कौशल विकास
और उद्यमशीलता मंत्रालय
MINISTRY OF
SKILL DEVELOPMENT
AND ENTREPRENEURSHIP

सत्यमेव जयते

MINISTRY OF
NEW AND
RENEWABLE ENERGY
GOVERNMENT OF INDIA

सत्यमेव जयते

Directorate General of Training

Skill India
कौशल भारत - कुशल भारत

PMKVY
प्रधानमंत्री कौशल विकास योजना

PM - Surya Ghar : Muft Bijli Yojana

ROOF TOP SOLAR PV
(Installation & Maintenance)

NSQF LEVEL - 3

सत्यमेव जयते

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ROOFTOP SOLAR PV
(INSTALLATION & MAINTENANCE)

NSQF - 3

TRAINING MANUAL

SECTOR: POWER

कौशलं बलम्

Directorate General of Training

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI.
Post Box No. 3142, CTI Campus, Guindy, Chennai - 600 032

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FOREWORD

The success of the PM Surya Ghar initiative hinges significantly on the comprehensive training of our solar technicians nationwide. It is heartening to note that the Ministry of Skill Development and Entrepreneurship, through its Directorate General Training, and in collaboration with the National Instructional Media Institute (NIMI), has undertaken the responsibility of skilling 1,00,000 Solar PV Technicians.

This skilled workforce will not only facilitate the deployment of rooftop solar systems but also contribute to the larger goal of energy independence and environmental sustainability. I am delighted to introduce the instructional material developed by NIMI for the course on Rooftop Solar PV (Installation & Maintenance).

This book, designed under NSQF - 3 for the Power sector, represents a significant milestone in vocational education. It provides comprehensive skills & knowledge to trainees who will be trained under this programme. With its structured approach and practical insights, this material promises to elevate the quality of training and ensure that our workforce meets international standards in solar technology.

I commend the Executive Director and the dedicated team at NIMI, as well as the members of the Media Development committee, for their unwavering dedication and expertise in developing this vital resource. Their efforts will undoubtedly pave the way for a skilled workforce that is not only capable of meeting the demands of today but also prepared for the challenges of tomorrow.

I am confident that this book will be instrumental in shaping the future of rooftop solar installation and maintenance in India. I encourage all trainees and stakeholders to utilize this material to its fullest potential, thereby contributing to the success of the PM Surya Ghar initiative and the sustainable development of our nation. Best wishes for successful training and implementation.

Sanjay Kumar, ISDS
Director, Curriculum Development
DGT, MSDE

PREFACE

It is with great pleasure to introduce the vocational instructional material developed by the National Instructional Media Institute (NIMI) for the course on Rooftop Solar PV (Installation & Maintenance). This BOOK, designed under NSQF - 3 for the Power sector, marks a significant milestone in our commitment towards fostering sustainable energy solutions in India.

The Government of India’s PM Surya Ghar: Muft Bijli Yojana is a visionary initiative aimed at promoting the widespread adoption of solar rooftop systems. This ambitious program not only seeks to empower communities by enabling them to generate their own electricity but also addresses the crucial need for skilled technicians who can ensure the quality installation and reliable maintenance of these systems. As we strive towards the installation of 1 crore rooftops across residential sectors, the role of trained solar technicians becomes indispensable. Recognizing the pivotal role of skilled manpower in the success of the PM Surya Ghar initiative, the Directorate General of Training- Ministry of Skill Development and Entrepreneurship, in collaboration with NIMI, has embarked on a mission to skill 1,00,000 Solar PV Technicians.

This skilled workforce will play a critical role in deploying rooftop solar systems nationwide, thereby contributing significantly to our goals of energy independence and environmental sustainability. This book has been meticulously crafted to provide comprehensive insight to trainees on essential skills who will be our future solar technicians. It combines theoretical knowledge with practical insights, ensuring that our workforce not only meets but exceeds international standards in solar technology. The structured approach of this material is aimed at enhancing the quality of training and equipping our technicians with the proficiency needed to meet the evolving demands of the industry.

I extend my sincere appreciation to the dedicated team at NIMI, as well as the members of the Media Development committee, for their relentless efforts in developing this vital resource. Their expertise and commitment have been instrumental in ensuring the relevance and effectiveness of this book.

I am confident that this instructional material will serve as a cornerstone in shaping the future of rooftop solar installation and maintenance in India. I encourage all trainees and stakeholders to utilize this resource to its fullest potential, thereby contributing effectively to the success of the PM Surya Ghar initiative and fostering sustainable development across our nation. Best wishes for productive training sessions and successful implementation.

EXECUTIVE DIRECTOR
NIMI, CHENNAI.

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National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Development Kommittee Members, SME & NIMI - Coordinators and their sponsoring organisation to bring out this training material for the trade of **Rooftop Solar PV (Installation & Maintenance) - Trade Theory & Trade Practical - NSQF - 3** under **PM SURYA GHAR : MUFT BIJLI YOJANA**

NIMI records its appreciation of the Data Entry, CAD, DTP Operators for their excellent and devoted services in the process of development of this trainning Material.

NIMI also acknowledges with thanks, the invaluable efforts rendered by all other staff who have contributed for the development of this trainning Material.

NIMI is grateful to all others who have directly or indirectly helped in developing this IMP.

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Solar energy fundamentals

Objectives: At the end of this lesson you shall be able to
- **explain the concept of potential & kinetic energy**
- **describe the division of energies**
- **explain solar energy fundamentals.**

Renewable Energy

The Renewable or natural energy sources are continuously produced by natural processes and forces occurring in the environment.

These energy sources are also available in a distributed manned around everyone, which means that the required energy can be generated where there is a need.

The following figure shows some renewable energy sources.

Solar Energy: Converting solar radiations in to electrical energy. (Fig 1)

Fig 1

Solar Energy

Wind Energy: Transforming K.E of wind into E.E (Fig 2)

Fig 2

Wind Energy

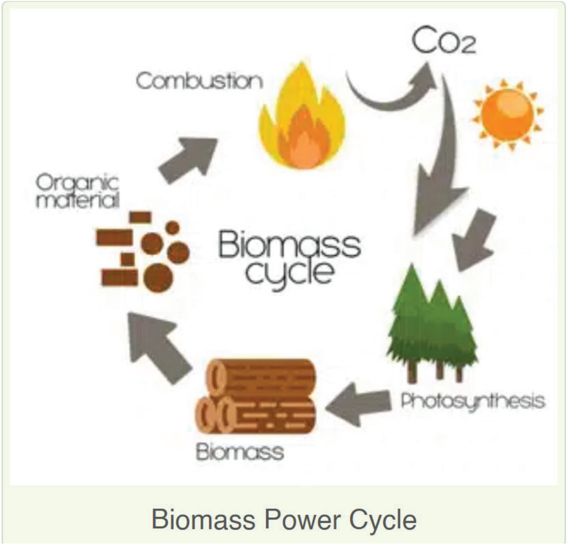
Hydro Energy: Converting energy of water flow into electricity. (Fig 3)

Fig 3

Hydro Energy

Biomass Energy: Transformation plant material in to energy. (Fig 4)

Fig 4



Hydro Energy

Solar Energy: Sun (Fig 5)

Fig 5

Sun

The Sun is the main, natural source of energy on Earth. The energy recorded from the sun by the earth is from of electromagnetic radiations.

The energy gets converted into various forms of renewable energy.]

On reaching the earth, some of the energy from the solar radiations.

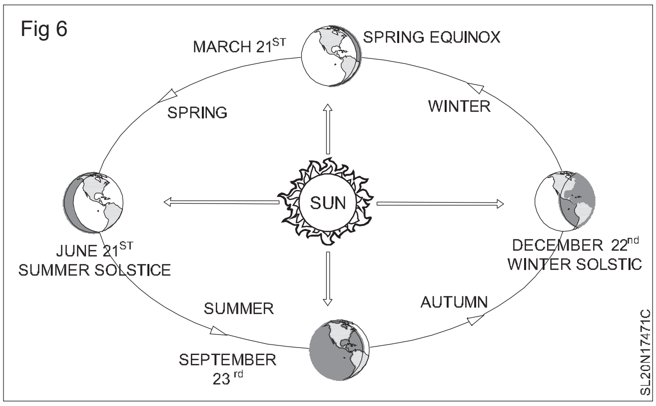
Solar Energy System: Solar panel (Fig) India is blessed with a large amount of sunlight. Solar radiation is received in a range of 4 to 7 kwh/m2/day. Such amount of radiation is good enough to generate electricity to fulfil electricity requirement of an entire region using this technology. The energy can be generated in any area. Where there is a need, by installing the solar energy system.

Geothermal power plants use heat released from the interior through Earth's crust. The heat can be used directly or converted to electricity.

Renewable energy technologies tap into natural cycles and systems, turning the ever- present energy around us into usable forms. The movement of wind and water, the heat and light of the sun, heat in the ground. The carbohydrates in plants all are natural energy sources that can supply our needs in a sustainable way because they are homegrown, renewable can also increase our energy security.

Seasonal Changes in a year period (Fig 6)

Fig 6



Sun paths at any latitude and any time of the year can be determined from basic geometry. The Earth's axis of rotation tilts about 23.5 degrees, relative to the plane of Earth's orbit around the Sun.

As the Earth orbits the Sun, this creates the 47° declination difference between the solstice sun paths, as well as the hemisphere-specific difference between summer and winter.

In the Northern Hemisphere, the sun path near to the winter solstice (November, December, January), rises in the southeast, transits the celestial meridian at a low angle in the south (more than 43° above the southern horizon in the tropics), and then sets in the southwest.

It is on the south (equator) side of the house all day long.

A vertical window facing south (equator side) is effective for capturing solar thermal energy.

For comparison, the sun path near the winter solstice in the Southern Hemisphere (May, June, July) rises in the northeast, peaks out at a low angle in the north (more than halfway up from the horizon in the tropics), and then sets in the northwest.

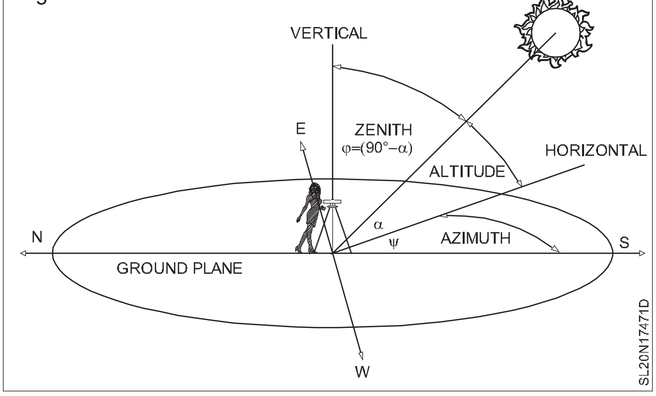
Duration of Daylight

North of the Arctic circle and south of the Antarctic circle, there will be at least one day a year when the sun is not above the horizon for 24 hours during the winter solstice, and at least one day when the sun is above the horizon for 24 hours during the summer solstice.

In the moderate latitudes (between the circles and tropics, where most humans live), the length of the day, solar altitude and azimuth vary from one day to the next, and from season to season. The difference between the length of a long summer day and a short winter day increases as one moves farther away from the equator.

Azimuth and Altitude (Fig 7)

Fig 7



Rise and set directions

On the northern hemisphere the north is to the left, the Sun rises in the east (far arrow), culminates in the south (to the right) while moving to the right and sets in the west (near arrow). Both rise and set positions are displaced towards the north in summer, and towards the south for the winter track.

On the southern hemisphere the south is to the left, the Sun rises in the east (near arrow), culminates in the north (to the right) while moving to the left and sets in the west (far arrow). Both rise and set positions are displaced towards the south in summer, and towards the north for the winter track.

On the imaginary line of the equator the Sun maximum elevation is great during all the year but it doesn't form every day a perfect right angle with the ground at noon. In fact it happens two days of the year, during the equinoxes.

The solstices are the dates that the Sun stays farthest away from the zenith but anyway also in those cases it's high in the sky, reaching an altitude of 66.56° either to the north or the south. All days of the year, solstices included, have the same length of 12 hours.

In the southern hemisphere, the Sun remains in the north during winter, but can reach over the zenith to the south in midsummer. Summer days are longer than winter days, but approximately the difference is no more than only two and a half hours.

Azimuth angle of the sun is defined as the angle from due north in a clockwise direction. (Sometimes from south)

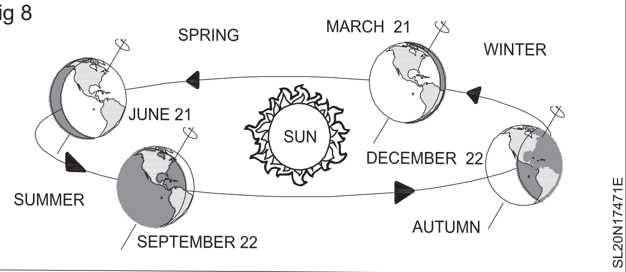
Zenith angle of the sun is defined as the angle measured from vertical downward.

Angle of inclination of radiant light and its relation with latitude and longitude of different locations on Earth.

Depending on a geographical location the closer to the equator the more "potential" solar energy is available. The earth reaches the point nearest to the sun in the beginning of January each year (Perihelion - 147 million kilometers). After 6 months, on the 4th of July, it reaches the farthest distance from the sun (Aphelion - 152 million kilometers). This means that, due to these different distances, the direct solar radiation reaching the earth's atmosphere is 7% more intense in January than it is on the 4th of July. These differing distances between the earth and the sun only have a minor effect on the seasonal temperatures on the earth.

Earth's orbit (Fig 8)

Fig 8



The angle of incidence of the solar radiation is changing continually as the earth is circling around the sun and also spinning around its own axis. The ratio of radiation intensity and angle of incidence may be described as a cosine function, which is also called Lambert's law.

The 23.5º inclination of the earth's axis also has an influence as can be seen from Illustration above. The all-important factor is the change of the angle of incidence during the different times of the day.

The earth is not a flat disk. It is almost spherical in shape and gravitational force binds the atmosphere like a shell. The intensity of the solar radiation at a point on the surface is therefore influenced by the curvature of the surface and the effective thickness of the atmosphere. The solar radiation reaches its highest intensity when the sun is at its zenith and the angle of incidence is 90° and the thickness of the atmosphere is at its minimum. The lower the sun's position is in the sky the more atmospheres the radiation must pass through, and so more radiation is scattered and absorbed by the atmosphere and less radiation reaches the ground surface.

The effective thickness of the atmosphere is called the Atmospheric Depth. Just above the horizon the Atmospheric Depth is approximately 11 times larger than at the shortest path, at 90º (solar zenith), see Illustration. The effects of solar radiation are also influenced by the composition of the ground surface. It is not difficult to understand that a surface covered with snow reflects more radiation than one covered with trees or with black rock. The fraction of the incident solar radiation that is reflected by the surface is called the Albedo.

Definition of key earth-sun angles.

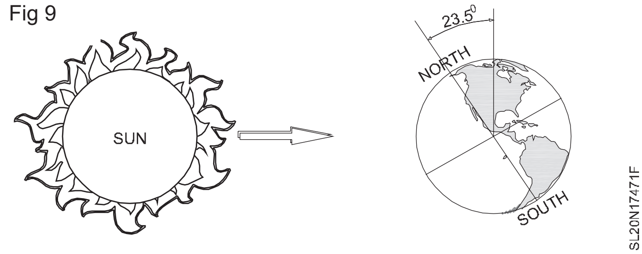
Factors Influencing Solar Collector Installation

Solar irradiation is affected by the following factors:

- Angle of Incidence of Solar Radiation
- Inclination of the Earth
- Atmospheric Depth

Inclination of Earth's axis (Fig 9)

Fig 9



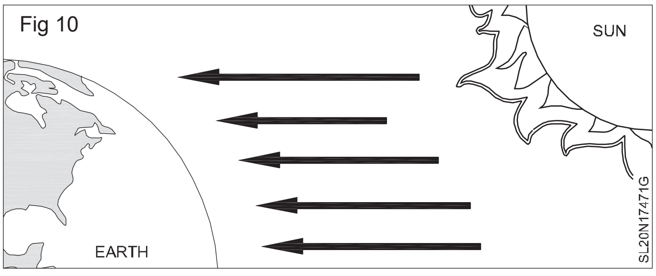
The all-important factor is the change of the angle of incidence during the different times of the day and throughout the year for a given location on earth. Based on these Solar collectors' installation varies place to place.

The closer to the equator the more "potential" solar energy is available. The earth reaches the point nearest to the sun (Perihelion - 147 million kilometers) in the beginning of January each year. After 6 months, on the 4th of July, it reaches the farthest distance from the sun (Aphelion - 152 million kilometers).

Due to these different distances, the direct solar radiation reaching the earth's atmosphere is 7% more intense in January than it is on the 4th of July

Direct radiation (Fig 10)

Fig 10



Measure intensity of solar radiation

Objectives: At the end of this exercise you shall be able to
- **use solar irradiance meter**
- **measure solar intensity.**

Requirements

Tools/Measurements/Equipments

- Pyranometer & Irradiance meter

A Pyranometer is a device that measures solar irradiance from a hemispherical field of view incident on a flat surface. The SI units of irradiance are watts per square metre (W/m²).

Radiometer is a device used to measure the intensity of radiant energy. In order to measure radiation emitted from a specific spectrum or to incorporate the radiometer within a certain spectral response, an optical filter is normally used.

PROCEDURE

1 Take a Pyranometer and a irradiance meter.

2 Measure the Solar intensity at different places inside the room, outside the room and in open sunlight.

3 Record your observations.

4 Compare results of both instruments.

S. No.	Location	Pyranometer reading	Irradiance reading

Conclusion:

Fig 1

Solar constants and sun's path

Objectives: At the end of this exercise you shall be able to
- **brief about equation of time, solar constant and global irradiance**
- **describe solar radiation map and sunlight spectrum.**

Sun path at Different seasons (Fig 1)

Accordingly, the installation angle varies from season to season, depending on a geographical location.

Installation of Solar Collector and Angle of incidence of Solar irradiation (Fig 2)

Equation of time, solar constant etc.

The equation of time describes the discrepancy between two kinds of solar time. The word equation is used in the medieval sense of "reconcile a difference". The two times that differ are the apparent solar time, which directly tracks the diurnal motion of the Sun, and mean solar time, which tracks a theoretical mean Sun with uniform motion. Apparent solar time can be obtained by measurement of the current position (hour angle) of the Sun, as indicated (with limited accuracy) by a sundial. Mean solar time, for the same place, would be the time indicated by a steady clock set so that over the year its differences from apparent solar time would have a mean of zero.

Solar constant is the rate at which energy reaches the earth's surface from the sun, usually taken to be 1,388 watts per square meter.

Fig 11

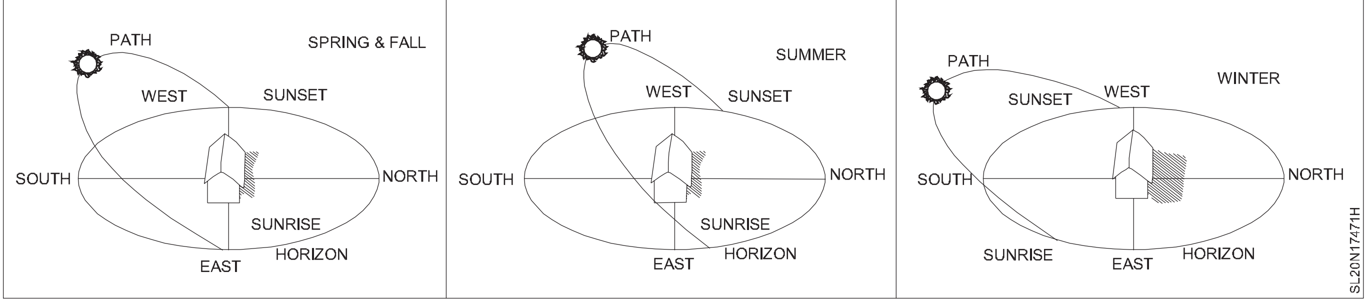
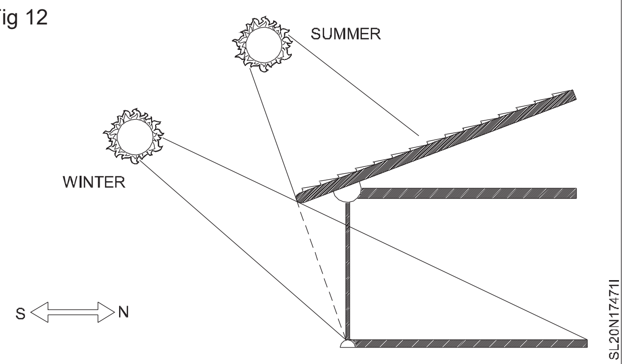


Fig 12



Solar Constant (Fig 3)

Solar constant, the total radiation energy received from the Sun per unit of time per unit of area on a theoretical surface perpendicular to the Sun's rays and at Earth's mean distance from the Sun. It is most accurately measured from satellites where atmospheric effects are absent. The value of the constant is approximately 1.366 kilowatts per square meter. The "constant" is fairly constant, increasing by only 0.2 percent at the peak of each 11-year solar cycle. Sunspots block out the light and reduce the emission by a few tenths of a percent, but bright spots, called plages, that are associated with solar activity are more extensive and longer lived, so their brightness compensates for the darkness of the sunspots. Moreover, as the Sun burns up its hydrogen, the solar constant increases by about 10 percent every billion years.

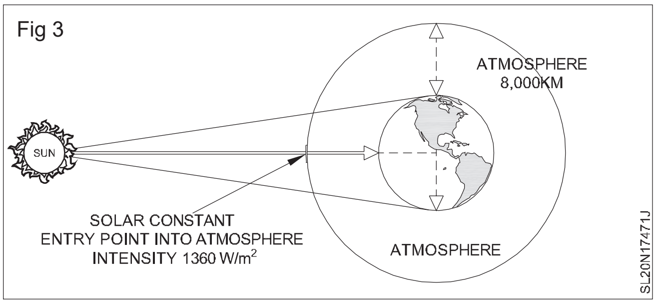
Definition of GHI & DNI

Global Horizontal Irradiance (GHI) is the total solar radiation incident on a horizontal surface. It is the sum of Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance, and ground-reflected radiation. Direct Normal Irradiance (DNI) is the amount of solar radiation received per unit area by a surface that is always held perpendicular (or normal) to the rays that come in a straight line from the direction of the sun at its current position in the sky. Typically, you can maximize the amount of irradiance annually received by a surface by keeping it normal to incoming radiation. This quantity is of particular interest to concentrating solar thermal installations and installations that track the position of the sun.

Diffuse Horizontal Irradiance (DHI) is the amount of radiation received per unit area by a surface (not subject to any shade or shadow) that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere and comes equally from all directions

Global Horizontal Irradiance (GHI) is the total amount of shortwave radiation received from above by a surface horizontal to the ground. This value is of particular interest to photovoltaic installations and includes both Direct Normal Irradiance (DNI) and Diffuse Horizontal Irradiance (DHI).

