve as the flow control for the use of water. In PV systems, the controller located between the battery and appliances serves as flow control for the use of electricity. This controller is called the discharge controller. It controls the amount of electricity coming out of the battery. It prevents damage to the battery from too much discharge.

On the other hand, water tanks have valves on their inlet to prevent them from overflowing. In PV systems a charge controller is placed between the panel and the battery to keep the battery from receiving too much electricity. The discharge and charge controller are usually combined into one box and is called the general term controller.

II.1.4 Appliances

Appliances are usually labeled as loads or the end use for the system. In rainwater collection system, usually the end appliance is the tap or faucet others are flush toilet. However, the flush toilet uses a lot of water and would not be advisable for use.

In PV systems, lights are the most common appliances. The radios, televisions, video are some examples of appliances which are being attached to the PV systems.

II.1.5 Transport

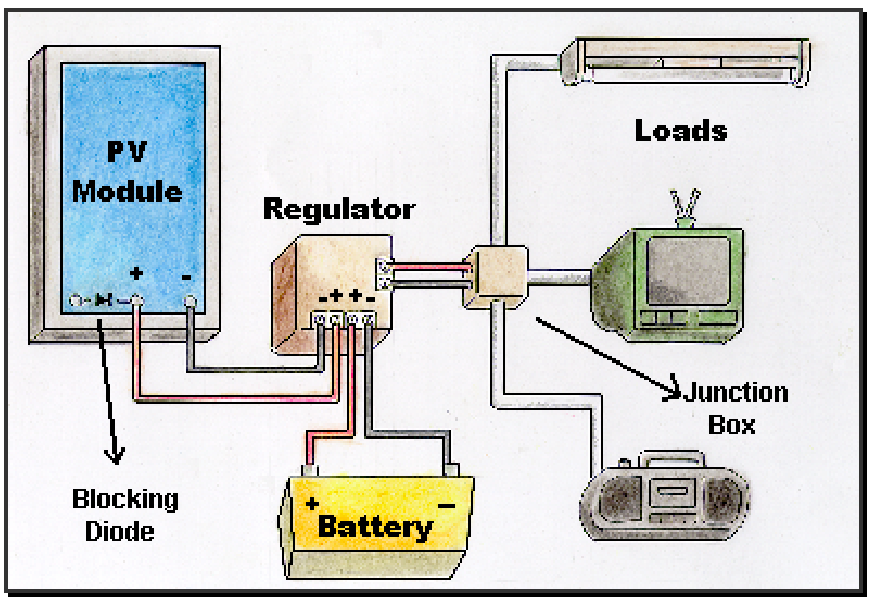
Water and electricity have to move from place to place. The pipes are used to move water from one place to another. For electricity, wires are used to move electricity from one place to another. The larger the pipe size, the more easily the water flows as compared to small pipes. The same way with the wires, the larger the wires the more electricity would flow easily than a small wires. Large wires are used when large amounts of electricity are to be moved quickly.

Leaks occur when pipes are not joined correctly and therefore the water may not reach the end appliance. In electricity, if wires were not joined correctly, it may not reach the load or appliance where it is needed.

III. Overview of PV Solar Home Systems

A SHS is a stand–alone type of PV system that is an alternative source to get electricity. Usually, the SHS is used in rural electrification where grid electricity is not available. It consists of components that turn sunlight into DC electricity to power electricity consuming devices. The brighter the sunlight, more electricity is produced. During rainy days where there is less sunlight, little electricity is produced. No electricity is produced at night.

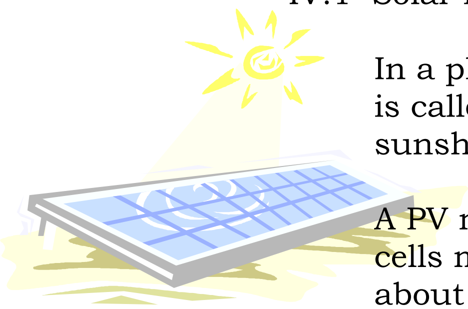
Electricity can be stored and drawn anytime from batteries for night use.



Typical Solar Home System Block Diagram

IV. Basic Components of the Photovoltaic System

IV.1 Solar Photovoltaic (PV) Module [Collection *(from II.1.1)*]

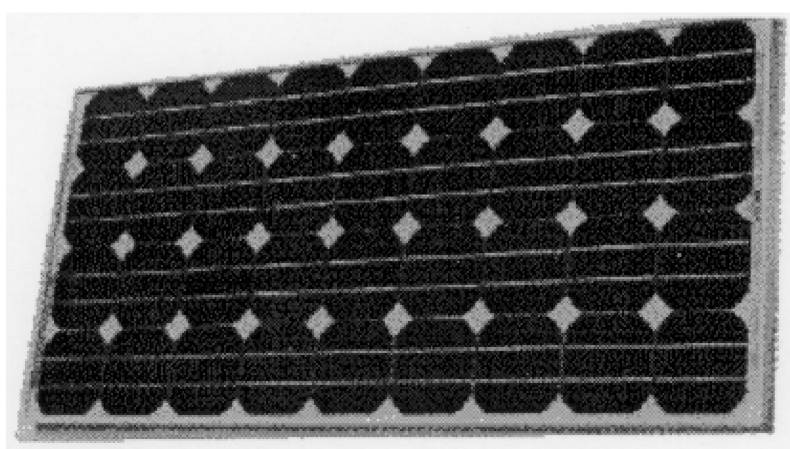


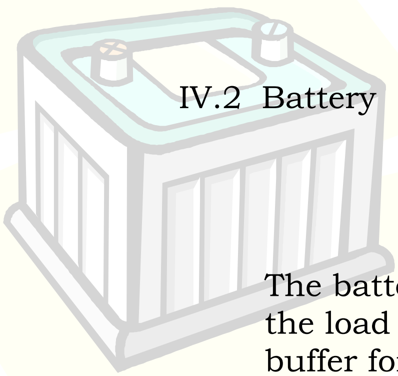
In a photovoltaic system, the part that converts sunlight to electricity is called a photovoltaic module. Place it where there is plenty of sunshine and you have electricity.