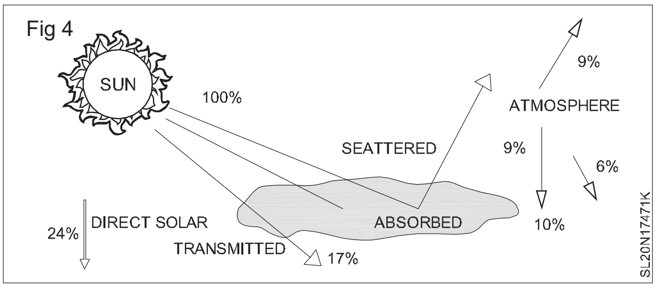
Fig 3



Global Horizontal (GHI) = Direct Normal (DNI) X cos(θ) + Diffuse Horizontal (DHI)

Solar radiation through space (Fig 4)

Fig 4



The surface receives about 47% of the total solar energy that reaches the Earth. Only this amount is usable.

Insolation:

- Insolation is the amount of solar irradiation reaching the earth.
- Also called Incident Solar irradiation or incoming solar irradiation
- Insolation reaches the earth, is absorbed and reflected
- Components of Solar Radiation:
  - Direct radiation
  - Diffuse radiation
  - Reflect radiation

Global Solar irradiation = Direct radiation + Diffused radiation

Basically there are two types of solar radiations:

- Global Horizontal irradiations (GHI)
- Direct Normal Irradiation (DNI)

GHI consists of diffuse radiations and direct horizontal radiations (beam).

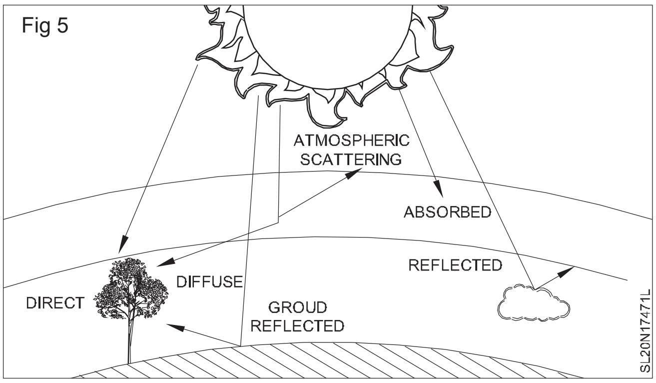
Minimum GHI – 1000 kwh/m^2

DNI is the amount of radiation received by a surface which is permanently aligned perpendicular to the incoming beam.

Minimum DNI – 1900 kwh/m^2

Direct, diffused and reflected radiation (Fig 5)

Fig 5



The energy emitted by the sun is 3.72 X 1020 MW, which equates to a irradiative power of 63 MW per m² of its surface. At the mean distance between earth and sun, this radiation reaches the outside of the earth's atmosphere with an intensity of 1.367 kW falling onto a 1 m² surface oriented normally to the sun's beams.

The Solar panel in fixed orientation needs to face south in Northern hemisphere and face north in southern hemisphere. The panel needs to be tilted at around Latitude angle of the location, in simple manner. At equator the tilt angle is 0˚.

Rooftop Met sensors installation (Fig 6)

Typical Solar Radiation research station is shown above. It has PV panels mounted on Solar tracker for measuring Seasonal solar intensity, Pyranometer, Wind mast mounted with sensors, rain gauge etc to monitor continuously the weather throughout the year in a location. Data collected from the various sensors and transducers are monitored by suitable software and recorded continuously. We can derive all weather data and plot graphs to find out renewable energy availability over year period. This helps in planning effectively a project. Recorded year wise data would be useful gauge and develop future projects.

Pyranometer (Fig 7)

The Solar radiation data country wise are shown in the maps given below which are generally called Solar PV Maps.

Solar radiation Map

The map indicates Yearly sum of global irradiation incident on optimally – inclined Equator facing Photovoltaic modules. Accordingly, in the map lowest annual Solar radiation regions are marked by Blue colour starting with 800 kWh/m^2 and highest radiation received regions are represented by Dark Brown indicating highest as 2800 kWh/m^2. In India the received solar radiation levels yearly are between 1600 kWh/$m^2$and 2500 kWh/m^2.

Application of sun chart on shadow identification.

Sundial (Fig 8)

An instrument which uses the shadow cast by the Sun to tell the time. Because the Earth's axis is tilted in space and because the Earth does not travel at a constant speed around the Sun, the time shown on a sundial can differ from true „clock" time. The correction needed to convert sundial time to clock time is called the Equation of Time.

$c = (h^2 + r^2)^{1/2}$

$h/r = \tan(\Theta)$

$\Theta = \tan^{-1}(h/r)$

Where

h = height of gnomon

r = length of shadow

Θ = incident angle of light source (sun or artificial light source)

Fig 6

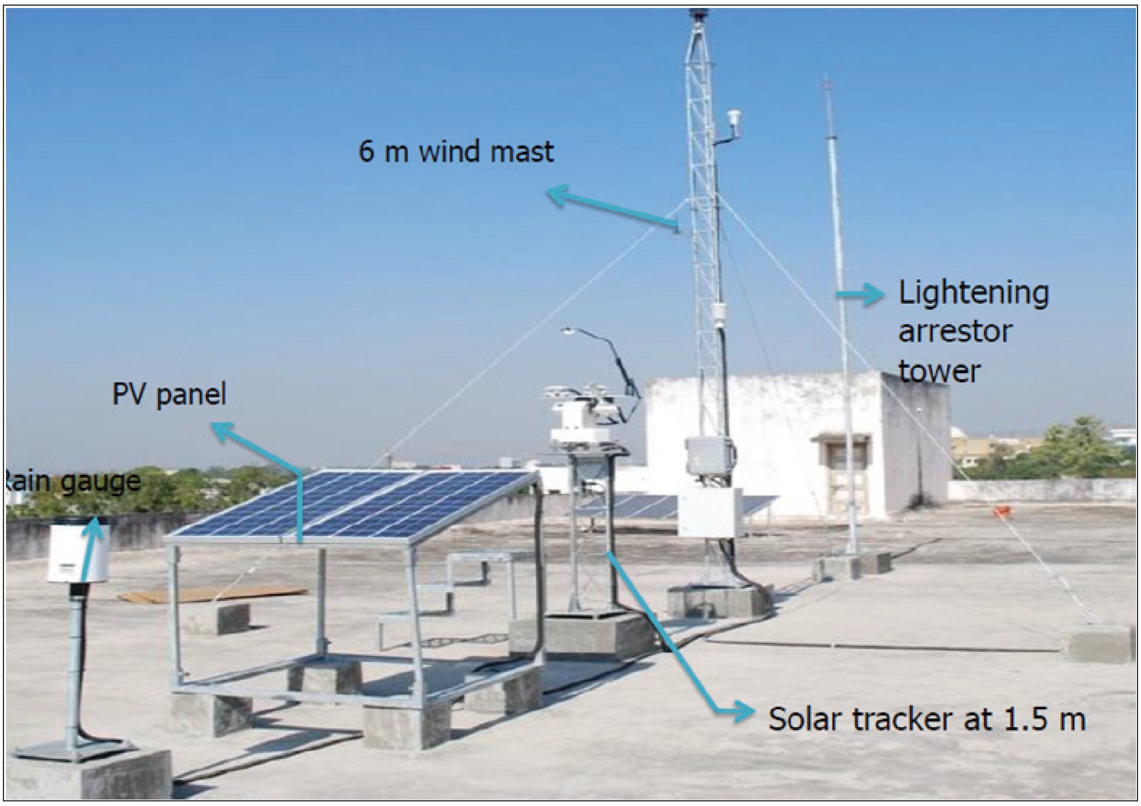


Fig 7

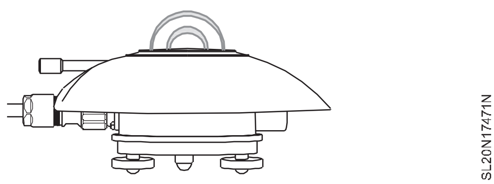
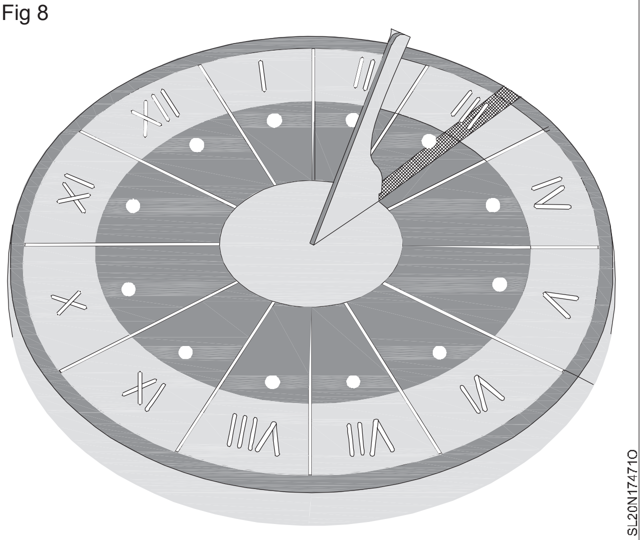
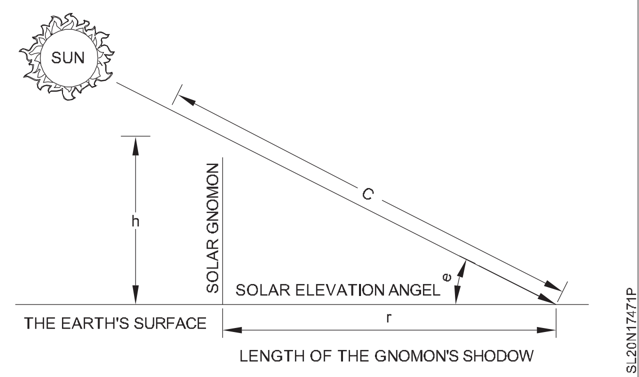


Fig 8



Sunlight spectrum (Fig 9)

Fig 9



The sun's outermost and relatively thin 400 km layer is called the Photosphere and has a temperature of approximately 5,770 Kelvin. This is the layer that emits the spectrum of radiation which is visible to the human eye and is termed 'light'.

Scattering of solar radiation takes place within the whole spectral range. However, there are different ways in which the scattering can occur:

- Scattering by water droplets and/or ice crystals in clouds relatively evenly across
- the whole spectral range;
- Scattering by molecules (Rayleigh-Scattering), predominantly of radiation at shorter wavelengths
- Scattering by aerosol particles (Mie-Scattering) at wavelengths dependent upon the particle size and distribution.

We can observe on the paper that the sunlight is split into a spectrum of colours like a rainbow energy colour in VIBGYOR pattern i.e. Violet, Indigo, Blue, Green, Yellow, Orange & Red can be seen. The conclusion drawn here is that sunlight is nothing but a mixture of seven colours.

Sunlight is broken down into three major components

1 Visible light: 0.4 & 0.8 μ meters

2 ultraviolet light: Shorter than 0.4 μ m

3 infrared light: Longer than 0.8 μ m

Sunlight spectrum (Fig 10)

Importance of solar Energy for various application.

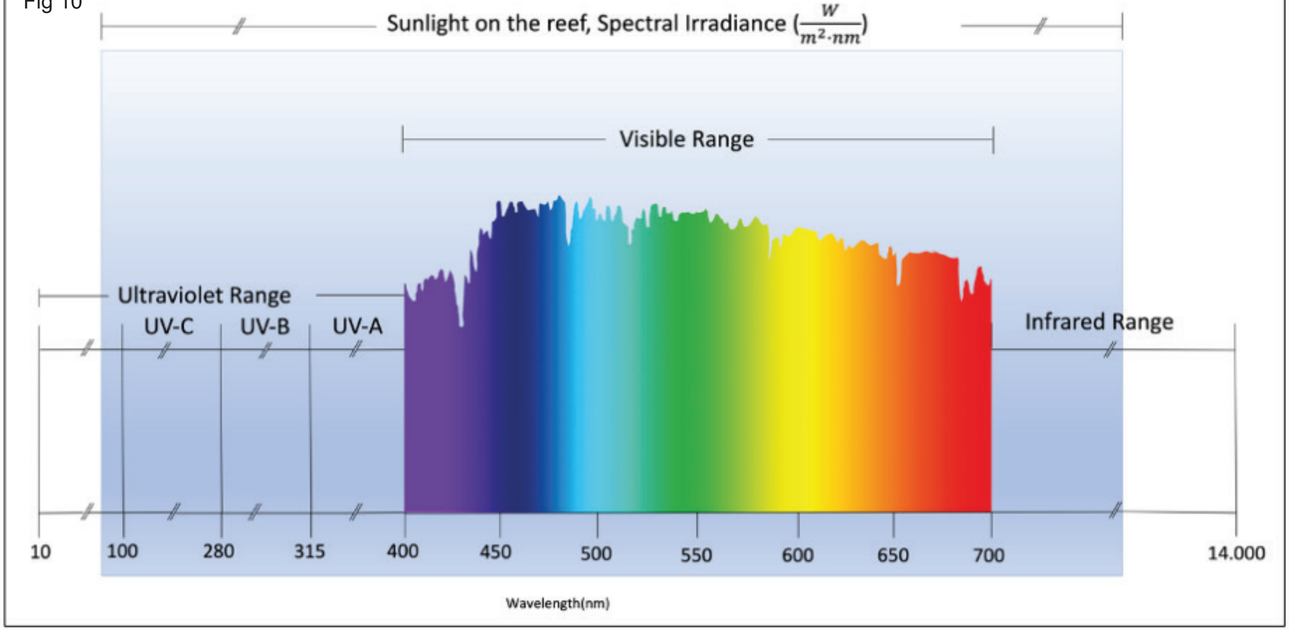
Solar Electrical Application

Solar Photo voltaic technology is employed for directly converting solar energy to electrical energy by using "Solar silicon cell"

The electricity generated can be utilized for different application directly as through battery storage system.

- Basic of site selection
  - Availability of Solar radiation
  - Availability of large land.

Fig 10



Identify various parts of rooftop solar power plant and its uses (On grid, Off grid & Hybrid)

Objectives: At the end of this exercise you shall be able to
- **identify the parts**
- **measure solar intensity.**

Requirements

Tools/Measurements/Equipments

- Solar PV System - on grid - 1 set.
- Solar PV System - off grid - 1 set.
- Solar PV System - hygrid - 1 set.

PROCEDURE

Identify the parts of rooftop solar panel

1 Identify the each parts of a roof top solar PV system
  - ON grid
  - OFF grid
  - Hybrid

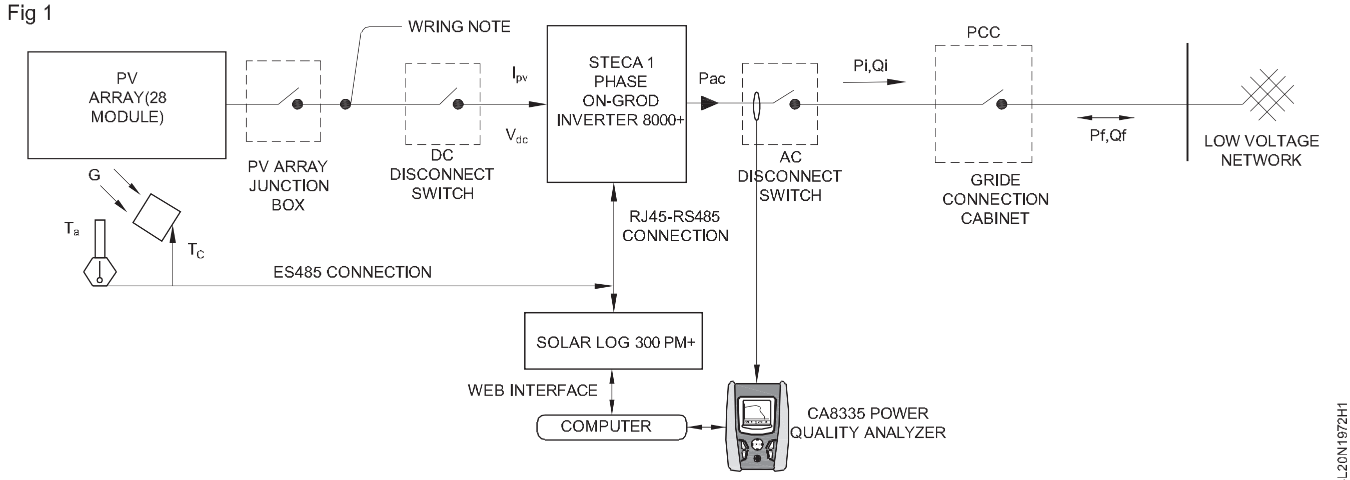
Example: PV Module, AJB, MC4 connector, SPO, DC fuse, charge controller, inverter and battery, etc.

2 Record their name one by one in a tabular column.

3 Note down their specification as per the name plate details/ Lasels/ Manuals.

4 Draw the single line diagram (SLO) of the given on-grid, off-grid and hybrid PV system (Fig 1)

Fig 1



Table

S. No.	Name of parts	Specifications	Remarks

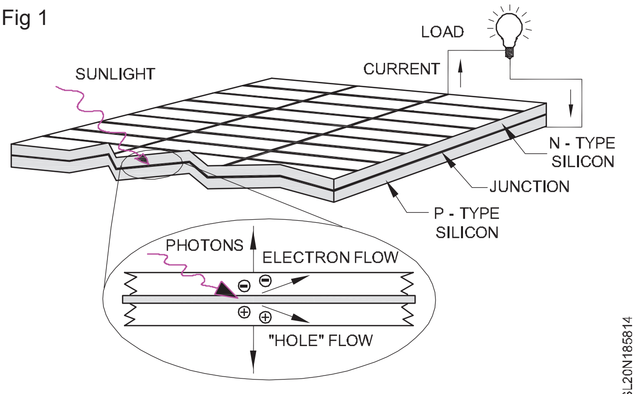
Conversion of solar radiation to electricity

Objectives: At the end of this lesson you shall be able to
- **define a photo voltaic (PV) cell and state it's application**
- **explain the IV curve of Solar PV cell and factors affecting its performance**
- **state various types of Solar cells and their properties**
- **define a charge controller and explain the types of Charge controller.**

Photovoltaic Cell / Solar Cell (Fig 1)

A solar cell or photovoltaic cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. It is a form of photoelectric cell (in that its electrical characteristics e.g. current, voltage, or resistance vary when light is incident upon it) which, when exposed to light, can generate and support an electric current without being attached to any external voltage source. This method converts the sun's energy into electricity.

Fig 1



A single solar PV cell will have an output of approximately 0.5 V and current of few mA which depends on various factors such as type & quality of the cell, Solar irradiation, incident angle of solar irradiation, shadow, Spectrum of incident radiation etc. They are grouped to get higher outputs.

Applications of solar cells:

The electricity generated by the photoelectric effect can be either used directly or can be stored in batteries or can directly fed into an electric utility's grid system. The energy stored in the battery (in the form of chemical energy) can be used to operate any electrical device. If the device operates on DC, then it can be directly connected to the output load. If the device operates on AC, then an inverter is required to convert DC into AC.

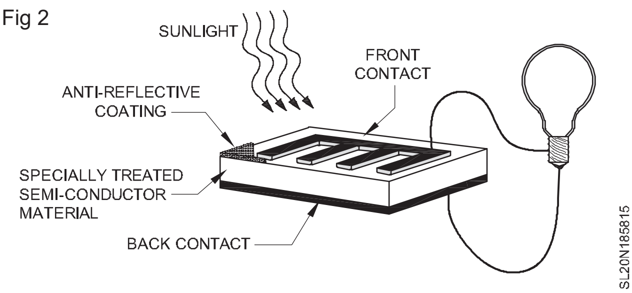
Main materials used to develop solar cells (Silicon, Cadmium tellurides, etc.)

A photovoltaic (PV) cell is an energy harvesting technology that converts solar energy into useful electricity through a process called the photovoltaic effect. There are several different types of PV cells which all use semiconductors to interact with incoming photons from the Sun in order to generate an electric current.

A photovoltaic cell is comprised of many layers of materials, each with a specific purpose. The most important layer of a photovoltaic cell is the specially treated semiconductor layer. It is comprised of two distinct layers (p-type and n-type), and is what actually converts the Sun's energy into useful electricity through a process called the photovoltaic effect.

Working

Fig 2



On either side of the semiconductor is a layer of conducting material which "collects" the electricity produced. Note that the backside or shaded side of the cell can afford to be completely covered in the conductor, whereas the front or illuminated side must use the conductors sparingly to avoid blocking too much of the Sun's radiation from reaching the semiconductor. The final layer which is applied only to the illuminated side of the cell is the anti-reflection coating. Since all semiconductors are naturally reflective, reflection loss can be significant. The solution is to use one or several layers of an anti-reflection coating (similar to those used for eyeglasses and cameras) to reduce the amount of solar radiation that is reflected off the surface of the cell.

Photovoltaic cell can be manufactured in a variety of ways and from many different materials. The most common material for commercial solar cell construction is Silicon (Si), but others include Gallium Arsenide (GaAs), Cadmium Telluride (CdTe) and Copper Indium Gallium Selenide (CIGS). Solar cells can be constructed from brittle crystalline structures (Si, GaAs) or as flexible thin-film cells (Si, CdTe, CIGS). Crystalline solar cells can be further classified into two categories—monocrystalline and polycrystalline.

As the names suggest, monocrystalline PV cells are comprised of a uniform or single crystal lattice, whereas polycrystalline cells contain different or varied crystal structures. Solar cells can also be classified by their number of layers or “p-n junctions”. Most commercial PV cells are only single-junction, but multi-junction PV cells have also been developed which provide higher efficiencies at a greater cost.

Accordingly, Crystalline Silicon (Si), Amorphous Silicon, Cadmium Telluride (CdTe), Copper Indium Selenide (CIS), Copper Indium Gallium Selenide(CIGS) are the main materials used to develop Solar Cells.

Plot I-V curve for photovoltaic cell based on the illumination at constant temperature

Objectives: At the end of this exercise you shall be able to
- **demonstrate the IV characteristics of PV cell for variation in illumination**
- **demonstrate the IV characteristics of PV cell for variation in load.**

Requirements

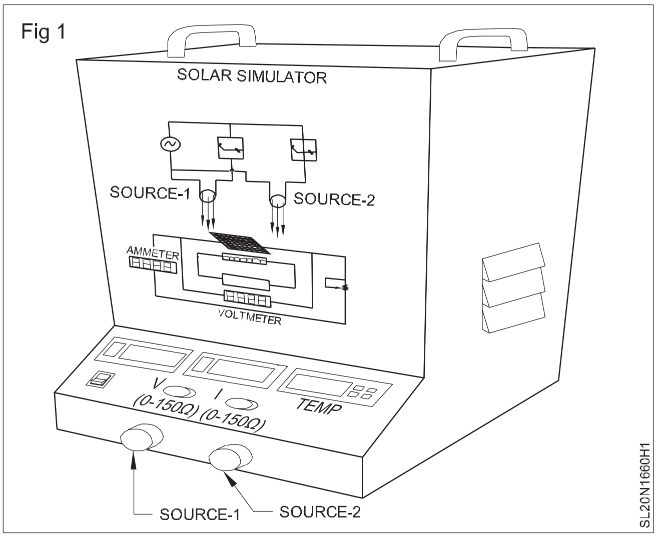
Tools/Measurements/Equipments

- Solar Power (Irradiance) meter -1 No.
- connecting wives - 20 Nos.
- Solar Simulator equipments - 1 Set.

PROCEDURE

TASK 1 : **Understand the lab equipment Solar simulator**

Fig 1



(All pictures and Circuit of Solar Simulator shown below are indicative. Actual design may vary.)

1 Study the lab equipment available in shop floor to learn the IV characteristics of PV cell.

2 Go through the manual supplied along with the equipment to know the different controls used in it and their usage.

3 Learn the do's and don'ts.

4 Get familiar with simulation with Solar light's properties.

5 Remember: Technical circuit inside and its functioning not required for your study of PV cell.

6 Common features of this Solar Simulator should be.

7 To simulate the sun, set of lamps are used as the source of light.

8 To simulate the sun for its heat radiation an electrical hot plate is used.

9 To simulate east-west movement of the sun the lamps are provided individual control.

10 To simulate variation in solar irradiation the intensity of the lamps need to be controlled.

11 To simulate variation in temperature the heat generated by hot plate needs to be controlled.

12 The location of the solar PV cell is to be over the hot plate facing the lamps.

13 A variable resistive load is required across the terminals of the solar PV cell to indicate actual load conditions.

14 A set of digital (Preferably) voltmeter and ammeter are essential on front side.

15 Control of intensity and heat should be independent.

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TASK 2: **Study of V/I, Characteristics of Solar Cell**

1 Connect the Solar Simulator equipment to mains power supply and switch ON.

2 Set both the intensity control rotary switch of lamps at maximum position to get the full intensity (Steps variation or continuous variation depending on the model)

3 Measure the intensity using Solar power meter and record the observed value (W/m^v)

4 Set the variable resistor load provided at high to simulate no load condition.

5 Measure and record the voltage and current of solar cell at no load condition on display.

6 The voltage displayed on Voltmeter is open circuit voltage (Voc)

7 Decrease the load gradually.

8 Measure and record the short circuit current (Isc) of PV Cell.

Observations

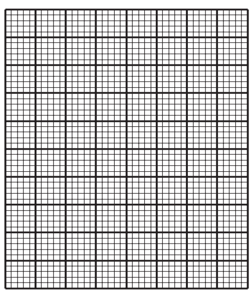
Intensity of lamps (Solar irradiation) = ………... W/m2

S. No.	Voltmeter reading (V)	Ammeter reading (A)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Graph

Plot the path of curve for recorded values of V and I to get the IV curve of the solar PV cell at fixed intensity.

Fig 1



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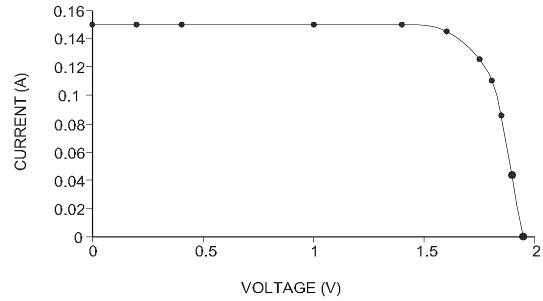
Indicative plot of graph

Fig 2



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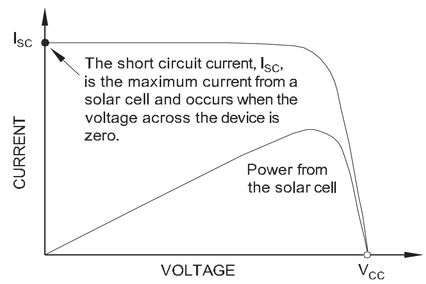
The Voc = 2 V indicates there are four numbers of PV cells are connected in series.

The Isc = 0.15 mA in this graph

Fig 3



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TASK 3: **Study of V/I, Characteristics of Solar Cell with variation of light intensity and varying load conditions**

1 Connect the Solar Simulator equipment to mains power supply and switch ON.

2 Set both the intensity control rotary switch of lamps at maximum position to get the full intensity (Steps variation or continuous variation depending on the model)

3 Measure the intensity using Solar power meter and record the observed value (W/m^2)

4 Set the variable resistor load provided at high to simulate no load condition

5 Measure and record the voltage and current of solar cell at no load condition on display

6 The voltage displayed on Voltmeter is open circuit voltage (Voc)

7 Vary the load progressively downwards, simultaneously measure the V, I readings and record the observations

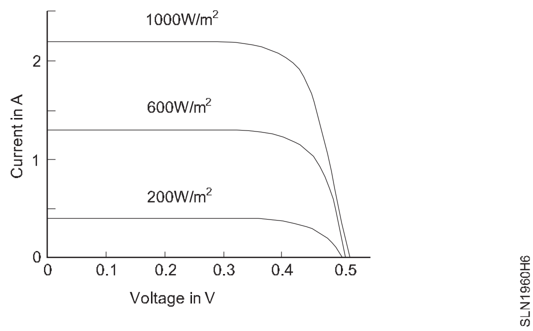
8 The minimum position of load indicates the short circuit across the PV cell and hence the current will be highest. It isthe short circuit current (Isc) of solar PV cell.

9 Repeat the above with reduced intensity at different levels.

Observations

S. No.	Intensity = …...W/m²		Intensity = …...W/m²		Intensity = …...W/m²		Intensity = ……W/m²	
	V	I	V	I	V	I	V	I

Fig 1

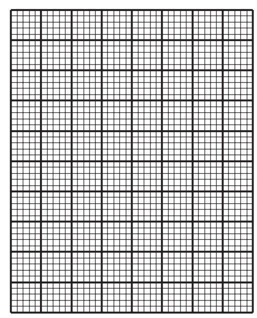


- Plot a graph for each set of observations to get the IV curves of the Solar PV Cell.

- Indicative IV curves for a Solar PV cell

Note : On increasing intensity of light you will observe Voc and Isc increases.

Fig 2



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Light sensitive properties of PN junction

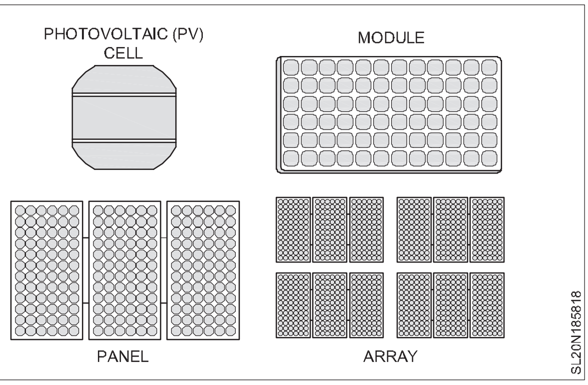
Objectives: At the end of this lesson you shall be able to
- **explan the light sensitivity property**
- **compar the solar cell panel & array.**

Light sensitive properties of PN junction.

P-N junction diode in the reverse-biased configuration is sensitive to light from a range between 400nm to 1000nm, which includes VISIBLE light. Therefore, it can be used as a photodiode. It can also be used as a solar cell. P-N junction forward bias condition is used in all LED lighting applications. The voltage across the P-N junction biased is used to create Temperature Sensors, and Reference voltages.

Comparison of a cell, panel and array (Fig 1)

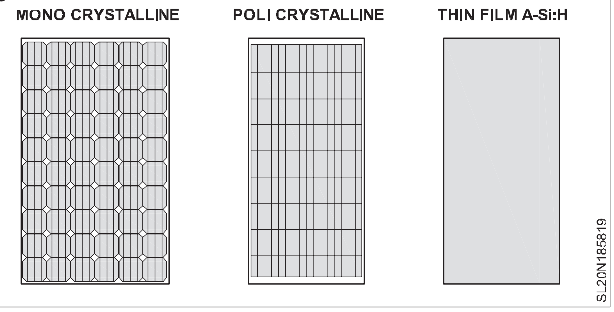
Fig 1



Selection of Solar PV panel

We should understand various features about a solar PV panel to be considered while buying it. Here we have a short look into it.

Fig 2



Types of Solar panel (Fig 2)

Points to remember for selection of a solar PV panel

1 Type

2 Size

3 Specification

4 Test certificate

5 Quality standard

Type

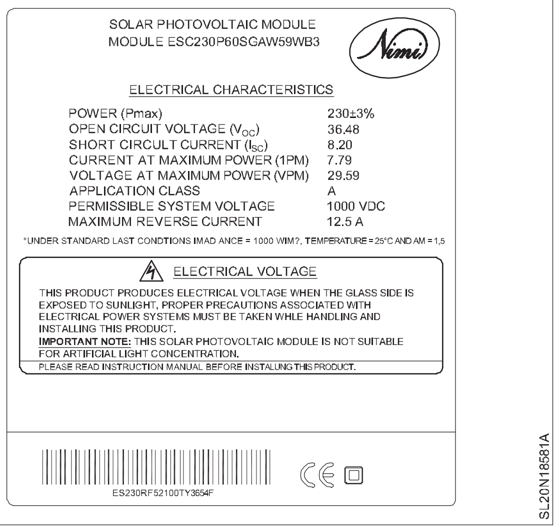
- Monocrystalline
- Poly/Multi crystalline
- Thin film

Size

- Peak power output (WP)
- Specification
- For selected WPlook for
  - V_M: Maximum voltage at W_P
  - I_M: Maximum current at W_P
  - Maximum system voltage
  - Standard Testing Condition (STC)

Typical Specifications of a solar panel (Label on backside of a panel) (Fig 3)

Fig 3

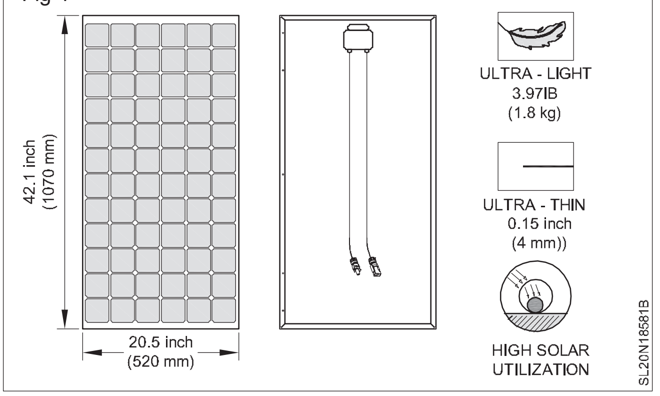


- Test Certificate
- Manufacturer’s test certificate
- Quality Standard

Backside of the Solar Panel (Fig 4)

In a designer approved Single Line Diagram (SLD) the above points are already considered and made available in SLD and part list. The technician can verify as far as possible the panels issued for installation or drawn from store shall have these information correct.

Fig 4



Plot I-V curve for photovoltaic cell based on temperature at constant illumination

Objectives: At the end of this exercise you shall be able to
- **demonstrate the IV characteristics of PV cell for variation in temperature on cell.**

Requirements	
Tools/Measurements/Equipments	
• Solar simulator equipment • Solar power meter	• Thermometer

PROCEDURE

TASK 1 : **Study the IV curve for three different temperatures on solar PV cell with constant intensity**

1 Connect the Solar Simulator equipment to mains power supply and switch ON

2 Set both the intensity control rotary switch of lamps at maximum position to get the full intensity (Steps variation or continuous variation depending on the model)

3 Measure the intensity using Solar energy meter and record the observed value (W/m2)

4 Measure the room temperature

5 Record the observations

Observations:

6 Use the temperature controller and set a value little above room temperature

7 Set the potentiometer to maximum to get no load condition

8 Measure the voltage(Voc) and current of solar cell at no load condition on display

9 Vary the potentiometer towards minimum. Measure the voltageand current (Isc) of solar cell at full load condition on display

10 Record the observations

11 Repeat the steps above with temperature at still higher set vaue. Record the observations

12 Draw the graph for normal, higher and much higher temperature values and compare

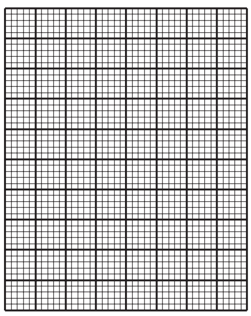
13 Record the observations

Observations : Intensity = …...W/m^2

S. No.	Temparature = …◦C		Temparature = …◦C		Temparature = …◦C	
	V	I	V	I	V	I

Graph

Fig 1



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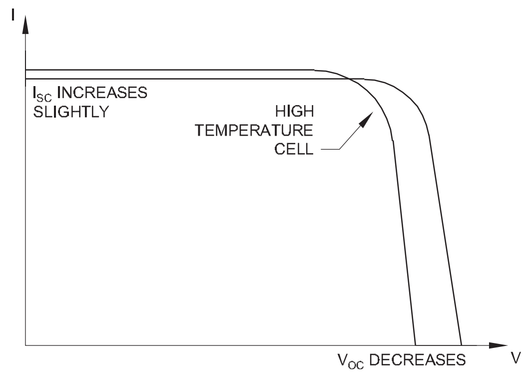
Note: With an increase in temperature Voc decreases and Isc increases slightly.

Fig 2



THE EFFECT OF TEMPERATURE ON THE IV CHARACTERISTICS OF A SOLAR CELL

SLN1961H2

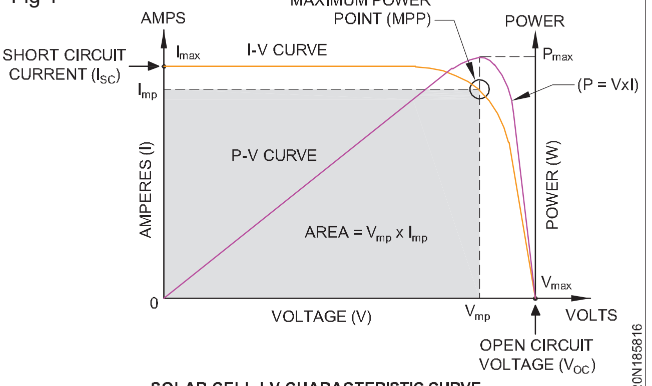
Notes:

I-V curve of PV cell

Objectives: At the end of this lesson you shall be able to
- **explain IV characteristics of PV cell.**

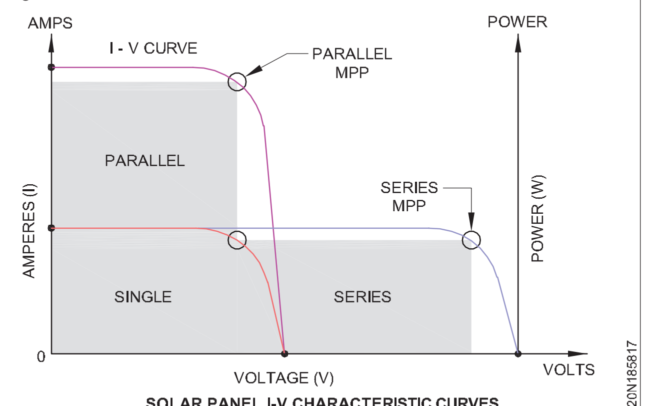
I-V curve

Fig 1



SOLAR CELL I-V CHARACTERISTIC CURVE

Fig 2



SOLAR PANEL I-V CHARACTERISTIC CURVES

The solar cell I-V characteristics curves shows the current & voltage (I-V) characteristic of a particular photovoltaic (PV) cell, module or array. If gives a detailed description of its solar energy conversion ability and efficiency. Knowing the electrical I-V cjaracteristics (mor importantly Pmax) of a solar cell, or panel is critical in determining the device's output performance and solar efficiency.

Photovoltaic solar cells convert the suns radiant tight directly into electricity. With increasing demand for a clean energy source and the sun's potential as a free energy source, has made solar energy conversion as part of a mixture of enewable energy source increasingly important.

The above graph shows the current voltage (IV) characteristics of a typical silicon PV cell operating under normal conditions. The power delivered by a single solar cell or panel is the product of its output current and voltage (IV) If the multiplication is done, point to point for all voltage from short- circuit to open circuit conditions, the power curve above is obtained for a given radiation level.

With the solar cell open circuited, that is not connected to any load, the current will be at its minimum (o) and the voltage across the cell and its maximum, known as the solar cell open circuit voltage or VOC. At the other extream when the solar cell is short circuited that is the positive and negative leads connected together, the voltage across the cell is at its minimum (Zero) but the current flowing out of the cell reaches its maximum, known as the solar cell short circuit current or Isc.

PV panels can be wired or connected together in either series or parallel combination, or both to increase the voltage or current capacity of the solar array. If the array panels are connected together in a series combination. Then the voltage increase increase and if connected together in parallel then the current increases.

The electrical power in walts, generated by these different photovoltaic. Combinations will still be the product of the voltage times the current, (P= V x I). However the solar panels are connected together, the upper right hand. Corner will always be the Maximum Power Point (MPP) of the array.

BIPV – qualification of Building-Integrated PV:

- Risk analysis
- Roof integration
- Facade integrated systems
- Hail testing
- Snow load testing

Measurement of area of the cells and compare with the module area in data sheet

Every solar panel is made up of individual solar photovoltaic (PV) cells. PV cells come in a standard size of 156 mm by 156 mm. (15.6 cm x15.6cm).

Example:

Area of one PV cell = 243.36 cm^2

Area of 60 PV cells = 14601.6 cm^2

Area of a Solar PV panel of 60 cells = 16335 cm^2

The average size of solar panels used in a rooftop solar installation is approximately 165 cm x99cm. The length can go upto 182.88 cm.

Most solar panels for rooftop solar installations are made up of 60 solar cells, while the standard for commercial solar installations is 72 cells (and can go up to 98 cells or more).

The number of solar cells on one panel is directly related to its length. 72-cell commercial solar panels are approximately 33 cm longer than 60-cell residential panels.

If you install a 6 kilowatt (kW) system with 20 average-sized panels, your system will likely measure approximately 8.23 m wide by 3.96 m long = 32.59 m^2.

Identification of faulty PV module.

Understand first how to test solar panels to make sure they're working properly.

Properly testing your solar panels is a very important but often overlooked procedure. Confirmtheir solar power output before installing them.By learning how to test solar panels you can ensure that you don't waste your time installing panels that you'll have to take down and fix.

Test photovoltaic cell in sunlight at various angles of inclination and direction

Objective: At the end of this exercise you shall be able to
- **perform working with PV cell/panel in sunlight at different angles and directions.**

Requirements

Tools/Measurements/Equipments

- Solar PV cell
- Voltmeter
- Ammeter
- 5 ohm resistor
- Magnetic compass
- Spirit Level
- Clinometer

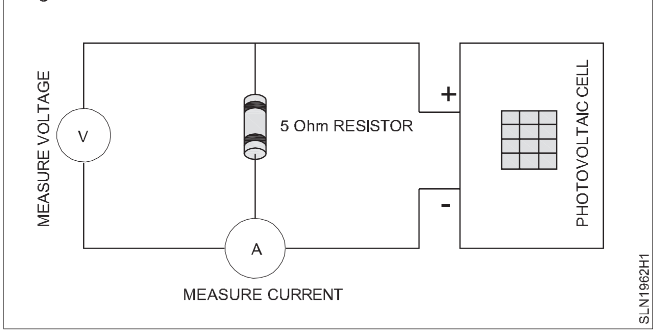
PROCEDURE

TASK 1: **Study the Solar power generated in different directions**

Note:The light sensor of the Solar energy meter should face in the same direction as the Solar PV cell in each case of testing

- Connect the given components as shown in circuit

Fig 1



- Place the Solar PV cell in sunlight.
- Locate the North pole using the Magnetic compass.
- Keep theSolar PV cell facing the North pole.
- Record the readings on Voltmeter and Ammeter and Solar irradiation intensity.
- Rotate the facing of theSolar PV cell by 90◦ from North clockwise.
- Record the readings on Voltmeter and Ammeter.
- Continue to rotate the facing of theSolar PV cell by 90◦ from earlier position clockwise.
- Record the readings on Voltmeter and Ammeter.
- Continue to rotate the facing of theSolar PV cell by 90◦ from earlier position clockwise.
- Record the readings on Voltmeter and Ammeter.
- Compare the results

Position	Solar intensity	V (Volt)	A (Ampere)
N			
E			
S			
W			

- - - - - - - - - - -

TASK 2: **Study the Solar power generated in different angle of inclinations**

Note: The light sensor of the Solar energy meter should face in the same direction as the Solar PV cell in each case of testing.

At any point of experiment mind that no shadow falls on the PV cell.

1 Connect the given components as shown in circuit

2 Place the Solar PV cell in sunlight at flat surface; if mounted on adjustable plane allowing different inclinations more suitable otherwise manually done

3 Check the spirit level shows flat surface parallel to the ground. Measure the angle using clinometer and confirm it shows 0◦.

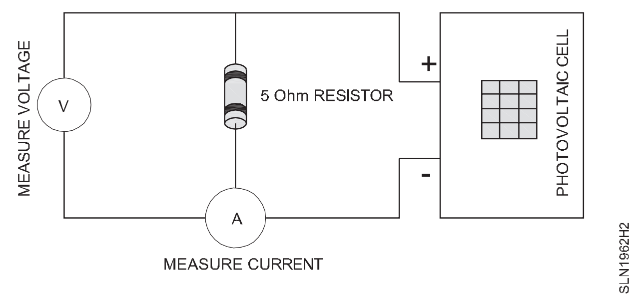
4 Keep theSolar PV cell facing the South.

5 Record the readings on Voltmeter and Ammeter and Solar irradiation intensity

6 Lift the facing of theSolar PV cell by steps of 5◦from 0◦. (Steps of 2 or 3 degrees of change in angles give better results)

7 Record the readings on Voltmeter and Ammeter

Fig 1



8 Continue to change the angle of facing of the Solar PV cell from earlier position towards south.

9 Record the readings on Voltmeter and Ammeter.

10 Repeat the above for some more angles.

11 Compare the results.

12 The angle that gives maximum Solar power is the Tilt angle for given location.

Angle (◦)	Solar intensity	V (Volt)	A (Ampere)
0			
5			
10			
15			
20			
25			

– – – – – – – – – – –

Record specification of different solar panels and compare specifications to select a panel

Objective: At the end of this exercise you shall be able to
- **compare the specifications of different rated solar panels.**

Requirements

Tools/Measurements/Equipments

- 5W, 10W, 40W and 250W poly crystalline modules

PROCEDURE

Compare specifications of different solar panels

1 Study the specification chart provided on each panel and fill up the table below

2 Compare and comment on their suitability for your use.

Specification	1	2	3	4
W_P: Peak Power	**5W**	**10W**	**40W**	**250W**
V_M: Maximum voltage at **W_P**				
I_M: Maximum current at **W_P**				
V_{OC}: open circuit voltage				
I_{SC}: Short circuit current				
V_{SYS}: Maximum system voltage				
S_{TC}: Standard Testing Condition				
No. of cells				

Observations:

Procedure for testing solar panels

Objectives: At the end of this lesson you shall be able to
- **brief about solar no load voltage & current**
- **explain about series & parallel of solar panels.**

Procedure for testing Solar Panels:

Testing using multi meter is easier. Test the solar panel for voltage across the output terminals. For this, first, Keep the solar panel in sunlight. Set your multi meter to “DC volts” setting. Touch the positive lead to the panels positive wire and negative lead to the negative wire of the solar panel. If meter reads selected range is low rotate the dial to increase the range. Note the voltage displayed and compare it with V_{OC} rating given on the back of the panel in the label. It should be close to V_{OC}. If it reads so then the given solar panel is good. If it is not then there is a problem with the given panel.