A PV module is made up of a number of individual solar cells. These cells may be round, square or some other shapes. Each cell produces about ½ volt. The amount of amperes a cell can produce depend on its size and this cells are connected in series to produce a higher voltage to charge a 12 V battery.

A Photovoltaic Module is:

- The smallest complete, environmentally protected assembly of solar cells, exclusive of tracking, designed to generate direct-current power under sunlight.
- Composed of Solar Cells connected in series
- Modules with more cells have higher V_{oc}
- Modules with larger cells have higher I_{sc}
- PV modules are connected in parallel to increase current
- PV modules are connected in series to increase voltage
- Weather-resistant





IV.2 Battery [Storage (from II.1.2)]

The battery stores electricity produced by the PV module. At night, the load can draw electricity from the battery. It also serves as a buffer for the load.

IV.2.1 Essential Parameters of the Rechargeable Battery

IV.2.1.1 Cell

- The most basic unit. For lead acid battery the nominal cell voltage is 2 Volts. For Nickel-Cadmium battery, it is 1.2 Volts

IV.2.1.2 Ampere-hour capacity

- The quantity of discharge current available for a specified length of time. Valid only for a specific temperature and discharge rate.
- Usually given in C/N where C=capacity in Ampere-hour (Ah) and N = no. of hours of discharge

IV.2.1.3 Voltage output

- Batteries can be connected in series to increase the terminal voltage (Capacity remains the same).
- Batteries can be connected in parallel to increase the capacity (Terminal voltage remains the same).

IV.2.1.4 State of charge

- The State of Charge of a battery is its available capacity expressed as a percentage of its rated capacity. Knowing the amount of energy left in a battery compared with the energy it had when it was new gives the user an indication of how much longer a battery will continue to perform before it needs recharging. Using the analogy of a fuel tank in a car, SOC estimation is often called the "Gas Gauge" or "Fuel Gauge" function.

IV.2.1.5 Depth of discharge

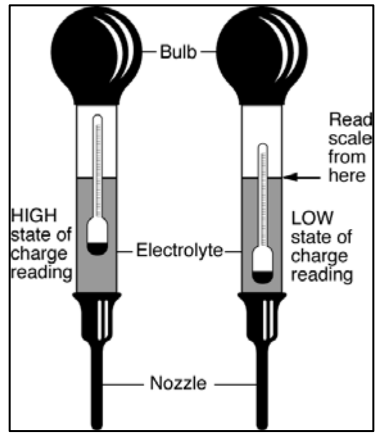
- The Ampere-hour remove from a fully charged cell or battery, expressed as a percentage of rated capacity.
- Example: 25 Ah removed from a 100 Ah battery. DOD = 25/100 = 25% DOD

IV.2.2 Specific Gravity

Specific gravity is the ratio of the density of a material to the density of water. The density of water is about 1 gram per cubic centimeter (g/cc). Materials which are lighter than water (specific gravity less than 1.0) will float. Most materials have specific gravities exceeding 1.0, which means they are heavier than water and so will sink.

In a lead-acid battery, the weight of sulfuric acid compared to the weight of an equal volume of pure water.

A **hydrometer** is used to measure specific gravity of battery electrolyte (sulphuric acid) in each cell, which is directly related to the SoC. This operation is more precise, but more cumbersome than the measuring with the multimeter. It also provides additional information, as it determines differences between the cells



High and low state of charge of the battery.

IV.2.3 Types

- The most basic unit. For lead acid battery the nominal cell voltage is 2 Volts. For Nickel-Cadmium battery, it is 1.2 Volts

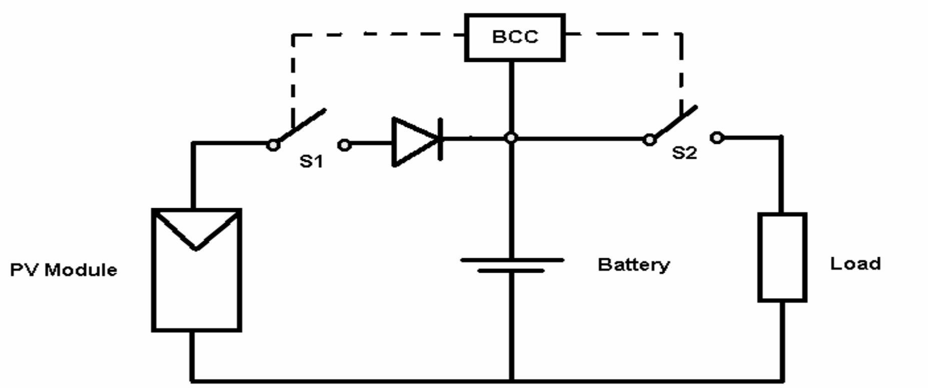
IV.3 Battery Charge Controllers [Flow Control (from II.1.3)]

A battery charge controller (BCC) controls charging and discharging of the battery. Overcharging causes the battery to gas thereby releasing hydrogen and oxygen gases which lead to water loss. Deep discharging causes the plates to evolve to sulphate crystal which is an insulator. Sulphates when flaked off to the bottom of the container cannot be charged back to lead and lead dioxide.

IV.3.1 Types

IV.3.1.1 Series Type

- In a SERIES type controller, the PV module is switched off when the battery reaches 14.4 Volts thereby charging of the battery is discontinued. When the battery voltage lowers to 13.5 Volts, the PV module is reconnected to the battery thereby charging is resumed.