In such a case go back and check the connections of solar cells, strings for any break or any crack in the solar cells. If you find anything like that we can’t repair ourselves. It should be sent to manufacturer for repair / replacement as the case may be.

Testing for amps:

If the V_{OC} is close to the printed value then we can go for current checking.

Keep the solar panel in sunlight. Set the multimeter for current reading. Set the range close to I_{SC} of the panel.

Connect the terminals to the suitable leads of the multimeter. If the meter reads some ampere, then slightly tilt the panel to and fro and check the current varies. Also note that at certain point it reads maximum current equal or closer to printed value of I_{SC}. This is good condition. If not, check for dust, blocks anything and clear. Test again when sky is clear. Results should be ok. Otherwise the solar given is faulty and to be sent to factory for reconditioning.

If the above test results are satisfactory, then Calculate wattage by multiplying the V_{OC} and I_{SC}. The answer should be closer or equal to W_P rating of the solar panel given.

Solar PV array; series and parallel calculation.

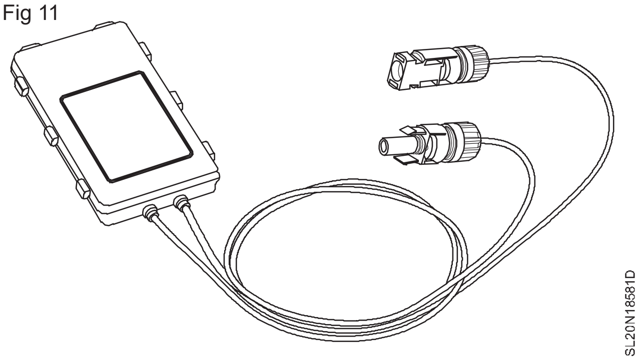
Series and parallel connection of solar panels (Fig 1)

Solar PV panels connected in series are called “STRING”. Strings connected in parallel make an array.

Series connection

For a series connection connect positive terminal of one panel to the negative terminal of other panel and so on. Then positive terminal of first panel is the positive terminal of the series path. And negative terminal of last panel is negative terminal of the series path. The voltage of series connected panels is addition of individual panel voltage. Thecurrent path is single and hence series connection’s current is equal to current of a single panel. Conditions are all panels in series path must be of same ratings and specifications. No mixing of ratings is allowed.

Fig 11



If

V_m = maximum voltage of each panel

I_m = maximum current of each panel

W_P = Peak Power output of each panel

n = no. of panels in series

Then

$V_{series} = V_{m1} + V_{m2} + \ldots V_{mn} = nV_m$

$I_{series} = Im$

$P_{series} = nV_mI_m = nW_P$

Parallel connection

For a parallel connection, connect positive terminal of all panels together and connect all negative terminals together. Terminals taken out from any one the panel gives positive and negative terminals of the combination.

If

V_m = maximum voltage of each panel

Feature	Residental panels	Commerical panels
No. of Solar Cells	60	72
Average Length	165 cm	198 cm
Average Width	99 cm	99 cm
Average Depth	3.81 cm	3.81 cm

I_m = maximum current of each panel

W_P = Peak Power output of each panel

m = no. of panels in series

Then

$V_{parallel} = V_m$

$I_{parallel} = I_{m1} + I_{m2} + \ldots I_{mm} = mI_m$

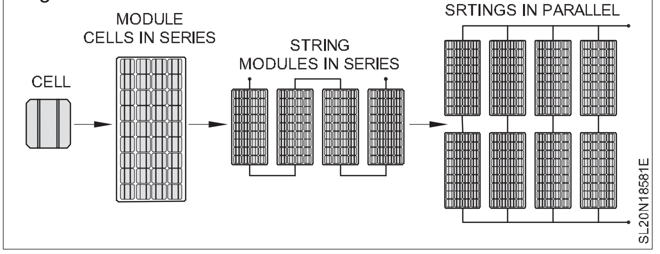
$P_{parallel} = mV_m I_m = mW_P$

Solar Array

Strings connected in parallel make an array.

In general, if n number of panels in series to form n strings and m such strings are connected in parallel then this combination forms an array.

Fig 2



Setect & connect suitably rated wires in the terminal box of a solar panel and connect end terminals using MC 4 connectors

Objective: At the end of this exercise you shall be able to
- **connect wires or DC cables to MC4 connectors.**

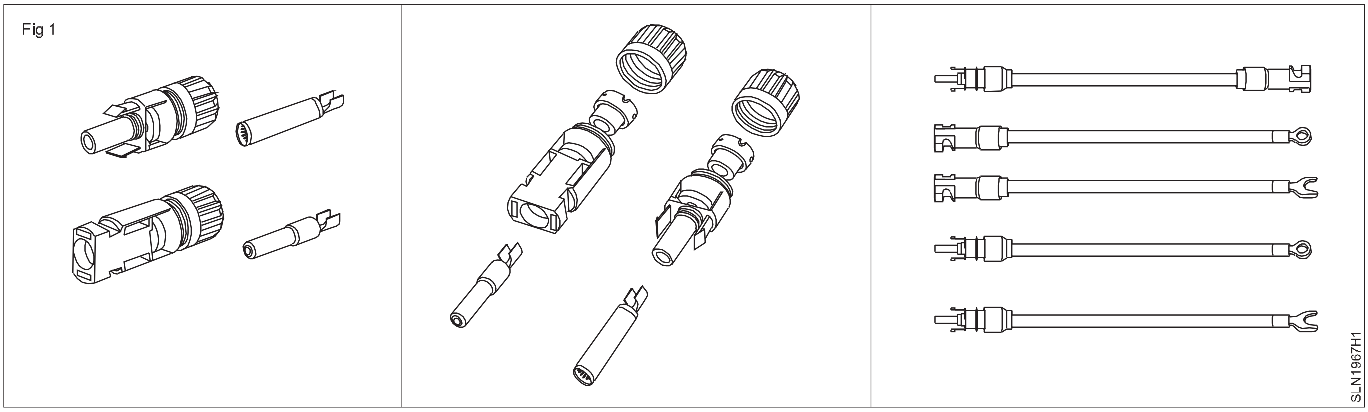
Requirements

Tools/Measurements/Equipments

- MC 4 connectors
- DC cables
- Wires
- Tools kit with crimping tool
- Soldering iron 25 W

Connecting MC 4 connectors

Fig 1



Caution: DC volt more than 70 volts prove very dangerous. Once solar panels are exposed to sunlight they start generating DC volt.

1 Study the pictures to familiarize with assembly parts of MC4 connectors.

2 Practice connecting the MC4 connectors on Red and Black DC cables suitably selected.

3 Practice extension of Solar panel output wires as per requirement.

4 Where panel terminal junction box do not have OEM output cables select suitable colour coded cables and on one end MC4 connectors. On another ends solder to the relevant terminals on the panel junction box.

Standard test conditions (STC) of a PV module

Objectives: At the end of this lesson you shall be able to
- **explain standard test condition**
- **brief about features to be verified in PV panel.**

Standard test conditions (STC) of a PV module

Every manufacturer tests their modules under something called Standard Test Conditions (STC).

STC is a set of rules to follow at manufacturing industry. These rules allow consumers and solar designers to compare panels.

Normal STC includes:

1 Solar Cell Temperature = 25°C

2 Solar Irradiance = 1000 W/m2

3 Air mass: 1 or 1.5

Air mass

The Air Mass is the path length which light takes through the atmosphere normalized to the shortest possible path length (that is, when the sun is directly overhead). The Air Mass quantifies the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust.

Air Mass is the measure of how far light travels through the Earth's atmosphere.

One air mass, or AM1, is the thickness of the Earth's atmosphere. Air mass zero (AM0) describes solar irradiance in space, where it is unaffected by the atmosphere. The power density of AM1.5 light is about 1,000W/m2; the power density of AM0 light is about 1,360W/m2, which is considered to be the solar constant.

The air mass coefficient defines the direct optical path length through the Earth's atmosphere, expressed as a ratio relative to the path length vertically upwards, i.e. at the zenith. The air mass coefficient can be used to help characterize the solar spectrum after solar radiation has traveled through the atmosphere. The air mass coefficient is commonly used to characterize the performance of solar cells under standardized conditions, and is often referred to using the syntax "AM" followed by a number.

"AM1.5" is almost universal when characterizing terrestrial power-generating panels

Other features to be verified:

ASTM : Standard Spectrum or the type of light that shines on a solar panel

Production Tolerance: Manufacturers often assign an allowable tolerance of plus or minus 5% to the module's rating. Hence a 100 watt solar can be either 95 or 105 watts.

Temperature: Higher cell temperature than the 25°C will decrease efficiency. Roof mounted array's will show temperatures in the 50° to 75° C range, which is two to three times the STC rating.

Dirt and Dust: theseblock sunlight reaching to cells. Eventually panels get dirty until the next rainfall or hose spray. This can account for about a 2% on average loss.

Wiring losses: DC wiring accounts for power losses due to the resistance of the wiring system. We usually design for a 2% wire loss.

Inverter losses: On average, over a day, this is about 90%.

Terminal box and connectors of a Solar PV module.

The PV junction box has a simple, but important role: housing all the electric bits on a solar panel and protecting them from the environment. Wires connect to diodes inside, providing an easy way to link panels together.

Although solar developers and owners don't get a choice in junction box type—module companies work out those contracts during manufacturing—the role of this enclosure is still important to understand, especially as it houses more "smart" technologies.

A junction box has bypass diodes that keep power flowing in one direction and prevent it from feeding back to the panels. Every string is protected by a diode in the junction box. The diode is the gateway that allows an endless stream of power. If part of a solar panel is shaded, that string will want to consume power, reversing the flow of electricity. Diodes inside the junction box prevent that from happening. There are two different junction box production techniques—soldering/potting and clamping. With the soldering and potting method, foils coming out of the solar panel are soldered to the diodes in the junction box. The junction box then has to be potted or filled with a type of sticky material to allow thermal transfer of heat, keep the solder joint in place and prevent it from failing. Once enough time has passed for sufficient curing of the potting material, the panel is good to go. With clamping production, a simple clamping mechanism attaches the foil to the wires. There are no fumes or major cleanup as with the soldering/potting method. The prices of both methods are fairly equal when comparing material and labor costs as a whole. The clamping box may be more expensive, but the labor needed to solder and pot the other boxes is often higher.

Identification of various test standards of PV module

Success in the solar industry starts with testing and certification. To thrive in the solar energy sector, manufacturers and retailers need to ensure that their products meet established quality and performance standards. This means demonstrating that their PV modules are robust and able to consistently deliver the guaranteed rated power reliably even under more severe climactic conditions. They must also be safe and durable, ensuring the system's high yield over the long term, and still need to be commercially viable.

Industries have developed testing services that address market needs and enable user to meet their goals. At ISO 17025 accredited laboratories around the globe, the manufacturers test and certify PV modules according to national and international standards, including IEC 61215 and IEC 61730. Besides this they offer testing under special as well as more severe conditions, performance characterization and energy yield testing, just to name a few.

International standards such as EN, IEC, ANSI keep abreast of changes and harmonization that affect market access for PV modules.

Few certification services consist of the following process steps:

- Laboratory tests on samples for a module family or type
- Recurring factory inspection
- Certificate and TÜV Rheinland test mark
- Certificate of conformity (CoC) or declarations for individual markets
- Bankability reports

Quality assurance measures for PV modules:

- PID – potential-induced degradation
- Electro-luminescence and IR imaging
- Pre-/Post-shipment inspections
- Ageing of micro-cracks
- LID test (light induced degradation)

Stress tests:

- Fire tests
- Corrosion tests (e.g., salt mist, ammonia and Sulphur dioxide)
- Outdoor long-term tests in different climate zones
- Transport and environmental simulation on PV module shipping units
- Sand abrasion tests
- Snow load testing (non-uniform, heavy snow load)

Added value services:

- PV+ benchmark
- Qualification Plus ("Q+") certification
- Energy yield testing under actual climate conditions in relevant target markets

Connect Solar panels in series and perform V, I measurements

Objective: At the end of this exercise you shall be able to
- **test series connected solar panels.**

Requirements

Tools/Measurements/Equipments

- 10 Wpoly crystalline module 4 Nos.
- DC load bank
- DC Voltmeter comparable with specifications of module
- DC Ammetercomparable with specifications of module
- DC watt meter
- MC connectors
- Connecting wires and DC cables

PROCEDURE

TASK 1: **Test 4 Nos of 10 W solar panels connected in series**

1 Prepare MC 4 connector and DC cables ready. (Fig 1)

2 Connect the 4 X 10 W panels in series.

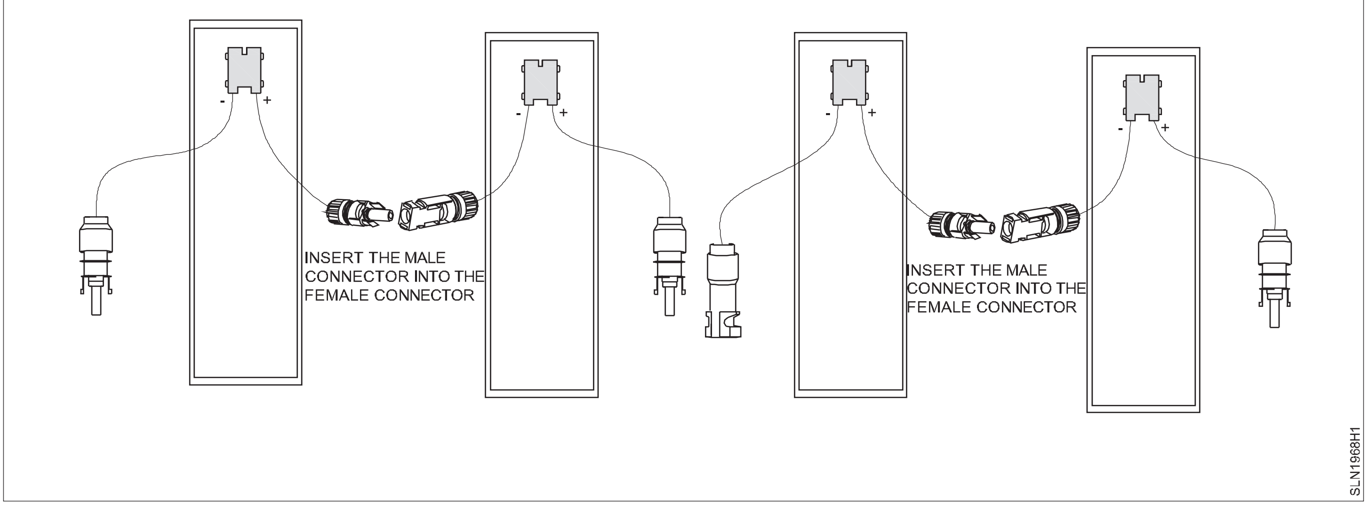
3 Connect suitable load, voltmeter, ammeter and wattmeter.

4 Keep the panels in sunlight.

5 Measure output voltage, current and power.

6 Record the observations.

Fig 1



Observations

Watt/Solar PV module = ...Watts

Table 1

Load condition	Voltmeter reading (V)	Ammeter reading (A)	Wattmeter reading (W)
No load			
Half load			
Full load			

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TASK 2: **Test 4 x 40 W Solar panels in series**

1 Replace the 10W PV solar module with 40W PV solar module.

2 Repeat the steps from 2 to 5 of task 1.

3 Record the observation in table 1.

Observations

Watt/Solar PV module = ...Watts

Table 1

Load condition	**Voltmeter reading (V)**	**Ammeter reading (A)**	**Wattmeter reading (W)**
No load			
Half load			
Full load			

– – – – – – – – – – –

Terminal box and connectors of SPV modules

Objectives: At the end of this lesson you shall be able to
- **brief the junction box of solar panel**
- **explain about power optimizer junction box.**

Junction box of Solar panel (Fig 9)

Although there are differing opinions on the best way to produce a junction box, there has been little discussion over the main role of this often-ignored product—until new technologies got involved in the industry.

Fig 9

Air mass	Solar irradiation reaching the surface (W/m^2)
AM0 (extra-terrestrial)	1376
AM1(sun at overhead position)	1105
AM1.5(sun at about 48^0 from overhead position)	1000
AM2(sun at about 60^0 from overhead position)	894

As modules have changed, the junction box has kept the same functionality. But now with increased power outputs and voltages, junction boxes have had to improve their ability to protect that power. In bifacial panels, Energy is still fed through one junction box even though power is being produced on both the front and backside of the module. Junction box manufacturers have had to get creative with their designs.

As the module output gets higher, those bypass diodes have to do more work. The way they absorb that energy is by shedding heat. You have to handle that heat of the diodes.

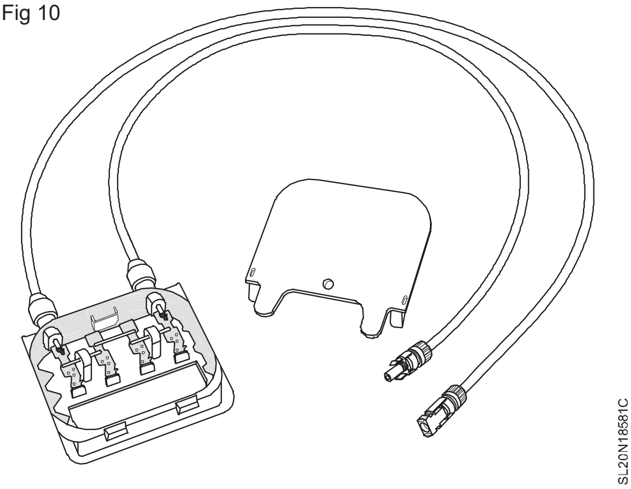
Cool bypass switches are replacing traditional diodes in some junction boxes to mitigate the excessive heat generated by higher module outputs. When shaded panels want to instinctively consume power, a traditional diode prevents that from happening, but heat is generated in the process. A cool bypass switch works like an on/off switch and opens the circuit when panels are trying to pull energy, preventing heat from building up.

Power optimizer Junction box (Fig 10)

A smart junction box enables customized printed circuit boards (PCBs) to be integrated into solar panel solutions with monitoring, optimizing and rapid shutdown functionality.

Most microinverters and optimizers are added to the back of the module in addition to the junction box. But power optimizer can replace the junction box on factory-assembled smart modules. The embedded power optimizer provides smart capabilities while performing the basic power functions of a junction box.

Fig 10



Junction box manufacturers are also looking into adding inverter technology to their future models. “The next step is going to be that module that has the inverter in the standard junction box with one AC source coming out. It simplifies the installation and makes the module more versatile.

Connect Solar panels in parallel and perform V, I measurements

Objective: At the end of this exercise you shall be able to
- **test parallel connected solar panels.**

Requirements

Tools/Measurements/Equipments

- 10 W poly crystalline module 4 nos
- DC load bank
- DC Voltmeter comparable with specifications of module
- DC Ammetercomparable with specifications of module
- DC watt meter
- MC 4 'Y' Branch Connector
- Connecting wires and DC cables

PROCEDURE

TASK 1: **Test 4 nos of 10 W solar panels connected in parallel**

1 Prepare MC 4 connector and DC cables ready. (Fig 1)

2 Connect MC 4 'Y' branch connector in each solar panel. (Fig 2)

3 Connect the 4 x 10 W panels in parallel.

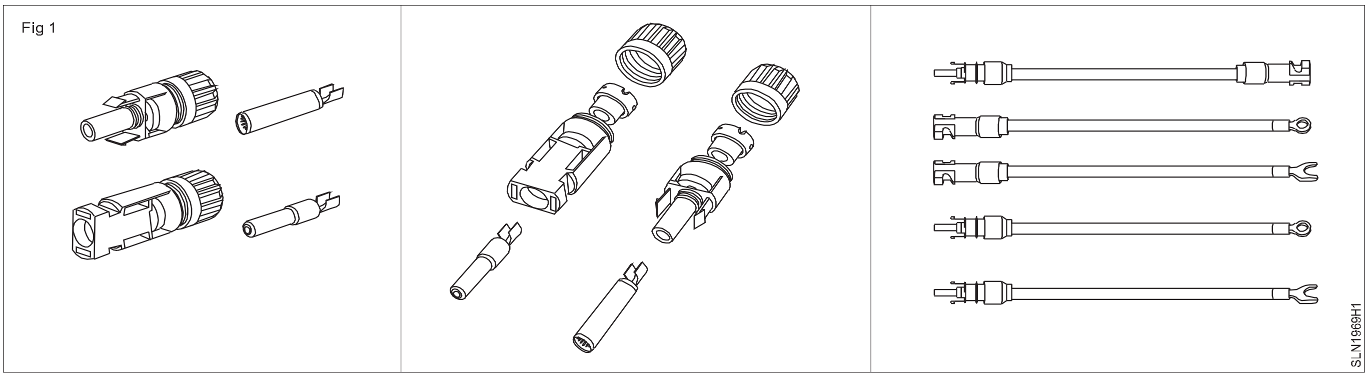
4 Connect suitable load, voltmeter, ammeter and wattmeter. (Fig 2)

5 Keep the panels in sunlight.

6 Measure output voltage, current and power.

7 Record the observations in table 1.

Fig 1



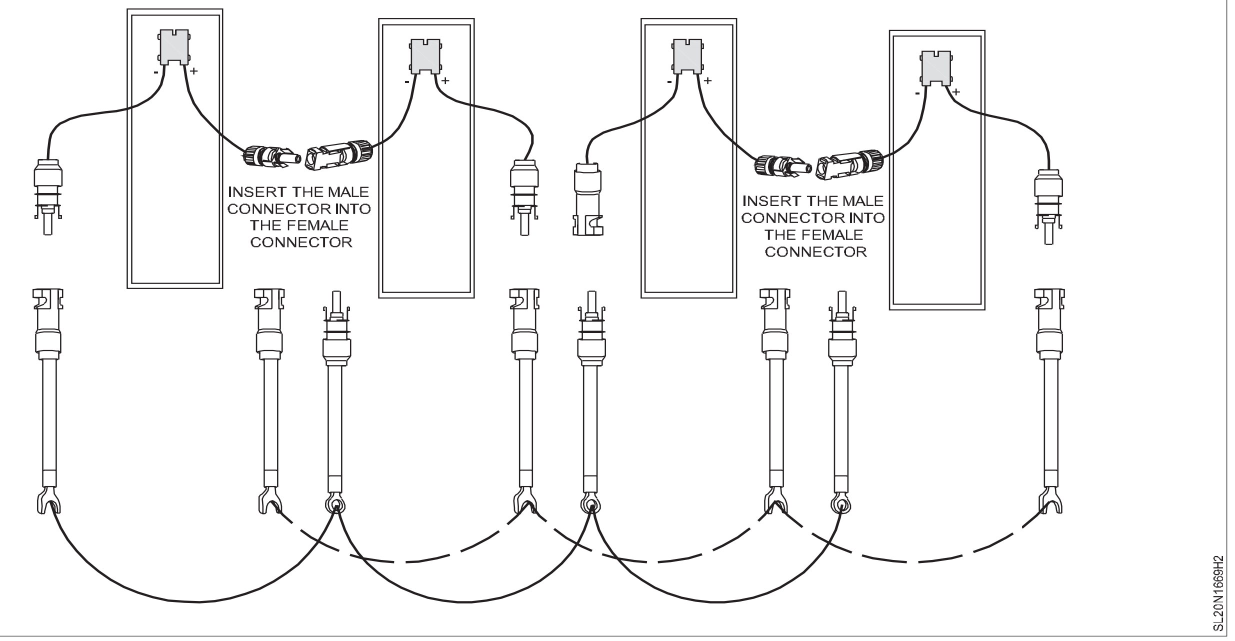
Observations

Table 1

Watt/Solar PV module = ...Watts

Load condition	Voltmeter reading (V)	Ammeter reading (A)	Wattmeter reading (W)
No load			
Half load			
Full load			

Fig 2



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TASK 2 : **Test 4 X 40 W Solar panels in parallel**

1 Replace the 10 W solar panel with 40 W solar panel.

2 Repeat the steps from 2 to 6 of task 1.

3 Record the observations in table 1.

Table 1

Watt/Solar PV module = ...Watts

Load condition	**Voltmeter reading (V)**	**Ammeter reading (A)**	**Wattmeter reading (W)**
No load			
Half load			
Full load			

Observations:

- - - - - - - - - - -

Customer requirement to install solar PV systems

Objectives: At the end of this lesson you shall be able to
- **brief about charge controller**
- **listout the function of charge controller.**

Charge controllers

The need for a charge controller

Though abundant, solar insolation is an unreliable source of energy, in the sense,it fluctuates as a function of time and is not available during the nights or in cloudy sky. Therefore when the PV systems are used for stand –alone applications, a backup source of energy is necessary to compensate for the balancepower demand of the load.

Batteries are used as generally backup source in such applications. To reduce the cost of system, the ratings of batteries are designed optimally. Battery feeds the load when the PV output power is less than load demand and is charged when PV output power is more than load demand. In applications where batteries are used, it is critical to prevent overcharging or deep discharging of the batteries to preserve their life and to ensure good performance. This is achieved using Charge controllers.

The block diagram of a stand –alone PV system with battery backup and a charge controller is shown in fig. 38. This shows the solar energy is received from the solar panel by the charge controller. The energy received is either used for charging the battery or delivered to the load based on energy level in the battery and the requirement by the load. Battery delivers out or receives in the energy.

A charge controller (an electronic circuit) is basically a voltage and/or current regulator to keep batteries gets charged and prevent from overcharging. It regulates the voltage and current coming from the solar panels and going to the battery.

Standalone solar PV electrical system

The Solar charge controller performs the following major functions:

- Charges the battery.
- Gives an indication when battery is fully charged.
- Connect/disconnect the load
- Monitors the battery voltage and when it is minimum disconnects the load
- Connects or disconnects solar panel to circuit
- Protects the battery from over charging
- Prevents battery from deep discharge
- Monitors the reverse current flow and block
- Indications for charging ON, Battery connect, Solar ON etc
- Commercial charge controllers have 10amp to 40amp of charging current

As a common application, the Solar Street lights use photovoltaic modules to convert sunlight into DC electric charge and use a solar charge controller to store DC in the batteries and automatically switch ON street light in the evening after sunset.

Home systems use PV module for house-hold applications in which charge controller plays important role.

Perform site survey for installation of rooftop solar plant create layout for avaliable space in a site prior to installation

Objective: At the end of this exercise you shall be able to
- **plan a layout for available space in a site prior to installation.**

Requirements

Tools/nstruments/Equipments

- 50-100 ft. measuring tape
- Digital camera
- Record/log book or diary

Note:

Knowledge of Electrical equipment, meter etc and domestic & industrial wiring.

Prior experience of installation of SPV systems or assisting thereof.

PROCEDURE

TASK 1: **Inspect the site**

1 Identify the actual work spot and assess the feasibilities of installation.

2 Identify the places to position the different components.

3 Identify accessibility to rooftop for men and material to reach as well as safe working.

4 Foresee and analyse the difficulties that may arise after landing in the work place.

8 Identify the shadow causing areas that may vary the power output later on.

9 Capture photographs.

10 Record your observations.

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TASK 2: **Locate existing components**

1 Identify already installed equipment such as electric meter, control boards, flow of wiring, division of wiring groups in the entire building etc.

2 Identify normal loads and high power loads.

3 Capture photographs.

4 Draw a rough plan based on above points collected showing existing electric meter, wiring path, main and auxiliary control boxes including MCBs (existing and proposed), additional wiring requirements etc.

5 Record your observations.

Rough sketch - example (Fig 1)

Photograph of Existing MCB layout (Fig 2)

Consider

Perform Load Assessment such that Solar array and batteries are sized according to need, Critical loads are backed up and the customer's gets maximum value for money.

Fig 1

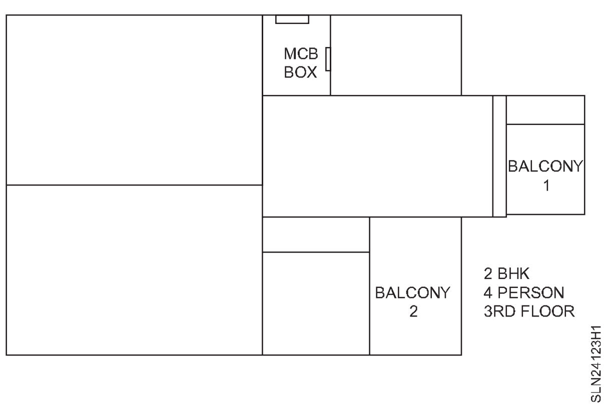
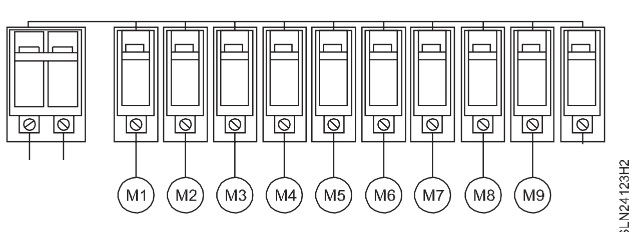


Fig 2



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TASK 3: **Recommend places for different components and submit site inspection report of proposed SPV installation**

1 Calculate the space requirement as per the work order.

2 Identify requirement of additional special tools, PPE, material handling equipment or services specific to the work place.

3 Draw a sketch for seating proposed PCU/inverter in safe, shadowed, dry, and adequately ventilated space.

4 Schedule pre requisite activities to be performed to carry out the installation work including clearing old items dumped area on roof with prior discussion with site owner, either through hiring or outsourcing.

5 Estimate additional cost probability specific to this site and inform owner of site as well as company so that the budget can be reset.

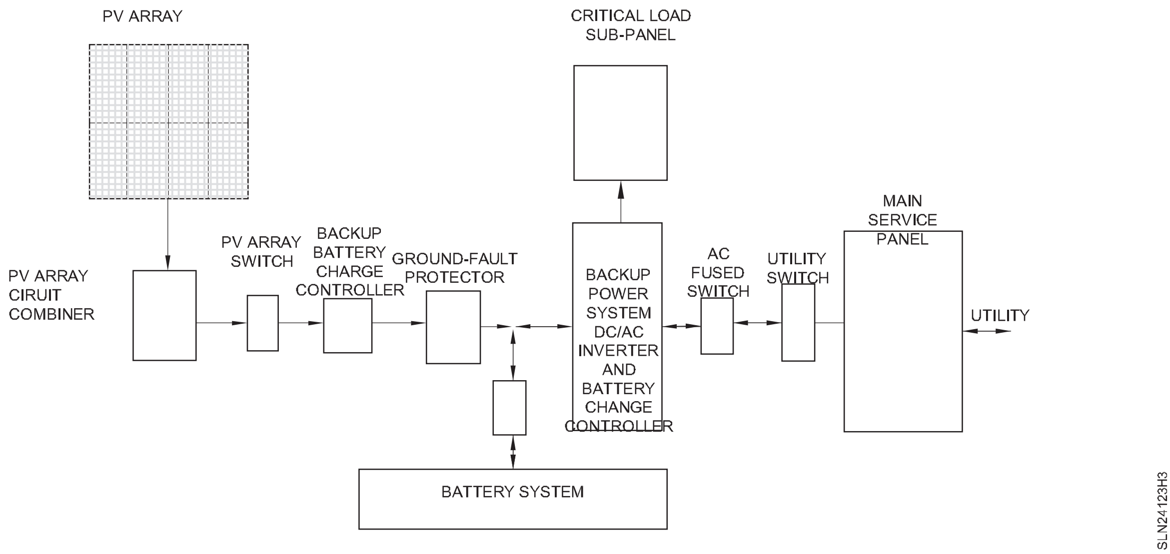
6 Submit and store the records including photographs properly in the company.

Consider

Perform Site Assessment so that Components are placed in proper locations where they function without hindrance, Shadows do not fall on the arrays maximizing output and The area remains safe for humans and equipment.

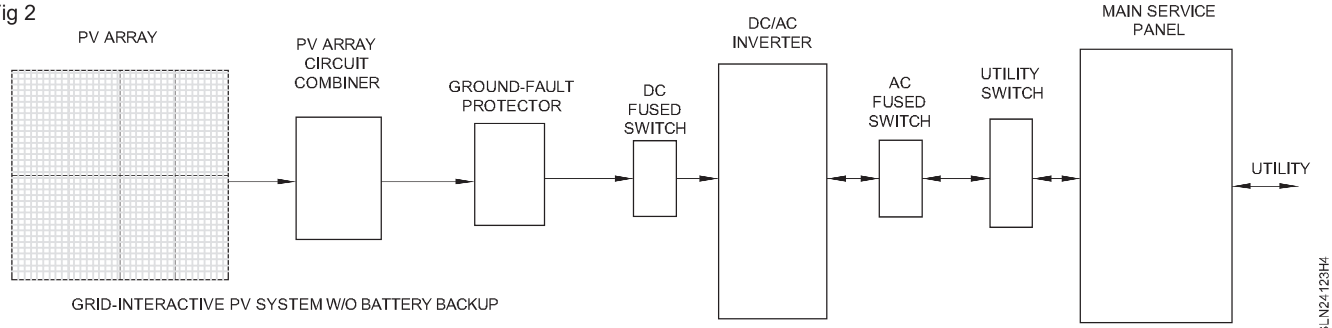
Components of SPV system proposed, layout and flow of energy directions (Fig 1)

Fig 1



Components of Grid interactive SPV system without battery backup. (Fig 2)

Fig 2



Observation

S. No.	List the observation

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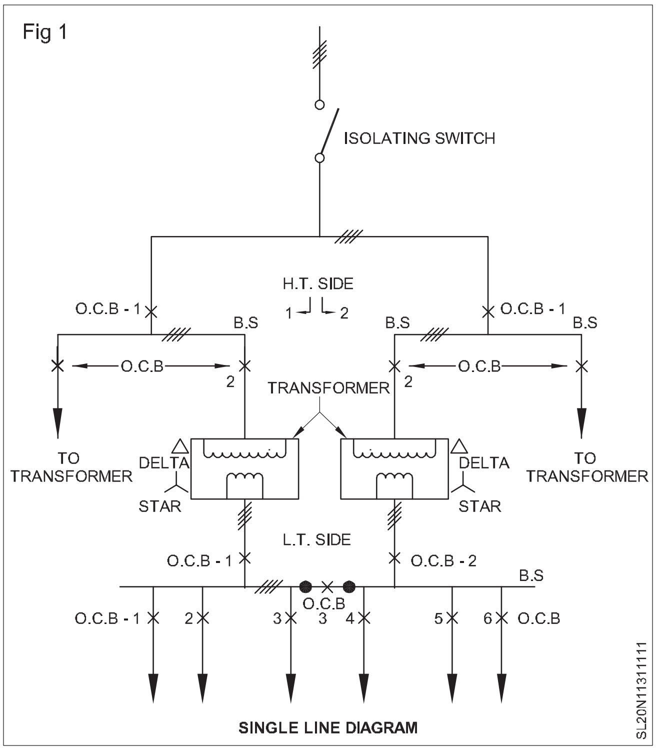
Single Line Diagram (SLD)

Objectives: At the end of this lesson you shall be able to
- **draw a single line diagram**

The electrical distribution system is depicted by a graphic or pictorial representation known as a single line diagram (SLD). A single line is used to show the complete system or a portion of it. It is very much adaptable and all-inclusive because it can show even simple DC circuits or a complex three-phase system as well.

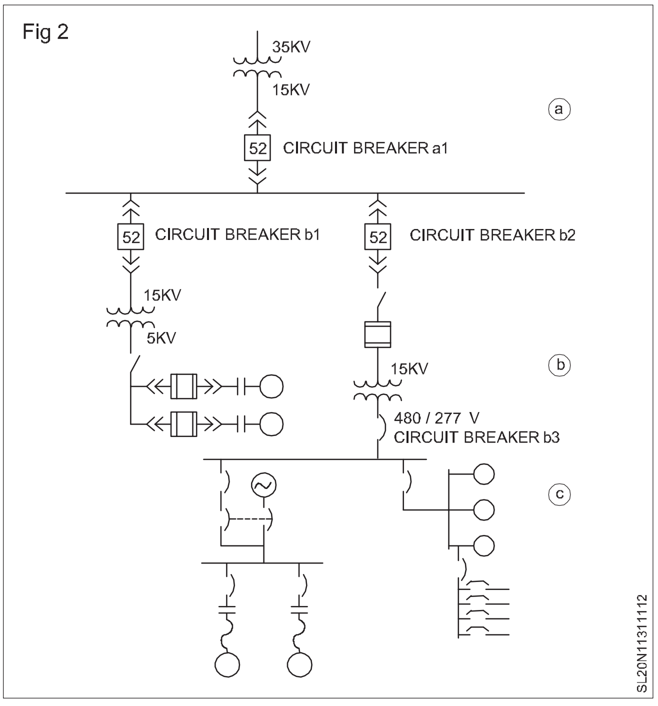
Fig 1 A sample SLD



When understanding a single line diagram, we should always start at the top where the highest voltage is and go down to the lowest voltage. This helps to keep the voltages and their paths straight. It is easily explained in three steps here.

Fig 2 Industrial SLD

A Starting at the top, see a transformer feeds power to the whole system. The transformer steps the voltage down from 35kV to 15kV. It is indicated by the numbers next to the transformer symbol. Once the voltage has been stepped down, a draw-out circuit breaker (a1) is encountered. We can assume this circuit breaker can handle 15kV, since it is attached to the 15kV side of the transformer and nothing else is indicated on the SLD. Following the draw-out circuit breaker (a1) from the transformer, it is attached to a heavier, horizontal line. This horizontal line represents an electrical bus, which is a means used to get electricity to other areas or circuits.

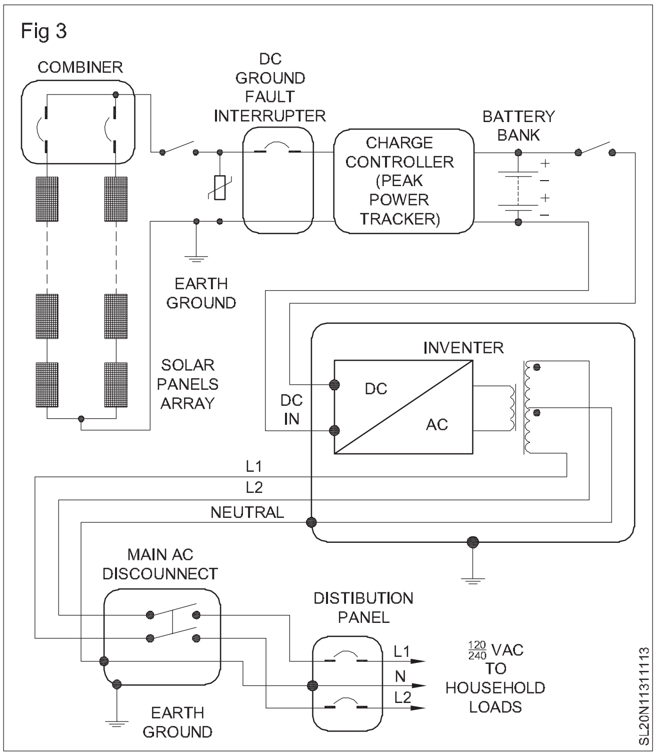


B Look at two more draw-out circuit breakers (b1 and b2) attached to the bus and feed other circuits. They are at 15kV, since there has been no indication of voltage change in the system. Attached to the draw-out circuit breaker (b1), a step-down transformer is used to take the voltage in that area of the system from 15kV down to 5kV. On the 5kV side of this transformer, a disconnect switch is shown, which is used to connect or isolate the equipment below it from the transformer. The equipment below the disconnect is at 5kV, since nothing indicates the contrary. The equipment attached to the lower side of the disconnect switch are two medium-voltage motor starters. A number of starters could be connected depending upon the particular system requirements. Now locate the second draw out circuit breaker (b2) that is attached to a fused disconnect switch and then connected to a step-down transformer. Notice that all the equipment below the transformer is now considered low voltage equipment, because the voltage has been stepped down to a level of 600 volts or lower. The last piece of electrical equipment in the middle portion of the diagram is another circuit breaker (b3). This time, however, the circuit breaker is a fixed low voltage circuit breaker, as indicated by the symbol. Moving to the bottom area of the SLD, notice that the circuit breaker (b3) in the middle is connected to the bus in the bottom portion.

C To the bottom left and connected to the bus is another fixed circuit breaker. Look carefully at the next grouping of symbols. There is an automatic transfer switch symbol. Also, notice that a circle symbol which represents an emergency generator is attached to the automatic transfer switch. This area of the single line diagram tells us that it is important for the equipment connected below the automatic transfer switch to keep running, even if power from the bus is lost. You can tell from the single line diagram that the automatic transfer switch would connect the emergency generator into the circuit to keep equipment running, if power from the bus were lost. A low-voltage motor control circuit is attached to the automatic transfer switch through a low-voltage bus. Make sure you recognize these symbols. Although we do not know the exact function of the low voltage motor control in this circuit, it is obvious that it is important to keep the equipment up and running. A written specification would normally provide the details of the application. On the right side of the third area there is another fixed circuit breaker connected to the bus. It is attached to a meter center, as indicated by the symbol formed by three circles. This indicates that the electric company is using these meters to keep track of power consumed by the equipment below the meter center. Below the meter center is a load center or panel board that is feeding a number of smaller circuits. This could represent a load center in a building that feeds power to the lights, air conditioning, heat and any other electrical equipment connected to the building.

Such diagrams tell about electrical system connections and equipment. Although some single line diagrams may appear overwhelming by virtue of their size and the wide variety of equipment represented, they can all be analyzed using the same step-by-step method.

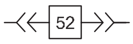
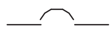
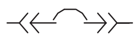
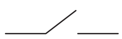
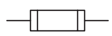
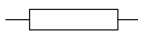
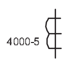
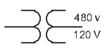
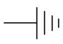
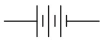
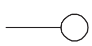
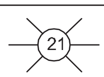
FIG 3 SLD of Off-grid SPV

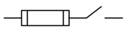
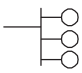
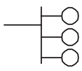
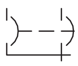
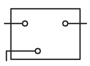
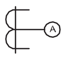
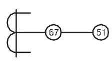


Identifying different component symbols in SLD

The table below shows often universally accepted electrical symbols to represent the different electrical components and their meaning within a circuit or system. These help in interpreting SLDs and understand the electrical symbols.

Individual electrical symbols

Symbol	Identification	Explanation
	Transformer	Represents a variety of transformers from liquid filled to dry types. Additional information is normally printed next to symbol indicating winding connections, primary /secondary voltages and KVA or MVA ratings.
	Removable or drawout circuit breaker	Normally represents a MV drawout circuit breaker 5kV and above.
	Future removable or drawout circuit breaker position	Represents a structure equipped to accept circuit breaker in the future, commonly known as provisions.
	Non-drawout circuit breaker	Represents a fixed mounted low voltage circuit breaker.
	Removable or drawout circuit breaker	Represents a drawout low voltage circuit breaker.
	Disconnect switch	Represents a switch in low or medium/high voltage applications (open position shown)
	Fuse	Represents low voltage and power fuses.
	Bus duct	Represents low and medium/high voltage bus duct.
	Current transformer	Represents current transformers mounted in assembled equipment. A ratio of 4000A to 5A shown.
	Potential or voltage transformer	Represents potential transformers usually mounted in assembled equipment. A ratio of 480V to 120V shown.
	Ground (earth)	Represents a grounding (earthing) point
	Battery	Represents a battery in an equipment package
	Motor	Represents a motor and is also shown with an "M" inside the circle. Additional motor information is commonly printed next to symbol, such as horsepower, RPM and voltage.
	Normally open (NO) contact	Can represent a single contact or single pole switch in the open position for motor control
	Normally closed (NC) contact	Can represent a single contact or single pole switch in the closed position for motor control
	Indicating light	The letter inside circle indicates the color. The color red is indicated.
	Overload relay	Protects a motor should an overload condition develop.
	Capacitor	Represents a variety of capacitors.
	Ammeter	A letter is usually shown to designate the meter type (A = ammeter, V = voltmeter, etc.)
	Instantaneous overcurrent protective relay	The device number designates the relay type (50 = instantaneous overcurrent, 59 = overvoltage, 86 = lockout, etc.)
	Emergency generator	The symbol is frequently shown in conjuction with a transfer switch.

	Fused disconnect switch	The symbol is a combination of a fuse and disconnect switch with the switch in the open position.
	Low voltage motor control	The symbol is a combination of a normally open contact (switch), overload relay, motor and disconnect device.
	Medium voltage motor starter	The symbol is a combination of a drawout fuse, normally open contact (switch) and motor.
	Meter center	A series of circle symbols representing meters usually mounted in a common enclosure.
	Load center or panelboard	One circuit breaker representing a main device and other circuit breakers representing feeder circuits usually in a common enclosure.
 (or) 	Transfer switch	• Circuit breaker type transfer switch • Non-circuit breaker type transfer switch
	Current transformer with connected ammeter	The instrument connected could be a different instrument or several different instruments identified by the letter.
	Protective relays connected to current transformer	Device numbers indicate types of relays connected, such as: • 67 – Directional overcurrent • 51 – Time overcurrent

Prepare bill of material for a 1 kW solar PV installation

Objectives: At the end of this exercise you shall be able to
- **select components for 1 kW SPV after sizing**
- **draw SLD for 1 kW SPV system.**

Requirements

Tools and Instruments/equipment

- Inputs regarding sizing of PV plants (from Trade Theory book as well as websites)
- Inputs from market about component specifications
- Input from market about cost of components

Note:

Knowledge of matching the specifications of components.