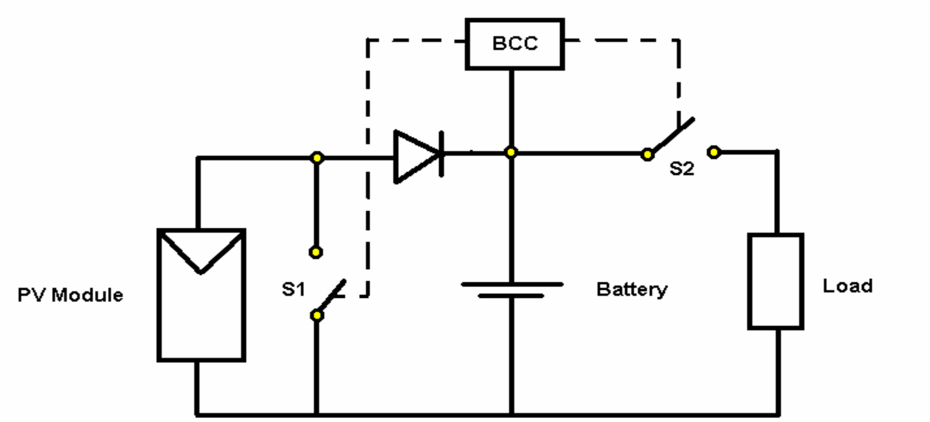


Series Type Charge Controller

IV.3.1.2 Shunt Type

- In a SHUNT type controller, charging of the battery is discontinued by throwing away the excess electricity from the PV module. When the battery reaches again a certain voltage, charging is resumed.

- Note that the short-circuit action does not damage the PV module or controller..



Shunt Type Charge Controller

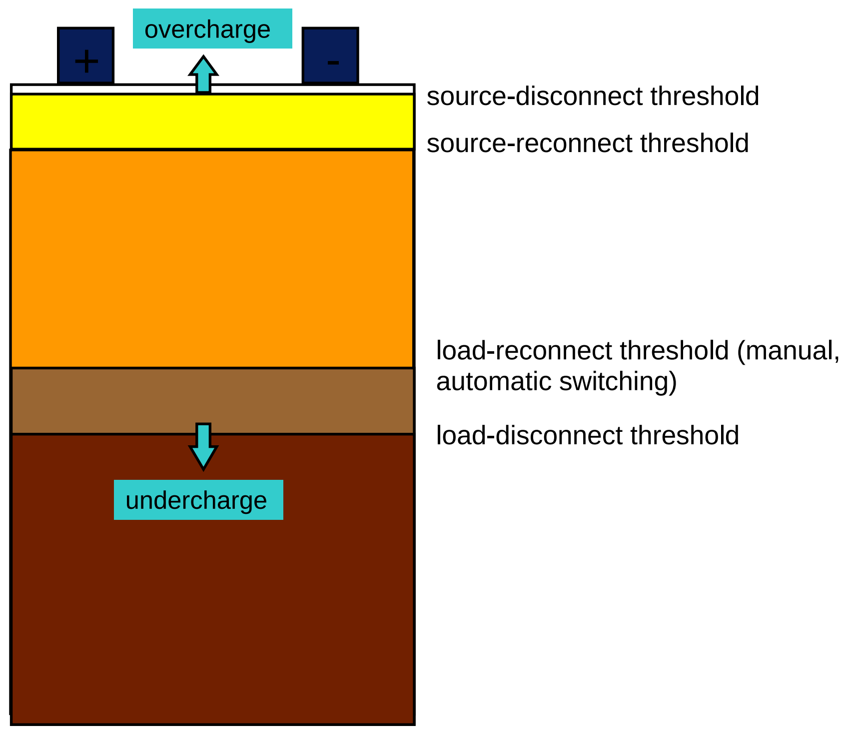
IV.3.2 Parts

IV.3.2.1 Charge control box

- source-disconnect voltage
- source-reconnect voltage

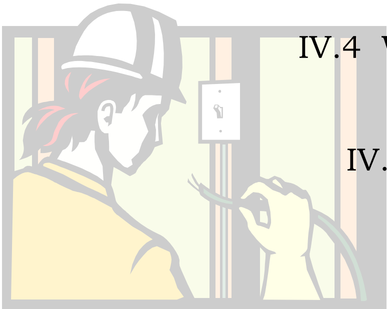
IV.3.2.2 Disharge control box

- load-disconnect voltage
- load-reconnect voltage



A discharge controller is like a valve on a rainwater collection system that stops you from collecting all the water from the water tank. The same way with the PV systems it automatically disconnects the appliances from the battery once it has detected the voltage of the battery is empty or low. It is connected in series with the battery. This is located between the battery and the appliances.

Sometimes these controllers are located in the same box. All controllers are connected to a battery and can be determined if it is a discharge or charge controller in their connections.



IV.4 Wiring and Appliances

IV.4.1 Wiring

Water and electricity have to move from place to place. The pipes are used to move water from one place to another. For electricity, wires are used to move electricity from one place to another. The larger the pipe size, the more easily the water flows compared to small pipes. Large wires are used when large amounts of electricity are to be moved quickly.

Leaks occur when pipes are not joined correctly and therefore the water may not reach the end appliance. In electricity, if wires were not joined correctly, it may not reach the load or appliance where it is needed.

- Wire length and voltage drop

  Wiring rule No. 1: Wires should be as short as practical
  Wiring rule No. 2: The voltage drop in a 12 V system should not be greater than 0.5V
  Wiring rule No. 3: Always use the right kind of wire for the job
  Wiring rule No. 4: Do not use wire smaller than 2.5 mm2 in a PV system wiring
  Wiring rule No. 5: Wires from the battery to any appliances with a motor have to carry currents that are at least double amperes needed.

- Wire connections

  As much as possible, always use a screw-type connector and always tighten the screws.