Knowledge of SLD.

Inputs from market about component specifications.

Input from market about cost of components.

Knowledge of matching the specifications of components.

PROCEDURE

TASK 1: **Discuss different probabilities of combinations of making 1 KW solar PV installation**

1 Study related theory and also from web about the technical details.

2 Discuss among trainees and instructors, the technical feasibilities.

3 Prepare at least three variants which deliver 1000 W AC power output.

4 Consider cost variation also.

5 Record your observations.

6 Prepare SLDs for each case.

Observations

_ _ _ _ _ _ _ _ _ _ _

TASK 2: **Prepare a bill of materials for the given SLD**

S. No.	Bill of Materials	Quantity

1 Study the SLD.

2 Review the sample component profiles.

3 Collect similar specifications from market.

4 Discuss and prepare a bill of materials for purchase.

Bill of materials

S. No.	Bill of Materials	Quantity

\- - - - - - - - - - -

TASK 3: **Prepare bill of materials for 1 kW SPV off grid plant**

1 Similar to task 2 above consider serial connection of solar panels.

2 Draw a SLD for 1 kW SPV off grid plant with serial connection of solar panels.

3 Consider changes required in ratings of other components.

4 Prepare bill of materials.

Bill of Materials

S. No.	Bill of Materials	Quantity

\- - - - - - - - - - -

System sizing: Selection of components of the Solar Photovoltaic Electrical system and their rating

Objectives: At the end of this lesson you shall be able to
- **size a load**
- **size an inverter**
- **size a battery bank**
- **solar PV array**
- **select other components of a SPV electrical system.**

Sizing means exact matching. Just like we have a size in number or letter(s) for our apparels such as 34, 36, M, XL etc. Same way, we have to identify the components and their specification as suitable for desired SPV system. Though many times discussed, it is good to list here the components of SPV system. Simultaneously let us have look at possible parameters for specification also.

Components	Specifications/Types/Features that influence sizing/selection
Load	AC load DC load Capacity: Watt Hours of usage V, I Rating Days of autonomy Type of load: Resistive (Lamp, TV, Oven, Heater, PC) and Inductive (Pump, Fridge, Air conditioner, Fan) Critical and non-critical load
Inverter	DC input range AC output Watt or kilowatt VA or KVA Power factor For p.f. = 0.8, 1000W = 1250 VA Waveform: Sinusoidal, square wave, Quasi sine wave
Battery Bank	V Voltage Ahr Ampere hour η efficiency DOD Depth of discharge C rating Hours of charging Maintenance or maintenance free
Charge controller	V System voltage I CC rating of Battery bank I > ISC of Solar array (ISC per panel X no of strings) DC input: Vmin to Vmax

Solar array	Panel specification Wp Vm Im ISC VOC All identical panel
Solar structure	Length and breadth based on panel size and number of panels per string as well as per frame Types of mount: Raft, Rack, Pillar, Ballast, Building Integrated, Fixed or Tracker, Manual, semi – automatic, or automatic, single or dual track Foundations based on RCC, roof, slope of tilted roof, soil of ground, rocks, Green bldg
Tools	Survey tools and equipment Foundation tools Installation tools Testing tools Maintenance tools Safety tools

Other components:

Accessories

AJB

Disconnects

Wire

Prepare bill of material for a 5 kW solar PV installation

Objectives: At the end of this exercise you shall be able to
- **select components for 5 kW SPV after sizing**
- **draw SLD for 5 kW SPV system.**

Requirements

Tools/Instruments/Equipments

- Product profile of solar panels, inverters, solar batteries etc.

Note: Knowledge of PV sizing.

PROCEDURE

Prepare bill of materials for a 5 KW solar PV installation

1 Calculate using PV sizing theory the approximate voltage, current requirements of PV array and inverter.

2 Select from obtained technical specifications of various models of inverters and panels suitable ones for your sized PV plant.

3 Match the different components.

4 Draw a SLD.

5 Prepare bill of materials.

Suggestions

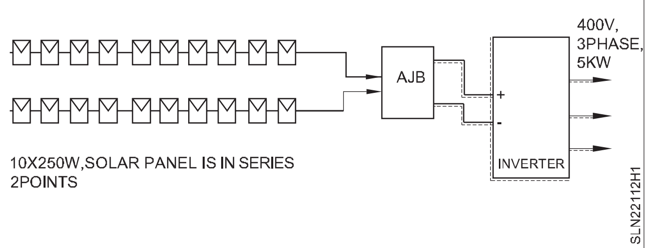
1 Select from available 200 W or 250 W solar panels.

2 Select a single phase 5 kW inverter.

3 Plan for a On grid SPV plant.

Sample SLD: Sample SLD for 5 kW SPV plant (Fig 1)

Fig 1



Bill of Materials

S. No.	Bill of Materials	Quantity

Load calculation of system sizing

Objectives: At the end of this lesson you shall be able to
- **calculate load of an installation**
- **brief about the system voltage.**

Load calculation

We have to calculate per day average utilization of electrical energy in 'watt-hours'. We have three methods.

Method 1: Total watt hour of all loads per day

Find out various loads in an installation (House, or school or office or industry). Find their ratings and fill up the following table. If it is not a residence then days/ week also may vary and to be taken into consideration.

Example:

S. No.	Name of load	W rating (W)	No of loads (n)	Hours of use (Hrs)	Whr/load (Whr)	Total Whr (n x Whr)
1	Bulb	100	5	6	600	3000
2	Fan	40	4	8	320	1280
3	Fridge	300	1	20	6000	6000
4	Heater	1000	1	2	2000	2000
5	Television	300	2	10	3000	6000

Total 18280
No of Electrical units consumed = Total Whr ÷1000 18.28
Because 1 unit = 1 KWhr =1000 Whr units

Hence if we are planning a SPV system it should generate average 18.28 KW per hour. That means 20 KW SPV system. For this we have to size remaining components.

Method 2. Daily average watt hour from twelve months electricity bill

Collect latest 12 months Electricity consumption bills received from Electricity board and fill up the following table. 'latest' means we may calculate from any of the 12 months in between not necessarily from Jan to Dec.

In the bills total units consumed per month would be given so that Amount to be paid is calculated based on this and rate per unit. If bills are generated once in two months then accordingly modify the table. Finally average out for 365 days/year to get daily consumption.

Sl No	Name of month	Units
1	January	138
2	Feb	135
3	Mar	143
4	Apr	150
5	May	165
6	Jun	145
7	Jul	138
8	Aug	142
9	Sep	135
10	Oct	144
11	Nov	154
12	Dec	160
	Total	1749/Annum
	Average daily consumption	1749÷365 = 4.79 units/day
	Approximate units per day	5
	Whr/Day = Units*1000	5000 Whr

Hence if we are planning a SPV system it should generate maximum 5000 W per hour. That means 5 KW SPV system. For this we have to size remaining components.

Method 3: Calculate Whr/Day from sanctioned load

Example:

If the sanctioned load of a residence is 5 KW then the total load shall not exceed 5000 W at any time. If the residence uses full load for one hour then power consumption at this time is 5000Whr or 5 units. Hence if we are planning a SPV system it should generate maximum 5000 W per hour. That means 5 KW SPV system. For this we have to size remaining components.

Check yourself: If in a group of flats the sanctioned load for every 2 BHK flat is 3 KW and for every 3 BHK flat is 5 KW, then calculate the size of the SPV required for this group of flats having 25 no. 2 BHK and 35 no. 3 BHK with a common utility of 10 KW.

System Voltage of a SPV system

For deciding on battery size or charge controller etc. we have to decide on system voltage first. System voltage is the operating DC voltage. Since we have the strings in array, Charge controller, battery bank and input of Solar inverter/PCU all are having operating DC voltage, there needs to be common value to be decided first before we size the ratings of the components individually.

Hence, System Voltage (Vsys) is a DC value in volts selected as working voltage common to all DC Components in a SPV system so that mismatch of level of voltages is avoided. It also depends on Total capacity of the SPV plant aimed at. Because the net power input is to be drawn from solar array and pass on to remaining stages and should also supply energy through inverter to meet the load capacity finally. That is why in the beginning we found the daily need of load in watt-hour.

Based on this the current rating of wires and cables in the system, disconnects etc will be determined for their specifications. Naturally other accessories like connectors, washers, and even tools required all dependable on this selection of system voltage. Hence its importance should understood by the technician and design engineer at this stage to avoid mismatches in components and due to that losses of components or even accidents that may happen.

Recommended values are given in the table:

Capacity of power plant	System Voltage
Less than 1 kW	12 V
1 – 3 kW	24 V
3 – 8 kW	48 – 96 V
10 – 20 kW	120 – 240 V

We can notice here the values of system voltage are multiples of 12 V since we have the unit size of battery is 12 V. Then according to the value preferred based on capacity of the system we can group the batteries in series, parallel or series – parallel combinations.

This is holding good for SPV systems with battery bank i.e. particularly for off-grid SPV systems.

Whereas for On-grid SPV systems like Grid –tied units, we find Solar array only external and the charge controller is in built in the Grid tie inverter. On the output side AC loads are there. Hence in this case we refer to the Solar DC input specifications of the Grid tie inverter and select a center value suitable as system voltage which will be string voltage also later on for the solar array. The technician will get more clarity on this in due course.

Hence in case of grid tied SPV systems the typical values of System voltage would be 50 V, 100V, 200V, 300V, …450 V…750 V. (Not a multiple of 12 V).

Demonstrate standard operating procedure of Off Grid PV System

Objectives: At the end of this exercise you shall be able to
- **follow SOP of solar photovoltaic electrical system**
- **demonstrate various safety measures to be taken in the field/site**
- **monitor activities and foresee problems**
- **solve issues onsite**
- **execute remedial actions at once**
- **adapt the standard operating procedures on SPV installation site.**

Note:
- **Work spot where installation is going on.**
- **Finished and operating PV plants.**
- **Plants under AMC.**
- **Plants not under AMC.**
- **Any other PV site selected by the instructor (Define nature of site….).**

PROCEDURE

TASK 1: **Collect information on probable activities by Solar Technician which may result in injury or accident to one or more persons in the team**

1 Divide the technicians into groups of four or five each.

2 Select work places different for each team.

3 Visit the spot on different days and time.

4 Collect details of occurrences all over which may lead to injuries, failures, health issue or accidents or any other kind (Specify).

5 Classify the events based on men, machine and material.

6 Evaluate the happenings based on:
- Risk
- Waste
- Fire and emergency
- Electrical
- Work at height and fall
- Tools and equipment
- Traffic (Men/material)
- Personal protection
- Fellow workers/onsite people protection
- Work permit
- Lifting or handling
- Health
- Safety

7 Highlight chances of failures to men or material or anything else (specify).

8 Suggest precautionary measures.

9 Suggest actions for remedies in case of failure.

10 Suggest educative aids to improve safety.

11 Prepare a SOP in general.

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TASK 2: **Preparation of safe work area: Arrange materials and tools for safe working**

1 Study the list of materials, tools and equipment.

2 Compare with site requirement and add/delete any item required/not required.

3 Recall the usage of the tools and equipment.

4 Learn and practice about unknown or forgotten means.

5 Educate the team members about everything in the list.

6 Demonstrate once usage of PPE kits and explain what happens when not used.

7 Prepare short guidelines after these exercises for safe working in the site as a reminder.

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TASK 3: **Assist to implement safety policies and procedures: Practice implementing**

1 Define hygiene.

2 Define first aid.

3 Practice Safety policies.

- Report abnormalities with reference to the safety policies to your Supervisor/team leader.
- Display the basic identity of hazardous products.
- Affix Material Safety Data Sheets at work place if not provided even after reminding.
- Implement for Housekeeping policy of tools and equipment, components and protective equipment.
- Adapt strictly safe working at heights policy: A worker must wear a safety belt of safety harness with a lanyard tied off to a fixed support whenever the worker may fall 3 meters or more.
- Display a statement of the purpose of the policy.
- Display an expression of the organisation's commitment to controlling the hazard or issue at its source.
- Display an outline of how the hazard or issue will be controlled, including resources to be provided and a timeframe for action.
- The roles and accountabilities of relevant stakeholders, particularly managers and supervisors.
- Affix a description of how the safety policy will be implemented.

Safety Policy Format (Fig 2)

4 Practice Safety procedures.

- Help to demonstrate and display a written statement of health and safety policy.
- Assist to implement the overall work flow, from materials coming into the workplace, to the final product going out;
- Inspect workplace safety.
- Display the step by step activity procedure where there are workplace hazards, and risks to health and safety.
- Identify workplace hazards and issues. - hazard identification, risk assessment and risk control.

Safety Procedure (Fig 3)

- Collect information about the hazardous activity or issue.
- Prepare the policy or procedure.
- Implement the policy or procedure.

5 Report hazards

- Help to investigate incidents and issues, with corrective actions.
- Support reactive and response activities such as: first aid and medical emergencies.

6 Report illness, injury.

7 Report incidents and dangerous occurrences.

- Help to establish the First Aid procedure.

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Sizing of battery bank and solar string

Objectives: At the end of this lesson you shall be able to
- **calculate the size of battery bank**
- **brief about solar panel sizing.**

Battery bank sizing

From first step, i.e. 'Load Calculation' carry forward the daily average consumption by connected loads in watt-hours. This is the AC energy required to be generated by our Off grid SPV system.

Ampere hour per day = (AC energy required)/(System Voltage) Ah

AC energy required is in watthour and system voltage is in Volts

Hence we get ampere hour per day while dividing watthour by system voltage.

Learn here a new word "Autonomy" which is nothing but additional 'backup time' required in 'Days'.

If

Ah = Ampere hour per day which PV system can provide

n = number of days battery backup is required

ηb = Battery efficiency

DOD = Depth of Discharge

Then Battery capacity = (n x Ah)/(ηb x DOD)

Normally for lowest case it is desired to have ηb = 0.9 and DOD = 0.8

Solar panel sizing

The actual energy required to be generated by Solar Array is calculated by considering the losses due to inverter.

Ah required to be generated by Solar PV array =

$$\frac{\text{(Proposed Ah required for the load at System voltage)}}{\text{(Inverter efficiency)}}$$

Average current drawn =

$$\frac{\text{(Ah required to be generated by solar PV array)}}{\text{(Estimated Solar hours per day)}}$$

Total number of panels required in parallel =

$$\frac{\text{(Average current drawn)}}{\text{(current of one panel)}}$$

Total number of panels in series =

$$\frac{\text{(System Voltage)}}{\text{(Voltage of one panel)}}$$

SLDs for small and medium solar PV projects

Objective: At the end of this lesson you shall be able to
- **draw a SLD for small, medium and mega SPV projects.**

1 Rooftop 1 kW off-grid Solar PV system

If you want to install on the terrace of your house or any building for a minimum 1 kilo watt capacity the the following list of components are required.

Solar PV panels 250 WP x 4 nos, (Sample specifications: Vm = 30 V, Im = 7.5 A, VOC = 34 V , ISC = 8 A, VSYS = 800 V, STC: 1000 W/m2, 25˚C, AM1)

Solar inverter (sample specifications)

Output : AC 230 V, 50 Hz

Power : 1.5 kVA

Solar DC input: 20 V to 60 V, 40 A (Max.)

Battery input: 24 V DC

Solar battery bank: 12 V, 100 AHr x 4 No

Back up time minimum 4 hours

Charge controller type: MPPT, 24 V, 20 A

You have to connect for these specifications, the four numbers solar panels in parallel through AJB and the output would be 30 V @ 30 A which is then fed to DC input of Solar inverter.

Batteries are connected such that a set of two batteries are series and both sets in parallel. Output of this combination will be 24 V, 200 AHr.

The SLD for this given below:

Fig 1 A 1 kW Solar plant SLD with parallel connected panels

Note: Battery bank is not shown

2 Rooftop 1 kW off-grid Solar PV system (Alternative)

Here main difference is specifications of inverter vary.

List of components are required.

Fig 1

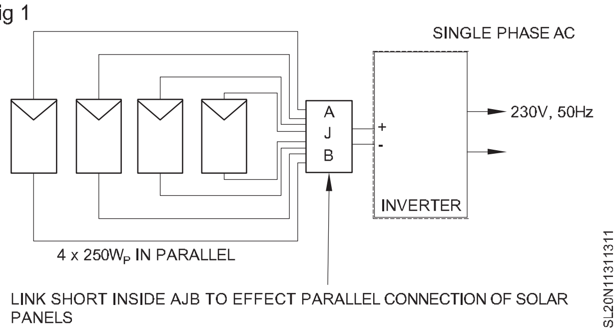
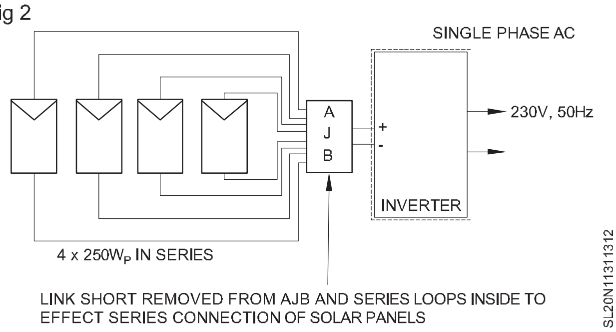


Fig 2



Solar PV panels 250 WP x 4 nos, (Sample specifications: Vm = 30 V, Im = 7.5 A, VOC = 34 V , ISC = 8 A, VSYS = 800 V, STC: 1000 W/m2, 25˚C, AM1)

Solar inverter (sample specifications)

Output : AC 230 V, 50 Hz

Power : 1.5 kVA

Solar DC input: 75 V to 150 V, 10 A (Max.)

Battery input: 24 V DC

Solar battery bank: 12 V, 100 AHr x 4 No

Back up time minimum 4 hours

Charge controller type: MPPT, 24 V, 20 A

You have to connect for these specifications, the four numbers solar panels in series through AJB and the output would be 120 V @ 7.5 A which is then fed to DC input of Solar inverter. Batteries are connected such that a set of two batteries are series and both sets in parallel. Output of this combination will be 24 V, 200 AHr.

The SLD for this given below:

Fig 2 A 1 kW Solar plant SLD with series connected panels

Battery bank for these two SLDs:

Fig 3 Battery bank 24 V, 200 AHr

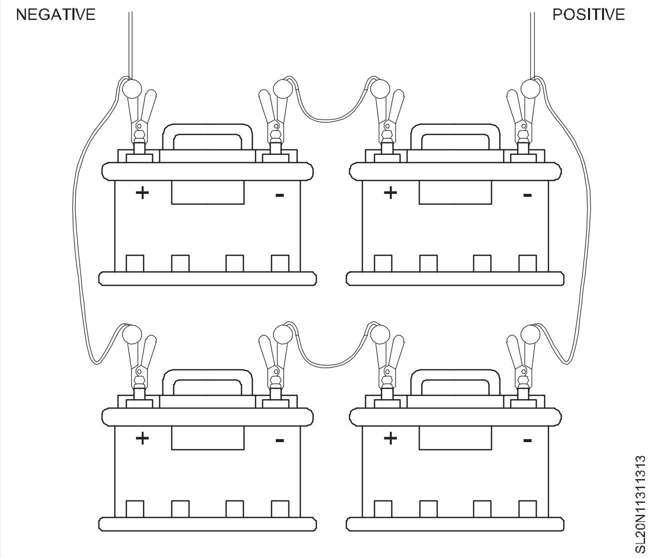
3 A 5 kW SPV system

To increase the plant capacity if we go on increase series connected solar panels it will result in Vm multiplies with ‘n’ number of panels used. We should keep at least two points in mind here: (very important)

nVm < 0.8 VSYS

Resulting string voltage should be within mid-point of solar input DC range of the inverter or PCU

Fig 3



In other words, the specifications of inverter or PCU should be decided based on the Solar array combination.

For a 5kW SPV plant say minimum 5000 W to be generated by solar array, then it can be achieved by grouping 20 number of Solar panels of WP = 250 W in multiple ways. That is:

20 X 250 = 5000. Series connection of all 20 panels. This results in string voltage of 600 V for a VM of 30 V per panel, which will necessitate PCU should have a range of 450 V to 800 V Solar DC input at 10 A.

If this is altered to have two series paths of 10 panels each and both connected in parallel then also we get 5000 W array output with string voltage 300 V but AJB output 300 V, 15.0 A. (if we have VM = 30 V, Im = 7.5 A). Then Solar DC input range for PCU/inverter should be 150 V to 450 V DC at 20 A.

If this is further altered to have four series paths of 5 panels each and all connected in parallel then also we get 5000 W array output with string voltage 150 V but AJB output 150 V, 30.0 A. (if we have VM = 30 V, Im = 7.5 A). Then Solar DC input range for PCU/inverter should be 75 V to 300 V DC at 40 A.

Therefore, observe the variations of above groupings and thereby resulting specification requirements. Accordingly, part list of SLD will vary.

SLD for case 2 is given below:

Fig 4: SLD for 5 kW SPV plant

4 SLD for 20kW SPV plant

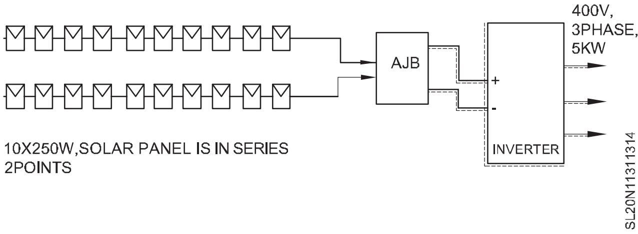
We can build 4 number of 5 kW SPV plant and combine the AC outputs of all to get 20 kW AC output with the help of AC combiner.

Otherwise a single 20 kW PCU can be fed with solar array DC input. Let us assume a typical 20kW PCU or inverter have the following specifications:

- Output: AC 400 V, 50 Hz, 3 phase
- Maximum Power output: 25 kVA

- Solar DC input: 450 V to 850 V, 30 A (Max.) X 2 inputs
- Total IM in maximum: 60 A
- Charge controller type: MPPT

Fig 4



We can still use same 250 WP solar panels but we require 80 numbers in this case. We can use 20 panels in one string and have total 4 such strings. Each string output will be 600 V, 7.5 A if specification is same. Two AJBs are required. Each AJB is combining two string outputs in parallel to give 600 V, 15.0 A. You can observe that, the 600 V is mid-point of MPPT input of inverter.

Both the AJBs' outputs are fed into 2 x MPPT inputs of the inverter. The output will be 3 phase, 400 V, 20 kW at 50Hz. SLD for this is given below:

Fig 5 SLD for 20 kW SPV plant

5 SLD for 100 kW SPV plant

We can combine five such 20 kW segments to generate 100 kW solar power. A box of 20 kW segment represents complete SLD of 20 kW SPV plant. AC combiner is used in the outputs of 5 such segments to deliver 100 kW, 3 phase, 400 V. This if fed to the 11 kVA transformer then the final output is 11kVA, 400 V 3 phase which is directly connected to the H.T. grid.

Fig 5

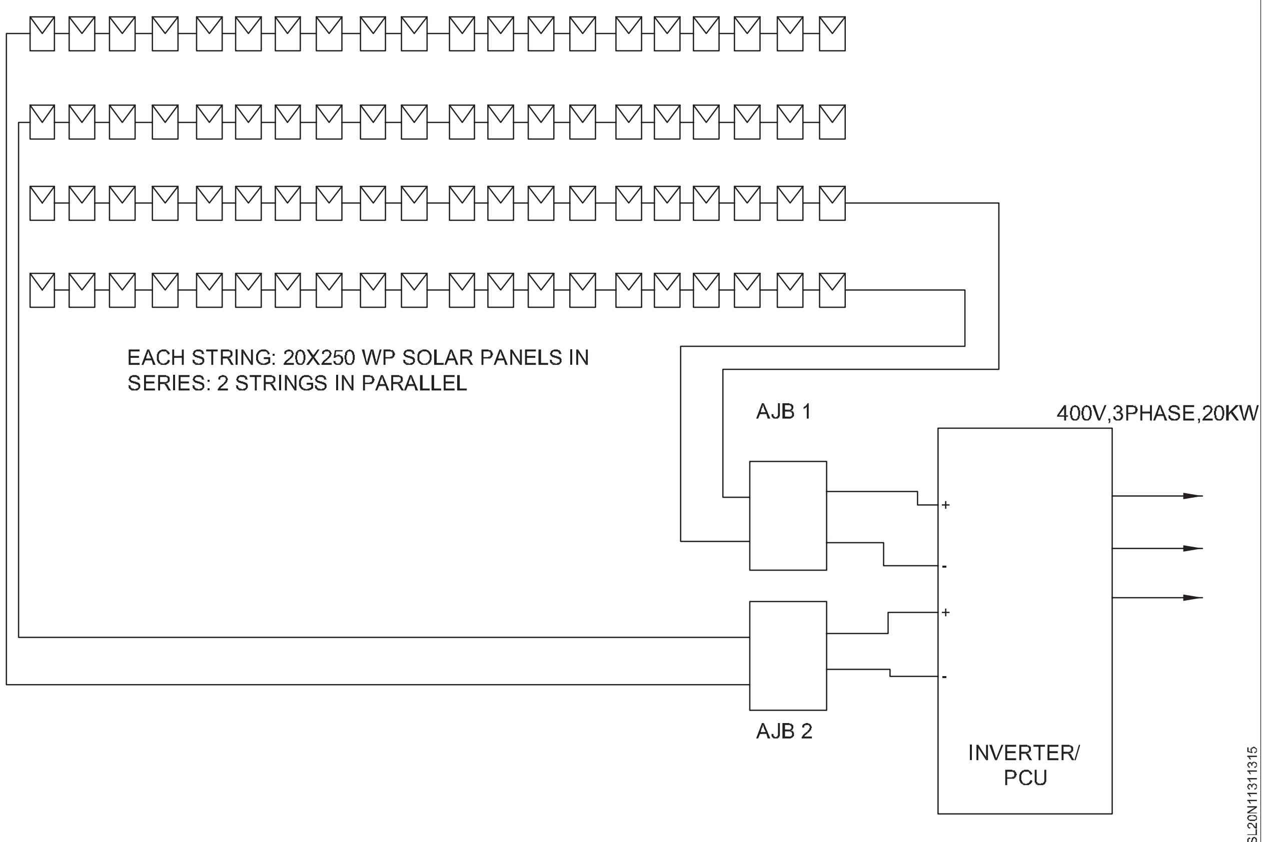
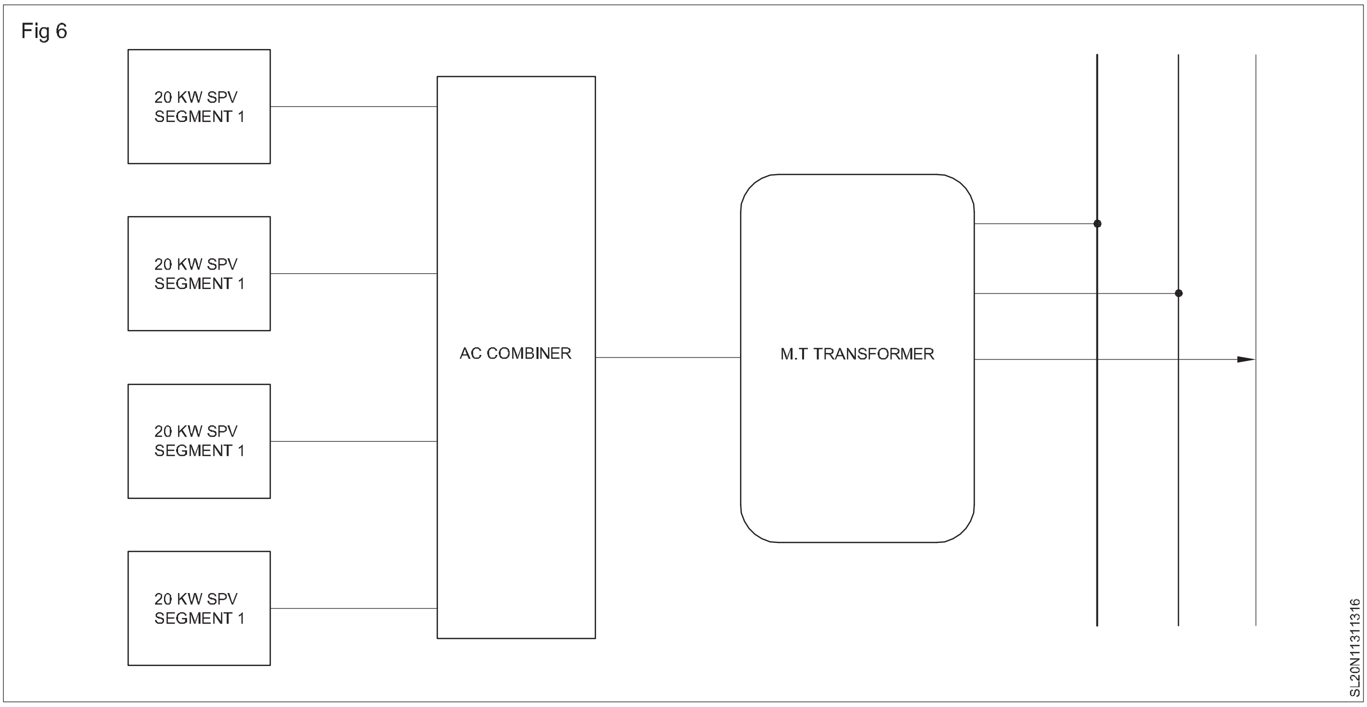


Fig 6 HT SPV plant: 100 kW On-grid



System types based on: Backup requirements, Grid availability, Budget and space

Objectives: At the end of this lesson you shall be able to
- **assess space requirement of a SPV plant.**

Selection of SPV plant for your requirement has to be approached with many guidelines. If the grid is available in your place and generally there is no power cut problem then it is better to go for an ON-grid plant because it earns money. While there is no much power cut keeping an OFF-grid plant but not used much, would be a waste investment.

While more power cut problems are there or in places where nearby grind is not available then the off-grid plant is a boon to the investor provided great utility of generated power is there. Back-up time in hours or days is decided on the need basis. Optimum utilization must be kept in mind to avoid unnecessarily parking the money on backup facility. It will prove loss if regular use is not there.

If proper utility or returns are not feasible then going for higher budget also not advisable. Balancing on financial feasibility and technical viability to be considered. Better market survey helps to earn or save huge money.

Space constraints or excess availability also to be kept in mind so that difficulties of planning a higher capacity in small space or low utilization of available space could be avoided.

Roughly 110 square ft or 10 square meter area is required for a 1 KW installation. Accordingly assess the site and recommend for more capacity. This will benefit the business as well as customer.

Various skill requirements during solar PV plant installation

Objectives: At the end of this lesson you shall be able to
- **acquire information on various skills required in SPV installation.**

While assessing the site the technician need to

- identify the actual work spot and assess the feasibilities
- identify the places to position the different components and draw a plan
- foresee the difficulties that may arise after landing in the work place
- identifying the shadow causing areas that may vary the power output later on
- calculating the space requirement as per the work order
- identifying requirement of additional special tools or services specific to the work place

Accordingly, we can understand the site survey skills

While preparing foundation of solar plant the typical activities would be:

- mark for foundation
- prepare and lay foundation for Solar PV structures on roof top
- prepare and lay foundation for Solar PV structures on ground
- erect the pillar mount

As such, the foundation skills identified are, On rooftop – Marking, Drilling, Fixing anchor bolt, Mounting pole, Mounting solar PV panels, Filling concrete on base etc and On ground – Marking, Digging, Bar bending, Filling concrete mix and Curing concrete are the identified skills.

Skill sets recommended for mounting panels Fabrication of super structure if not available readily (involves structural planning, drawing, dimensions of solar panel, sheet metal works, welding etc), Fitting poles, arms and lever, Mounting or clamping the panels.

When the technician comes to the electrical works he/she has to identify the connectors, crimple the terminals end, interconnect the panels, conduit pipe laying, lay underground cable and connect end terminals to inverter. Assembly of batteries, erecting battery rack and housing batteries, connect battery bank to inverter etc are skills relevant to off-grid plants.

All the above skills are commonly known as installation skills. This is followed by commissioning skills which include check for errors and removing, procedural switch ON of plant, testing and report making, load testing, customer orientation etc.

On-site observation and remote monitoring are post commissioning skills. Status monitoring and recording, reports making, alerting, preventive maintenance, corrective maintenance are other activities that draw importance.

Guidance for Solar Installation by MNRE

Objectives: At the end of this lesson you shall be able to
- **obtain information on MNRE.**

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy. The broad aim of the Ministry is to develop and deploy new and renewable energy to supplement the energy requirements of the country.

- Commission for Additional Sources of Energy (CASE) in 1981.
- Department of Non-Conventional Energy Sources (DNES) in 1982.
- Ministry of Non-Conventional Energy Sources (MNES) in 1992.
- Ministry of Non-Conventional Energy Sources (MNES) renamed as Ministry of New and Renewable Energy (MNRE) in 2006.

The role of new and renewable energy has been assuming increasing significance in recent times with the growing concern for the country's energy security. Energy self-sufficiency was identified as the major driver for new and renewable energy in the country in the wake of the two oil shocks of the 1970s. The sudden increase in the price of oil, uncertainties associated with its supply and the adverse impact on the balance of payments position led to the establishment of the Commission for Additional Sources of Energy in the Department of Science & Technology in March 1981. The Commission was charged with the responsibility of formulating policies and their implementation, programmes for development of new and renewable energy apart from coordinating and intensifying R&D in the sector. In 1982, a new department, i.e., Department of Non-conventional Energy Sources (DNES), that incorporated CASE, was created in the then Ministry of Energy. In 1992, DNES became the Ministry of Non-conventional Energy Sources. In October 2006, the Ministry was re-christened as the Ministry of New and Renewable Energy.

National Institute of Solar Energy has assessed the Country's solar potential of about 748 GW assuming 3% of the waste land area to be covered by Solar PV modules. Solar energy has taken a central place in India's National Action Plan on Climate Change with National Solar Mission as one of the key Missions. National Solar Mission (NSM) was launched on 11th January, 2010. NSM is a major initiative of the Government of India with active participation from States to promote ecological sustainable growth while addressing India's energy security challenges. It will also constitute a major contribution by India to the global effort to meet the challenges of climate change. The Mission's objective is to establish India as a global leader in solar energy by creating the policy conditions for solar technology diffusion across the country as quickly as possible. The Mission targets installing 100 GW grid-connected solar power plants by the year 2022. This is line with India's Intended Nationally Determined Contributions(INDCs) target to achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources and to reduce the emission intensity of its GDP by 33 to 35 percent from 2005 level by 2030.

In order to achieve the above target, Government of India have launched various schemes to encourage generation of solar power in the country like Solar Park Scheme, VGF Schemes, CPSU Scheme, Defence Scheme, Canal bank & Canal top Scheme, Bundling Scheme, Grid Connected Solar Rooftop Scheme etc.

Various policy measures undertaken included declaration of trajectory for Renewable Purchase Obligation (RPO) including Solar, Waiver of Inter State Transmission System (ISTS) charges and losses for inter-state sale of solar and wind power for projects to be commissioned up to March 2022, Must run status, Guidelines for procurement of solar power though tariff based competitive bidding process, Standards for deployment of Solar Photovoltaic systems and devices, Provision of roof top solar and Guidelines for development of smart cities, Amendments in building bye-laws for mandatory provision of roof top solar for new construction or higher Floor Area Ratio, Infrastructure status for solar projects, Raising tax free solar bonds, Providing long tenor loans from multi-lateral agencies, etc.

Recently, India achieved 5th global position in solar power deployment by surpassing Italy. Solar power capacity has increased by more than 11 times in the last five years from 2.6 GW in March, 2014 to 30 GW in July, 2019. Presently, solar tariff in India is very competitive and has achieved grid parity.

Demonstrate standard operating procedures of On Grid PV System

Objectives: At the end of this exercise you shall be able to
- **maintain inverter/PCU**
- **maintain cable**
- **maintain junction box**
- **maintain fault indicators of PCU.**

Requirements

Tools/Instruments/equipments

- Service manual of PCU/inverter
- Digital multimeter
- SLD

PROCEDURE

TASK 1: **Review the safety precautions to avoid injury and to prevent damage to the SOLAR PCU or inverter**

1 To avoid potential hazard use the SOLAR PCU or inverter only as specified.

2 Service shall be done ONLY by qualified / authorized personnel!.

3 To Avoid Fire or Personal Injury, never use Automobiles Batteries with your SOLAR PCU. They are not suitable for these applications.

4 Always check the water level in batteries (For flooded batteries only).This will keep your batteries in good condition and also enhance its life.

5 Verify whether 'Do's are followed, such as:

- Provide proper ventilation!.
- Install the power SOLAR PCU in a location that is well ventilated so that the heat it generates can be dissipated easily.
- Do check the water level of your battery for every 3 months as this is very much essential to keep the battery in good condition.
- Keep your batteries rust-free, good lubricating oil or petrol can be beneficial to lubricate your battery terminals at least once every month.
- Check that your SOLAR PCU is earthed properly.
- Always mount the SOLAR PCU in a cool and dry location.
- While wiring your Power SOLAR PCU use Standard and insulated Wires, poor.
- Wiring may lead to Short Circuit that may even lead to fire.

6 Verify that 'Don't 's are strictly not done.

- Do not operate without covers!.
- Do not operate SOLAR PCU with covers removed.
- Avoid exposed circuitry!.
- Do not touch exposed connections and components when powered.
- Do not operate with suspected failures! If you suspect that the SOLAR PCU is damaged, have it inspected by qualified personnel.
- Do not operate in an explosive atmosphere!.
- Do not touch the SOLAR PCU terminals while the power is applied to the SOLAR PCU even if the SOLAR PCU stops.

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TASK 2: **Troubleshoot PCU/inverter as allowed by user or technician visiting user**

1 Check only in any case of unsatisfactory operation.

2 If symptom is "Battery is not charging even if mains available" check if LCD display shows "MAINS : OFF" or Batteries are fully charged / Check if input MCB is OFF.

3 If the symptom is - LCD Displays "OVERLOAD" then Check load and wiring; Reset the SOLAR PCU by switching; OFF the unit first and then by switching ON the unit again.

4 Similarly follow the user/service manual and perform remaining checks.

5 Call factory service personnel wherever it is mentioned to do so; do not overdo there.

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TASK 3: **Check the indicators**

1 Follow the service manual.

2 Verify the indicators on front panel of PCU.

3 LCD Indication display is provided for SOLAR PCU charge controller and it displays following items:

- Battery Voltage.
- Charging Current of Battery.
- Total power(in terms of wattage) supplied from PV to Battery.

4 LED indicators are provided to show indication related to Inverter mentioned as below:

- Main ONMAINS ON
- Charge ON
- SOLAR PCU ON

— — — — — — — —

TASK 4: **Maintain cable and junction boxes**

1 Visually inspect the site even while normal function.

2 Look for damages due to regular activities in the site due to preventive maintenance activities.

3 Check for damages due animals or insects.

Sample log sheet for inspection during periodic maintenance

Balance of systems log sheet

		Date	**Date**	**Date**
Name				
Battery voltage				
Regular				
	Item clean			
	Insects removed			
	Cables connections OK			
	Functioning OK			
Inverter				
	Item clean			
	Insects removed			
	Cables connections OK			
	Functioning OK			
Battery Charger				
	Item clean			
	Insects removed			
	Cables connections OK			
	Functioning OK			

Safety related to solar panel installation

Objectives: At the end of this lesson you shall be able to
- **plan a foundation for a solar PV installation.**

Construction of foundation and Erection of pillar or pole mount can be on roof top or ground. Mostly requires civil work related skills, can be outsourced for a larger plant but when a solar technician functions as a self-employed person he/she possessing these skills to some extent can make the small project attempts more profitable.

While the technician understands the steps involved in civil work and fitting the solar structure, he/she may appraise the combination of works at the erection of solar structure, collect the tools required in work place (roof top or ground mount), collect the materials required, plan and make foundations, make right facing of solar panels and make right inclination for a given location.

Tools required for making of foundation include Civil construction work related tools: crowbar, spade etc, Drilling machine for rooftop, Marking pen and nail, Thread , Measuring tape, Ruler, Tool kit and Safety gadgets.

Material handling equipment or machineries include earthmovers, diggers, tractors, concrete mixers, water tanks etc. their capacity varies based on size of the project.

Materials required include Gravels, sand, cement as per requirement, Pole or pillar as per design, Anchor bolts for RCC roof, Other bolt and nuts etc.

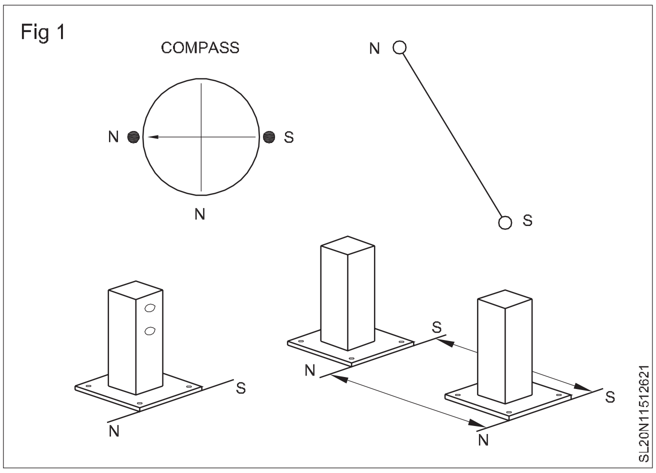
Civil works in work area involve Skills required in making foundation, On rooftop - Marking, Drilling, Fixing anchor bolt, Mounting pole, Mounting solar PV panels, Filling concrete on base etc. Skills required on ground include Marking, Digging, Bar bending, Filling concrete mix and Curing concrete.

Steps for making foundation on rooftop

- Use compass and mark true north and south poles
- Draw line connecting north and south poles points
- Place the pillar mount aligned to the connecting lines
- Mark the holes of base on ceiling
- Remove the pillar mount
- Drill holes on the markings
- Hammer the anchor bolts on the holes
- Keep the pillar mount aligned to the anchor bolts and fix nuts
- Mark parallel to the first pillar mount and repeat the above steps

Repeating these steps for as many numbers of pillars or poles to be mounted as per drawing is there to be noted.

Fig 1 Marking foundation on rooftop



Steps in Making foundation on ground

- Use compass and mark true north and south poles
- Draw line connecting north and south poles points
- Place the pillar mount aligned to the connecting lines
- Mark the base
- Remove the pillar mount
- Dig pit (Crater) as per drawing (Eample: if Base is 1ft x 1 ft then the crater should be 1ft x 1 ft x 1.5ft as shown)
- Use the wooden stencil of base of the pillar mount
- Fix the bar bended TMT rods with thread on top end on to the stencil
- Keep the assembly in the carter with the stencil on ground level
- Fill in concrete mortar in the pit and allow to harden doing proper curing
- Remove the stencil and place pillar mount & fasten the bolts

Repeating the steps for as many numbers of pillars or poles to be mounted as per drawing is there to be noted.

Fig 2 Wooden stencil

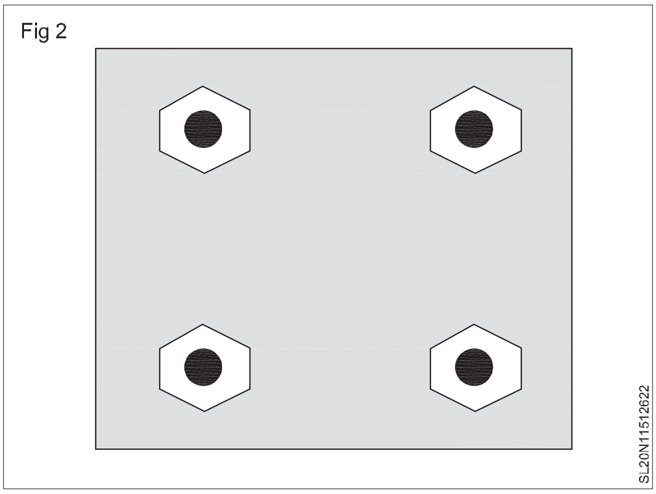


Fig 3 Finished foundation

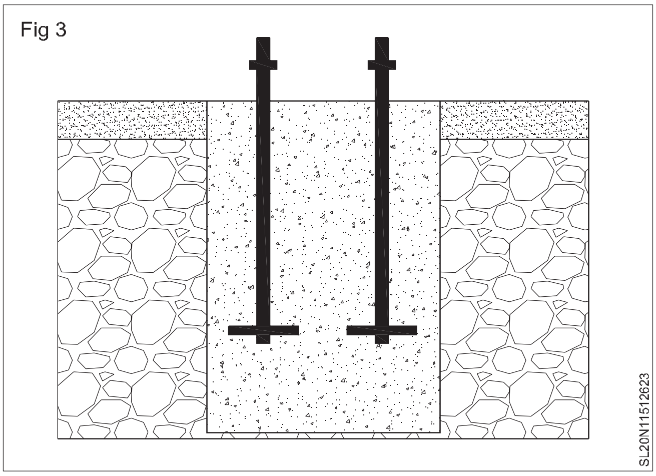


Fig 4 Steps involved - Ground mount foundation

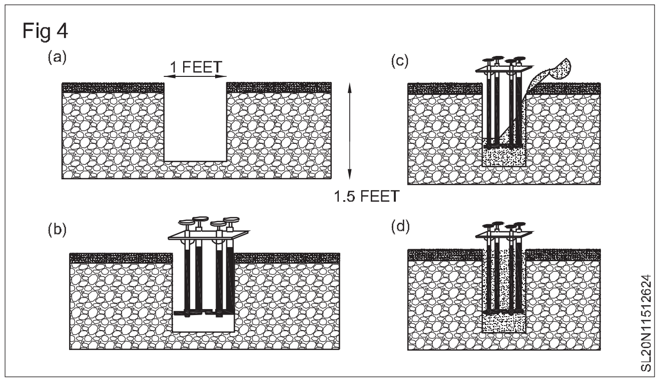
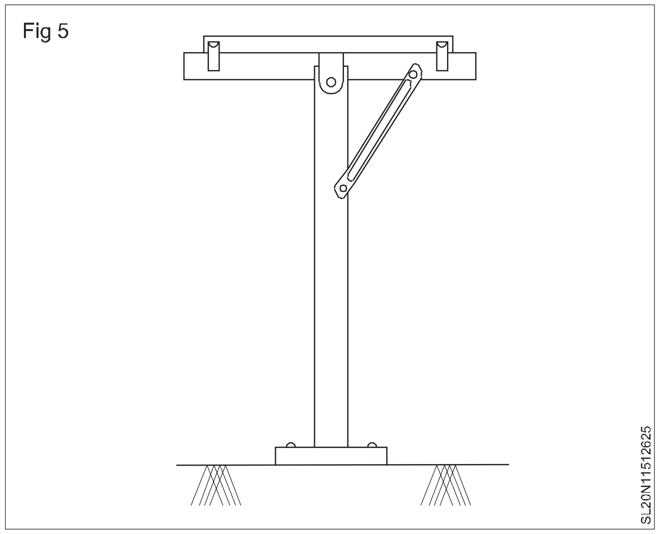


Fig 5 Installed Pillar mount



Similar activities the technician can come across while doing foundation for solar street light also.