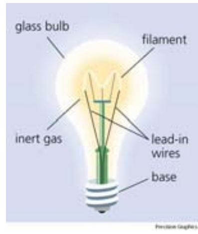
IV.4.2 Appliances

The reason why we need a PV system is what the end appliance can do for us. The PV systems are carefully designed to match with the needed appliance or appliances. It is important many different appliances can be powered by the solar PV system but when new appliances are added make sure that necessary adjustment follows to maintain the balance of the supply and demand for electricity. It is best to choose the appliances designed for solar power and should match the voltage of the battery.

Appliances used:

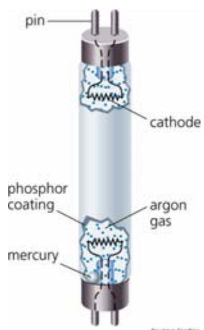
- Lamp

  - Incandescent lamp



An electric lamp consisting of a glass bulb containing a wire filament (usually tungsten) that emits light when heated.

  - Fluorescent lamp



A lamp consisting of a tube coated on the inside with a fluorescent material. Unlike incandescent lamps, fluorescent lamps always require a ballast to regulate the flow of power through the lamp.

  - Compact fluorescent lamp

A **compact fluorescent lamp** (CFL), also known as a **compact fluorescent light bulb**, is a type of fluorescent lamp which screws into a regular light bulb socket, or plugs into a small lighting fixture. In contrast to incandescent light bulbs, they have a longer life and use less electricity. In fact, their savings in electricity expenditures are many times their higher initial cost.

  - LED

(**Light Emitting Diode**) A display and lighting technology used in almost every electrical and electronic product on the market, from a tiny on/off light to digital readouts, flashlights, traffic lights and perimeter lighting

- Radio
  - Receiver

An electric lamp consisting of a glass bulb containing a wire filament (usually tungsten) that emits light when heated.

  - Tranceiver

A battery-powered portable sending and receiving radio set.

A handheld device that provides communications between two or more people using dedicated frequencies over short distances, typically less than a mile. There is no dial-up procedure; it is always on and is activated instantly by pressing a button and talking.

- AC loads via Inverter
  - Electric Fan

  - Television and Video Players

V. Introduction to Tools and DC measurements

Some tools for installing and maintaining PV power systems are needed. Careful planning of the installation process will help prevent loss of time due to missing tools and accessories.

V.1 Required Tools

- Compass
- Tilt angle indicator, or protractor
- Measuring tape
- Screw Drivers:
  - Flat blade in sizes for all mounting hardware;
  - Philips in all sizes for all mounting hardware;
  - Small jewelry size for adjusting controls.
- Wrenches:
  - Specific sizes for all mounting bolts
- Socket Wrench
- Wire Crimping, Stripping and Cutting tools
- Electrical Tape
- Hammer
- Metal Hack saw, Wood saw , Chisel
- Miscellaneous for connections: Split bolts, wire nuts, lugs, etc.

V.2 Digital Multimeter, with at least 10 Amp current capability

A multimeter is a device used in diagnosing electrical problems. It can be used to test resistance and to measure voltage. Resistance can be safely tested with the power off. However, voltage can only be measured with the power on. Because of the risk of electric shock, an individual trained in the use of a voltage tester should only conduct voltage tests.

The tests described below should be done when current is NOT present. Always unplug the device or turn off the main circuit breaker before attempting these tests. Always test your test equipment for proper operation before use.

The common multimeter is a small handheld device with an indicator needle over a measurement scale or a numeric LCD display. The device has a switch to select the type of test to be performed. A multimeter also has two wires, one red (+) and one black (-), with metal tips. They are called probes.

NEVER LEAVE THE TEST LEADS IN ANY AMPERE MEASURING POSITIONS! AS SOON AS AN AMPERE MEASUREMENT IS FINISHED MOVE THE RED LEAD TO THE VOLTAGE MEASUREMENT POSITION OTHERWISE SOMEONE MAY ATTEMPT TO MEASURE VOLTAGE WHILE THE TEST LEADS ARE SET FOR AMPERE MEASUREMENTS AND CAUSE DAMAGE TO THE METER.

V.2.1 Testing for Continuity

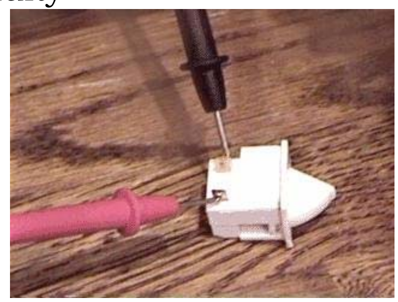
This test should be done when current is NOT present. Always unplug the device or turn off the main circuit breaker before attempting a continuity test.

A continuity test is done to determine whether a circuit is open or closed. To test the continuity of a circuit requires the use of a multimeter or multitester.

Set the multimeter to the ohm setting. The symbol for ohm is , the Greek letter omega. If there is more than one ohm setting, choose X1.

Note that while the probes are not touching anything, the multimeter will indicate a reading of infinity. A reading of infinity indicates that the circuit is open and cannot conduct current. When you touch the two probes together, the reading changes to zero. A reading of zero indicates that the circuit is closed and can conduct current. Touch each probe to one of the terminals (or poles) of the device. **If the reading changes to zero the device has continuity**.

V.2.1.1 Testing a switch for Continuity



To test a switch, place a probe on each pole of the switch. When you move the switch from the off to the on position, the meter reading should change from infinity to zero, which implies that the switch is working. To test a component such as a motor, touch a probe to each pole. A reading of zero indicates that motor has continuity and current can pass through it.

V.2.2 Measuring Resistance

This test should be done when current is NOT present. Always unplug the device or turn off the main circuit breaker before attempting to measure resistance.

Resistance is how much the flow of current in a circuit is impeded. Resistance is necessary for heat to be generated in heating elements like those used in an electric stove or oven, dryer or hair dryer.

It is necessary to know what the proper resistance rating should be for a particular device in order to determine if it is functioning properly.

Set the multimeter to the ohm setting. Touch a probe to each of the terminals. The reading on the multimeter should change from infinity to the level of resistance detected in the element. Compare the measurement to the manufacturer's specification for the element.

VI. Installation and Maintenance

Below is a typical SHS installation technique

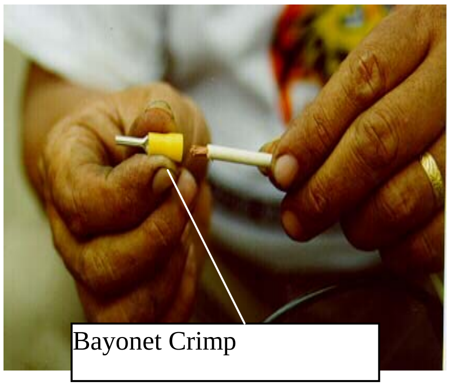
VI.1 PHOTOVOLTAIC MODULE

VI.1.1 Wiring

- Cut the two-conductor Royal cord, no. 12 AWG to the required length (not more than 15 m.). Strip one end of the Royal cord of its insulation about 4 inches using a cable stripper or a knife.

Illus. A
Stripping of Royal Cord with a knife

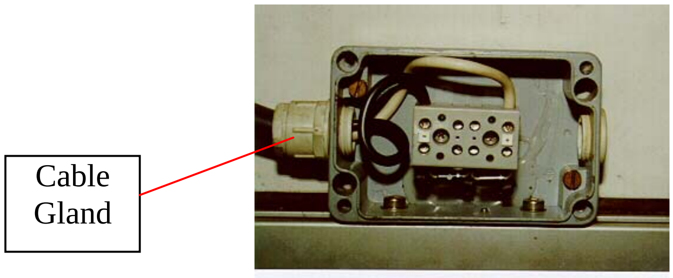
- Strip the conductors of 5 mm of its insulation and insert bayonet crimps into the stranded conductor. Crimp using crimping pliers. Pull the cable to test tightness of the crimp made. If it is loose, crimp the conductor again.



Illus. B
Stripped conductor ready for crimping

Illus. C
Crimping conductor with crimping tool

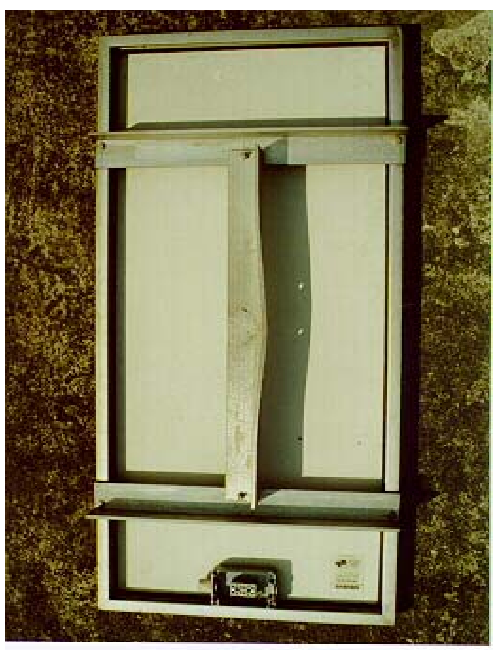
- Pass the cable through the cable glands on the side of the PV module junction box as shown below. Tighten the cable glands so that a tight seal is formed around the cable. Replace the PV module junction box cover.



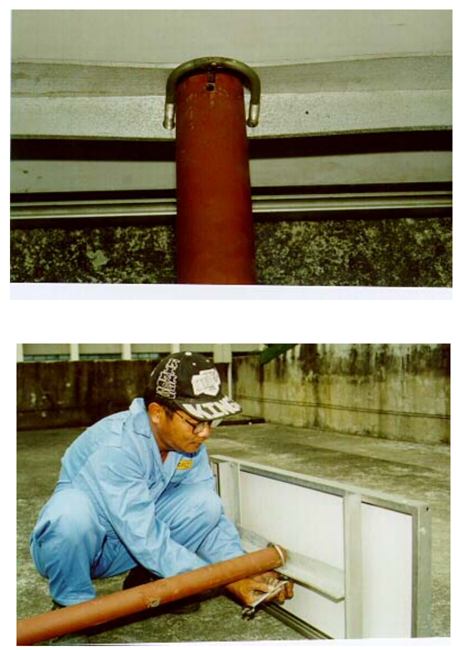
Illus. D
Royal Cord through cable glands

VI.1.2 Mounting the Module

- Mount the PV module using the support structures provided for.
- Lay the PV module face down so that the aluminum frame faces upward.
- Place the support bars on the aluminum frame of the PV module. Secure with the bolts and nuts provided. Tighten afterwards the bolts with a wrench.



Illus. E
PV module mounted on aluminum frame



Illus. F
PV module mounted on steel post and secured with a 2 inches U-Bolt

- Place the two inches U-bolt on the center bar. The PV module is now ready for mounting to steel pole. Frame is fabricated, already tilted at the desired angle.

TABLE 1. Recommended Module Tilt Angels by Province

PROVINCE	TILT	PROVINCE	TILT
ABRA	18	LANAO DEL SUR	10
AGUSAN DEL NORTE	10	LEYTE	11
AGUSAN DEL SUR	10	MAGUINDANAO	10
AKLAN	12	MARINDUQUE	10
ALBAY	13	MASBATE	12
ANTIQUE	11	MISAMIS OCCIDENTAL	10
APAYAO	18	MISAMIS ORIENTAL	10
AURORA	16	MOUNTAIN PROVINCE	17
BASILAN	10	NCR	15
BATAAN	15	NEGROS OCCIDENTAL	10
BATANES	21	NEGROS ORIENTAL	10
BATANGAS	14	NORTH COTABATO	10
BENGUET	17	NORTHERN SAMAR	12
BILIRAN	12	NUEVA ECIJA	16
BOHOL	10	NUEVA VIZCAYA	16
BUKIDNON	10	OCCIDENTAL MINDORO	13
BULACAN	15	ORIENTAL MINDORO	13
CAGAYAN	18	PALAWAN	10
CAMARINES NORTE	14	PAMPANGA	15
CAMARINES SUR	14	PANGASINAN	16
CAMIGUIN	10	QUEZON	14
CAPIZ	11	QUIRINO	16
CATANDUANES	14	RIZAL	15
CAVITE	14	ROMBLON	12
CEBU	10	SARANGANI	10
DAVAO	10	SIQUIJOR	10
DAVAO DEL SUR	10	SORSOGON	13
DAVAO ORIENTAL	10	SOUTHERN COTABATO	10
EASTERN SAMAR	12	SOUTHERN LEYTE	10
GUIMARAS	11	SULTAN KUDARAT	10
IFUGAO	17	SULU	10
ILOCOS NORTE	18	SURIGAO DEL NORTE	10
ILOCOS SUR	17	SURIGAO DEL SUR	10
ILOILO	11	TARLAC	15
ISABELA	17	TAWI-TAWI	10
KALINGA	17	WESTERN SAMAR	12
LA UNION	17	ZAMBALES	15
LAGUNA	14	ZAMBOANGA DEL NORTE	10
LANAO DEL NORTE	10	ZAMBOANGA DEL SUR	10

VI.2 POLE Structure

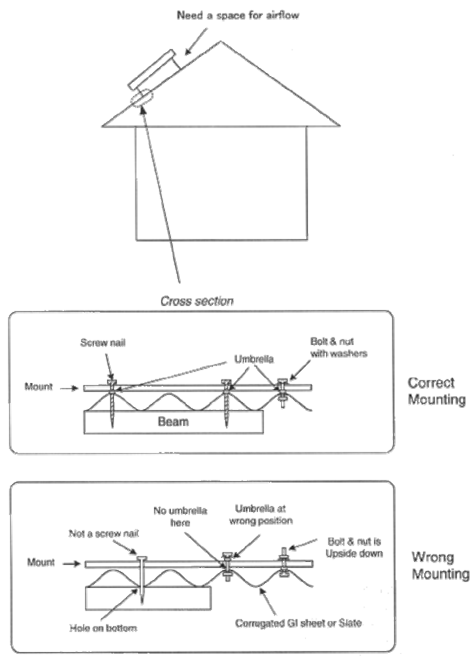
VI.2.1 Types of Mounting

VI.2.1.1 Roof Mount

Mounting solar photovoltaic generators on the roof has the advantage that no additional ground area needs to be set aside or special stands constructed. As requirements for this method, roofs must have the correct tilt and orientation and are free of shadows making them the ideal supports for solar modules.

Usually, a PV module is installed above an existing roof. This is normally done by mounting PV modules to an aluminum or galvanized steel framework lying a few centimeters above the roof, preferably at least 10 cm to allow air to flow. Fixing to the roof structure is then made using special 'roof hooks' or mounting slates which give a secure fastening to the roof structure. But this work must be done very carefully for these will be troublesome spots for water leakage.

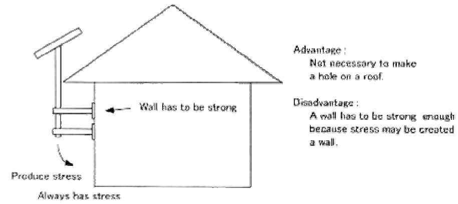
If the roof is corrugated galvanized iron sheet, always make holes on the ridge of corrugation and use umbrella nails or washers to avoid water leakage from holes.



Illus. G
Roof mounting details

VI.2.1.2 Wall Mount

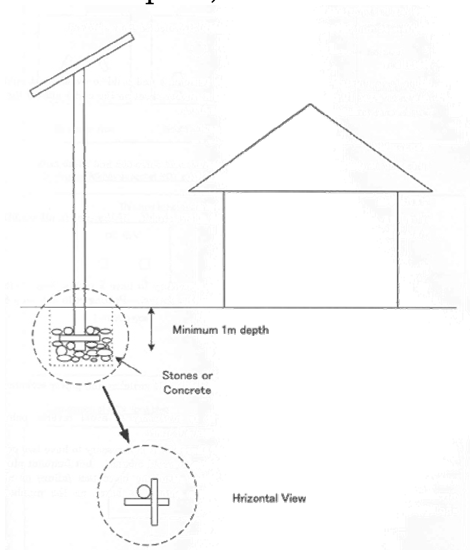
This type of mounting is possible if there is enough wall space, and if the wall is strong enough to carry the weight of the structure. This is preferable but not limited to concrete walls. On some cases, brackets or extensions are used so that the pole does not touch the roof.



Illus. H
Wall mounting details

VI.2.1.3 Pole Mount

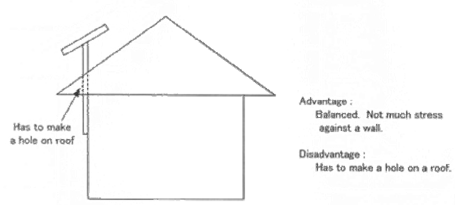
This type of mounting would be used if the PV module is to be installed away from the house. This requires a long pole and the end (1/5th of the length or a minimum of 1 meter) is buried on the ground by cement or concrete. This is to ensure that the poll does not tip over. The pole must not rotate and should be stable, and this must be ensured by proper means, *e.g.*, by inserting iron rods thru the pole, etc.



Illus. I
Pole mounting details

VI.2.1.4 Roof-Pole Mount

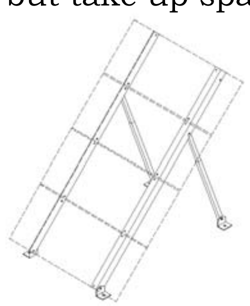
The pole is secured to the wall by clamps and the pole passes through the roof. There would be a need to patch up the holes created by using waterproof seal.



Illus. J
Roof-pole mounting details

VI.2.1.5 Ground Mount

This type of mounting provides easy access & installation but take up space.

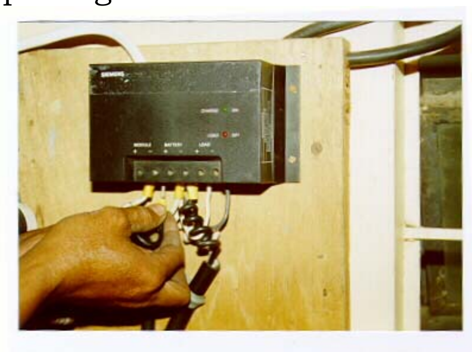


Illus. K
Sample of ground mounted module

VI.3 CONTROLLER

VI.3.1 Installation

- Mount the BCC vertically on a wall.
- Fasten the BCC with wood screw securely to the wall.
- The BCC should not be more than two meters from the battery and six meters from the load junction box.
- When all the cables from the various components such as PV module cable, battery cable and load distribution cable make the connections as follows:
  - Insert the battery cable into the Battery + and Battery – terminal. Tighten securely the connection. Test tightness by pulling the cable.
  - Insert the load cable into the Load + and Load – terminal. Tighten securely the connection. Test tightness by pulling the cable.
  - Insert the PV module cable into the Array + and Array – terminal. Tighten securely the connection. Test tightness by pulling the cable.



Illus. L
BCC wall mounted and wired

Illus. M
PV module, battery and load connected to BCC

- **CAUTION**:
  Some Battery Charge controllers are not reverse polarity protected and short circuit protected.
  Always connect the component cables in its correct polarity. Failure to do so may damage the controller and load as well as cause injury to the installer.

VI.4 BATTERY

VI.4.1 Preparation and Installation

- Remove the plastic cover, for a new battery. Remove the seal on each cap of the cell to expose the vent holes. Remove the cap afterwards.
- Using a funnel, pour the battery solution in each cell. Be careful not to overflow the battery as the solution is a corrosive acid which can cause burns on the skin as well as damage clothes.

- Wipe-off excess solution on the surface of the battery using a rag.
- Prepare the battery cable for connection to the battery charge controller as described in Illustrations B and C.
- On the other end of the cable going to the battery, connect the battery cable by means of battery clips or clamps.
- Lay out and fasten securely the battery cable along the wall going to the controller by means of ½ in. cable clamps.
- The sequences of connecting the battery to the BCC are as follows
    1. Connect the POSITIVE + terminal followed by the NEGATIVE – terminal to the BCC.
    2. Connect the POSITIVE + terminal followed by the NEGATIVE – terminal to the BATTERY.
- Tighten the connections as loose connections on the battery terminals can cause arcing.
- Apply battery grease or plain grease on the battery terminals to prevent corrosion.

VI.5 LIGHTING FIXTURES

VI.5.1 Installation

- Mount the lighting fixture on the ceiling or roof truss using wood screws. The lighting fixture should not be more than 10 meters from the load distribution box. The lighting fixture should be located where it can give-off most light in a room.
- From the load distribution box, lay-out the lighting cable (usually type NM or commonly known as LOOMEX or PDX Cable) to the lighting fixture using staple wires.
- Connect the POSITIVE + conductor of the lamp cable to the POSITIVE + conductor from the load distribution box and the NEGATIVE -- conductor of the lamp cable to the NEGATIVE -- conductor from the load distribution box.
- Splice the conductors by twisting the conductors together with a plier. Tape afterwards with an electrical tape.
- Splice the lamp, switch and load distribution cable in the load distribution junction box as shown below. Check the connections for shorts in the connections before taping with an electrical tape.

VI.5.2 Checking for short circuit on the connection

- Set the multimeter to RESISTANCE setting. With the switch on “OFF mode” connect the multimeter probes on the splice. If there is no short-circuit in the connection, the meter should read an open connection. If a short-circuit in the connection is present, an OHM reading close to zero or zero can be read in the meter. In digital multimeters, a short circuit reading is accompanied by a beeping sound.
- For a number of lamps installed, follow the above mentioned steps. In the light distribution junction box, the lamps are connected in parallel with the LOAD conductors from the battery charge controller.

Maintenance

Solar PV systems are designed to be reliable and hassle-free. However, it is advisable to check everything regularly and to fix small problems before they become large ones. Although maintenance includes repair of the system, it is better to keep the systems from breaking down than to just do the maintenance when something is broken. Thus, the following discussion will be about preventive maintenance.

Regular Maintenance:

1. Ask the user about the operation of the PV system to see if there are problems.
2. Check every part of the PV system for correct operation, cleanliness and tight connections.
3. Repair or replace component that are not in good conditions.
4. Check the system to make sure that no changes have been made that have not been authorized.
5. Make a record of any action taken during the maintenance visit.

Rules for Maintenance

A. Panels
    1. Check the Module or Panel mounting. It should be strong and well attached.
    2. Check the module glass. If broken should be replaced.
    3. Check the connection box. Wires should be tight and water seals are not damaged
    4. Check for shading problem.

B. Wires
    1. Check the wire covering for cracks or breaks.
    2. Check the attachment of the wire to the house to make sure that it is well fastened and can not rub against sharp edges when the wind blows.
    3. Correct wiring size should be observed and practiced.
    4. Check for tampering.
    5. Check connections.

C. Controller
    1. Check if firmly attached.
    2. Must be clean.

D. Appliances
    1. Turn on each appliance to see if it is working.
    2. Check if the appliances are mounted securely.
    3. Clean all exposed parts.

E. Battery
    1. Clean the top of the battery and check the connections for

tightness and corrosion.

2. Check each cell with hydrometer and record the readings.
3. If any cells are low on water, add distilled water.
4. If any caps for the cell are lost or broken, cover the fill holes loosely with plastic or glass until replacement is found. Never leave the holes uncovered and do not use cloth, metal, paper or cork as temporary cover.

Maintenance Record:

Maintenance record should be made at the time of the visit. It is not a good idea to wait until later to write down what you did. One copy of the maintenance records for yourself and leave another copy at the site.

VII. Load Management

What is load management?

It is important that the end-user should know as well as the technicians assigned in their respective community the proper handling in using the appliances particularly of the time used. Load management is simply managing the time on the usage of its appliances.

Why do load management?

Like the rainwater collection system, if one uses the water too much in the storage tank and that rain did not come to replenish the used water. Eventually, there would be days the household wont have water.

The PV systems works the same way, if the rate of discharge of your battery through the use of appliance is too much as compared to the charging rate from the PV module, the battery would eventually causes the battery plates to evolve to sulphate crystal which would shorten the battery's life.

Who should do the load management?

Load management should be practiced by the RE clientele or the end-user. However, it would be advisable that technicians should have some knowledge on this. If users want to add more appliances they should add more PV module.

What should the end-user do?

The usual rule is to that the daily power consumed should not exceed daily output of the PV module.

Example: For a 55 Wp PV Module and having good sunshine hours of at least 3.5 hrs per day: Solution: 55 x 3.5 = 192.5 Watt-hrs/day

Compare to the Usage @: Not Advisable

Appliances	Capacity	Hours used	Watt-hours
Load 1 CFL	10 watts	4 hours	40 watt-hours
Load 2 CFL	10 watts	4 hours	40 watt-hours
Load 3 radio	10 watts	6 hours	60 watt-hours
Load 4 TV	18 watts	4 hours	72 watt-hours
		TOTAL	214watt-hrs > 192.5watt-hrs BAD!

VIII. Monitoring

VIII.1 LEVEL 1 MONITORING

To be done by the local technician, trained in simple but effective monitoring and troubleshooting skill that focus on battery, because battery problems may take months to show up clearly, there needs to be a continuing record of battery measurements (voltage, time and date of visit, hydrometer readings for each cell, and the amount of water needed by the battery) so problems that are increasing in severity can be easily identified by comparing prior readings.

VIII.2 LEVEL 2 MONITORING

A simple monitoring procedure to be made by the projects technical people together with the local technician that will focus on overall system performance, to be done on a quarterly basis.

Activities:

- Perform all inspections of Level 1 monitoring.
- Measure the Voc and Isc of Solar Module.
- Measure the battery voltage.
- Switch one load after another and measure:
  - Voltage at battery terminals
  - Current at battery terminals
  - Voltage at load terminals
- Compute for the voltage drop on every loads.

Any time components are repaired or changed, a note of the action taken should be made so it is clear what components are causing problems and to bring site records up to date with corrections also made to the office copies. Copies should also be made for the user.

VIII.3 LEVEL 3 MONITORING

IX. Troubleshooting and Repair

IX.1 PHOTOVOLTAIC MODULE, Common Problems

IX.1.1 Shading

Remove shading on the PV module by cutting/trimming tree branches that cause shading. If this is not possible, transfer the PV module to a location not shaded between 9 a.m. to 3 p.m.

IX.1.2 Loose and corroded connections

Experiences we have encountered show that most the common problem with connections is just loose connection. Twist the wires to tighten connection and tape with an electrical tape. As much as possible always use a wire sleeve or solder the wire before connecting the solar panel.

IX.1.3 Busted Diode

IX.2 BATTERY CHARGE CONTROLLER

IX.2.1 Busted Fuse

The most common trouble regarding BCC is user intervention e.g. tapping of loads and line extensions which causes short circuit to the unit. This is the cause of the busted fuse in the controller. Trace the short-circuit and disconnect all unnecessary connections. Replace fuse with appropriate rating.

IX.2.2 Wrong Voltage Hysteresis

Check voltage setpoints for overcharge and deep discharge modes. Adjust to appropriate voltage set points when necessary.

IX.2.3 No Current Passing Through

This usually happens when the Shunting Transistor in a Shunt type BCC remains shorted. Check transistor. If found shorted, replace with similar type and rating.

IX.2.4 Wrong Connections

This is a very common problem with controllers. As much as possible use wire sleeves or solder all ends before connecting wires to the controller.

IX.2.5

.

IX.3 BATTERY

IX.3.1 Discharged State

Decrease capacity of the battery is due to excessive use by the consumer, Caution the consumer that discharging the battery will affect its lifetime. Teach the user load management.

High acidity of the battery may be caused by filling the battery of acid solution instead of distilled water. To counteract this, put distilled water on the cell and equalize charge the battery.

Equalized cell voltage by disconnecting the BCC to the battery and then connect the PV module directly to the battery to equalize the cell voltages. Fill the battery with distilled water if necessary.

IX.3.2 Poor Contacts

Poor connections to the battery are one of the main causes of the BCC malfunction. This will also cause arcing which may damage the whole unit. The best way to connect the battery is to use a terminal lug and connect it tightly to the battery poles and as much as possible solder or use wire sleeve.

IX.4 LIGHTS

IX.4.1 Busted Fuse

Main cause of the busted fuse is reverse polarity connection. Another caused is loose connection to the terminals of the lighting fixture. Connect the wires to the light terminal in correct polarity and as much as possible solder or use wire sleeve.

IX.4.2 TV / Radio Interference

Connect the radio or TV in another circuit to avoid interference when turning on the lights.