While doing multiple poles/pillars for a mega project, care is taken for maintaining parallelisms between them as well as accessibility for installation and maintenance activities.

Installation of solar panels

Objective: At the end of this lesson you shall be able to
- **install a solar PV mounting.**

Here we have mechanical fitting nature of works such as lifting, shifting, storing, mounting, setting gaps between panels and adjusting angle of tilt.

While mounting of Solar PV panels, the solar technicians have to

- mount the connecting arms over the pillar mounts
- fit the angle adjusting rod between the arms and pillar mount
- mount the solar PV panels on the arms
- set the angle of inclination (Tilt angle) for the solar array towards south for given location
- adjust the angle for different locations
- set manually the Tilt angle for different seasons.

Steps involved in mounting Solar PV panels over Pillar structure are

1 assemble the complete structure of pillar mount (rooftop/Ground mount)

2 mount the solar panels (example 4 X 250WP panels for 1 kW plant)

3 face the solar panels towards south

4 adjust the inclination towards proper facing

Tools required include mainly Spanners set.

Skill set involve mainly

- Fabrication of super structure if not available readily (involves structural planning, drawing, dimensions of solar panel, sheet metal works, welding etc)
- Fitting poles, arms and lever

- Mounting or clamping the panels

Procedure for mounting connecting arms over Pillar mounts:

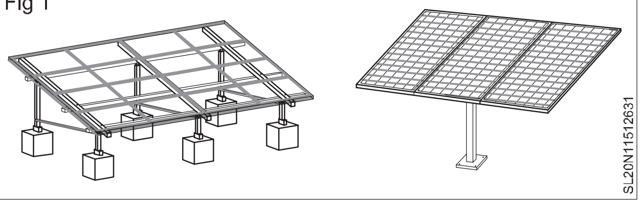
- Mount the swinging arm on the pillar mount by keeping the hole for angle adjustment rod/lever towards south
- Mount the angle adjustment rod/lever connecting the pillar and swinging arm
- Repeat the steps for second or more pillar mounts
- Mount the long connecting arm over the swinging arms
- Adjust the levers and fit evenly.

Procedure for mounting the Solar PV panels:

- Place the panels on the connecting arms matching the holes if available
- If not mark the holes over the arms; repeat for remaining panels and mark leaving air gap of minimum 10 mm between the panels
- In marked case drill holes on the arms
- Place the panels and fit with bolt and nuts

Fig 1 Solar panels mounted over structures

Fig 1



Install a roof top solar panel mounting structure for 1 kW installation

Objective: At the end of this exercise you shall be able to
- **install 1 kW solar panel mounting structure.**

Requirements

Tools and Instruments/equipment

- Pillar mounts Qty - 2 Nos
- Connecting frames Qty - 2 Nos
- Swinging rod Qty - 2 Nos
- Angle adjusting rod Qty - 2 Nos
- Panel fitting arms Qty - 8 Nos
- Tool kit
- Mounting screws, bolts and nuts, washers, anchor bolts
- Tools, drilling machine
- Magnetic compass
- Marking pen and nail
- Thread
- Measuring tape
- Ruler

PROCEDURE

TASK 1: **Marking base of pillar mount on roof top**

1 Follow carefully the steps for making foundation on rooftop.

2 Wear necessary PPE kits.

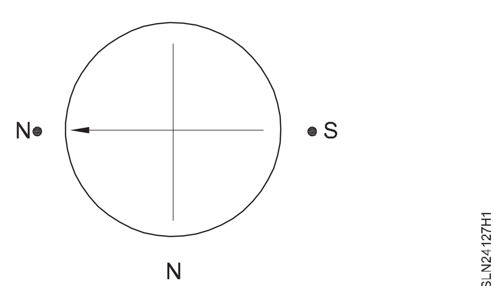
3 Collect all elements of Pillar mount on the roof top.

4 Collect all tools on the rooftop.

5 Use compass and mark true north and south poles.

Marking magnetic poles (Fig 1)

Fig 1



6 Draw line connecting north and south poles points.

Connecting N - S marked points (Fig 2)

Fig 2

7 Place the pillar mount aligned to the connecting lines.

8 Mark the holes of base on ceiling.

9 Draw a parallel line in the direction of N - S, at a distance as per the drawing.

10 Place the second pillar.

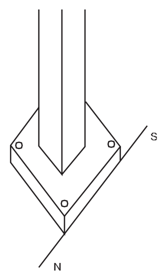
11 Mark the holes of second base on ceiling.

12 Remove the pillar mounts.

13 Verify the dimensions and parallelism before going to Task 2.

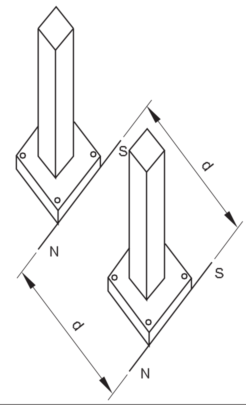
Marking Pillar base (Fig 3)

Fig 3



Marking second pillar parallel to first (Fig 4)

Fig 4



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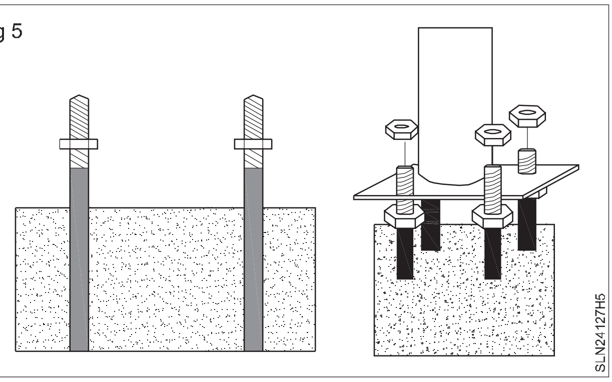
TASK 2: **Drilling on rooftop for pillar mount base**

1 Drill holes on the markings for both pillar bases.

2 Hammer the anchor bolts on the holes.

Fixing anchor bolts on RCC roof (Fig 5)

Fig 5



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TASK 3: **Fixing the pillars on rooftop**

1 Keep the pillar mount aligned to the anchor bolts and fix nuts.

2 Mark parallel to the first pillar mount and repeat the above steps for second pillar.

3 Fix the second parallel pillar and fasten the nuts.

4 Check the parallelism between pillars.

— — — — — — — —

TASK 4: **Assemble remaining components on the pillar mounts on rooftop**

Finished pillar mount (Fig 6)

1 Assemble swinging rods to the top of pillars.

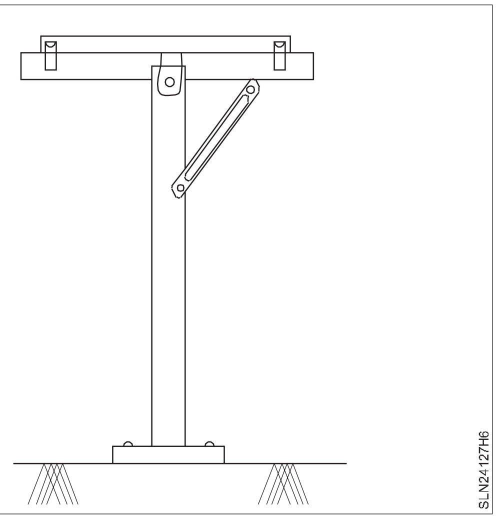
2 Assemble angle adjustment link rod between Pillar and swinging rod.

3 Assemble connecting frames between swing rods over the pillars.

4 Leave the frames assembled to incline towards south.

5 Do not tighten all the bolts.

Fig 6



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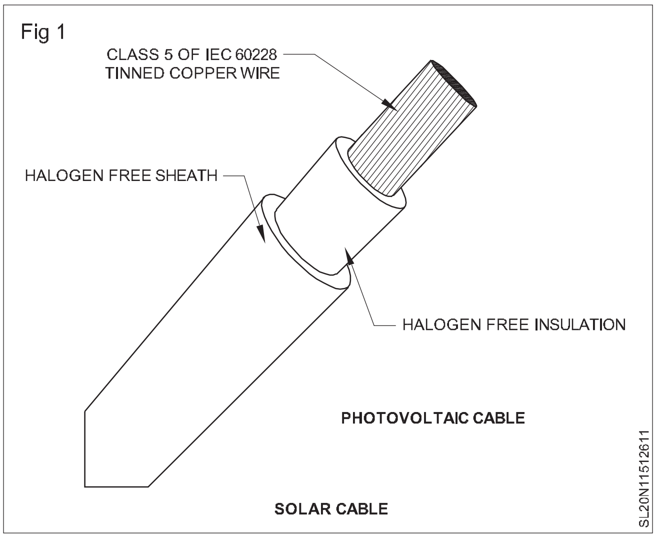
Wire (cable) requirement/ estimation

Objectives: At the end of this lesson you shall be able to
- **elaborate on selection of solar cables.**

Most solar panel systems include basic cables, but sometimes we have to purchase the cables independently. The solar cable, sometimes known as a 'PV Wire' or 'PV Cable' is the most important cable of any PV solar system. The solar panels generate electricity which has to be transferred elsewhere - this is where solar cables come in. The biggest distinction in terms of size is between solar cable 4mm and solar cable 6mm.

Fig 1 Solar cable



To understand how solar cables function, we must get to the core functionality of the cable: The wire. Even though people assume cables and wires are the same things, these terms are completely different. Solar wires are single components, known as 'conductors'. Solar cables are groups of wires/conductors that are assembled together.

The following is an introduction to correct sizing and terminology.

To start with, the most common size for solar wires is "AWG" or 'American Wire Gauge'. If you have a low AWG, this means it covers a large cross-sectional area and hence has lower voltage drops. The solar panel manufacturer supplies the charts that showcase connecting basic DC/AC circuits. They should give information on the maximum current allowed for the cross-sectional area of the solar system, the voltage drop, and DVI.

The chart below shows the capacity of various wire gauge sizes and their average amp rating:

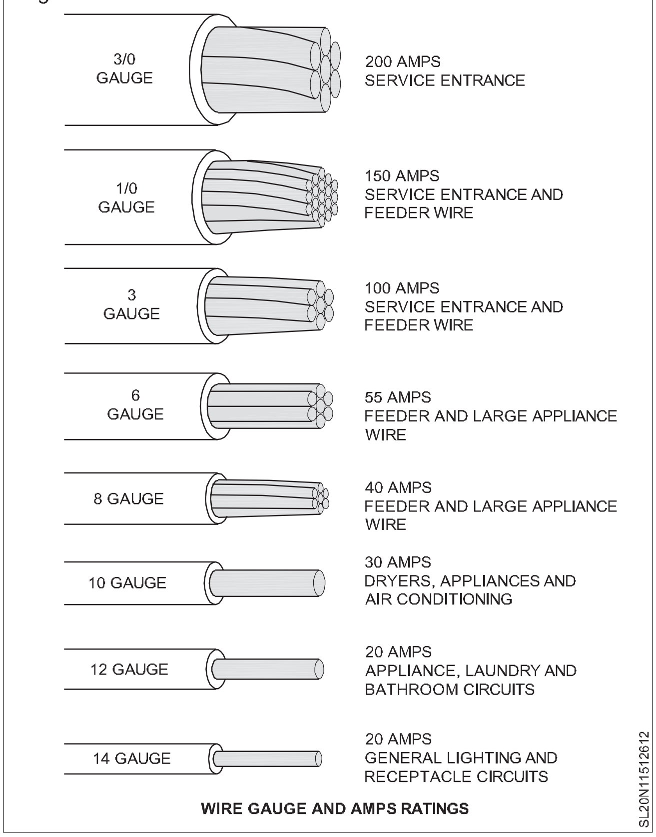
Fig 2 Wire Gauge and Amps ratings

The size of solar panel cable used is important. The size of the cable can affect the performance of the entire solar system. If a smaller cable than recommended by the solar manufacturer is used, we can experience severe drops in voltage across the wires which eventually results in power loss. If we undersize the wires this can lead to a surge in energy that leads to a fire. If a fire erupts in areas such as the rooftop, it could quickly spread to the rest of the house.

To illustrate the importance of PV cable size, imagine the cable like hose carrying water. If you have a large diameter on the hose, the water will flow easily and won't put up any resistance. However, if you have a small hose then you will experience resistance as the water can't flow properly. The length also has an impact - if you have a short hose, the water flow will faster. If you have a large hose, you need the right pressure or the water flow will slow down.

All electric wires function in the same manner. If you have a PV cable that is not large enough to support the solar panel, the resistance can result in fewer watts being transferred and blocking the circuit. PV cables are sized using American Wire Gauges in order to estimate the gauge scale. (The Standard Wire Gauge (SWG) series commonly used in Great Britain were given in BS 3737: 1964. The standard is now withdrawn. The basis of the system is the mil, or 0.001 inches.) The lesser gauge number (AWG) of a wire, the lesser the resistance and the current flowing from the solar panels will arrive safely. Different PV cables have different gauge sizes. Each gauge size has its own AMP rating which is the maximum amount of AMPs that can travel through the cable safely.

Fig 2

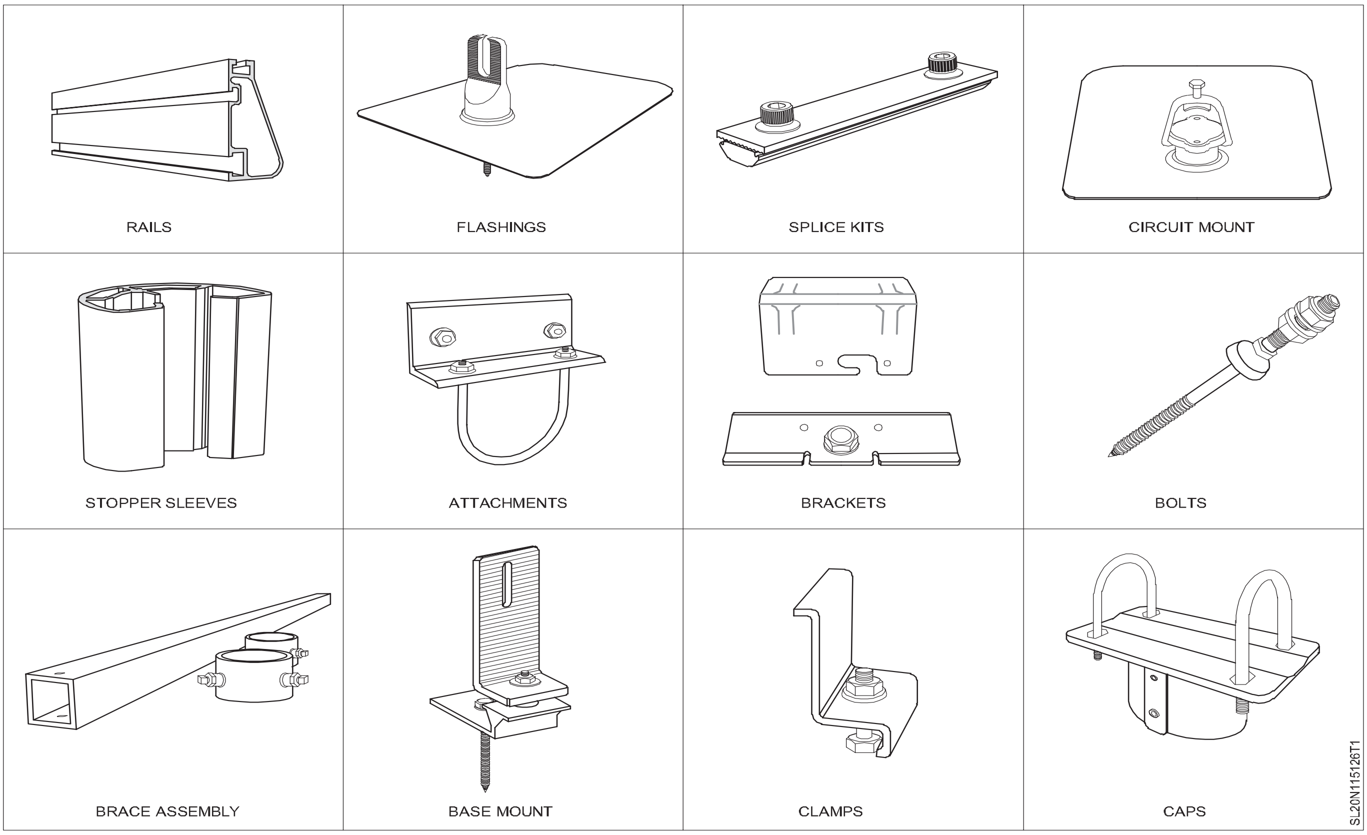


WIRE GAUGE AND AMPS RATINGS

Solar panel mounting structures

Objectives: At the end of this lesson you shall be able to
- **Select from varieties of fittings for mounting solar panels.**

Racking and Mounting products are market ready, for all roof-top, ground mount and solar tracker PV arrays. Market available large assortment of solar racking and mounting components can be uniquely fitted for any type of solar energy system.



Make fastening of concrete over mounting base

Objective: At the end of this exercise you shall be able to
- **construct a ballast foundation.**

Requirements

Tools and Instruments/equipment

- Readymade ballasts with best specifications
- Material handling equipment
- Civil construction utensils
- Civil materials
- Plan of solar array with clear dimensions
- Measuring tape
- Spirit level
- Plumb Bob

PROCEDURE

TASK 1: **Make ballast foundation**

1 With ballast-mounted systems, the flat roof mounts are anchored without penetrating the roof.

2 Place Concrete blocks, slabs or plinths on the flat roof without any further fixing.

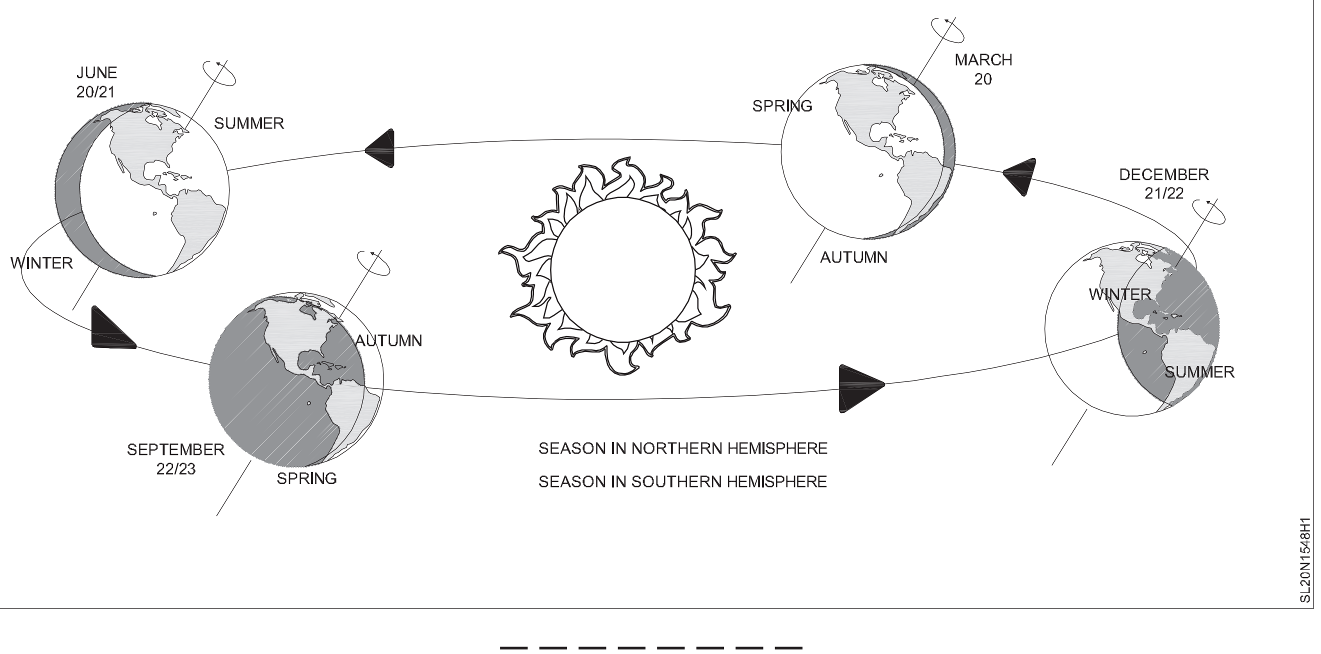
3 Secure the support frames to these with screw anchors.

4 Use standard building materials such as curbs, paving slabs or specially made foundation slabs for the concrete elements.

5 Lay mat beneath to protect the roof skin from sharp edges.

6 Alternatively, insert the concrete weights in channels on the support frame.

Fig 1



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Solar panel wiring and cable Laying

Objectives: At the end of this lesson you shall be able to
- **wire the solar PV panels mounted on the structure.**

After completing fixing of mounting structures and fitting solar panels on mounts then we have the activity of solar panel wiring. This involves:

- connect the solar PV panels with the array junction box
- extend the wire/cable up to inverter input

In the process, the solar technicians have to perform assembly of connectors, wiring and extension till inverter input. The steps involved are:

- identify the connectors
- crimple the terminals end
- interconnect the panels
- conduit pipe laying
- lay underground cable
- connect end terminals to inverter

These skills have been discussed in detail in volume I and briefly recalled here.

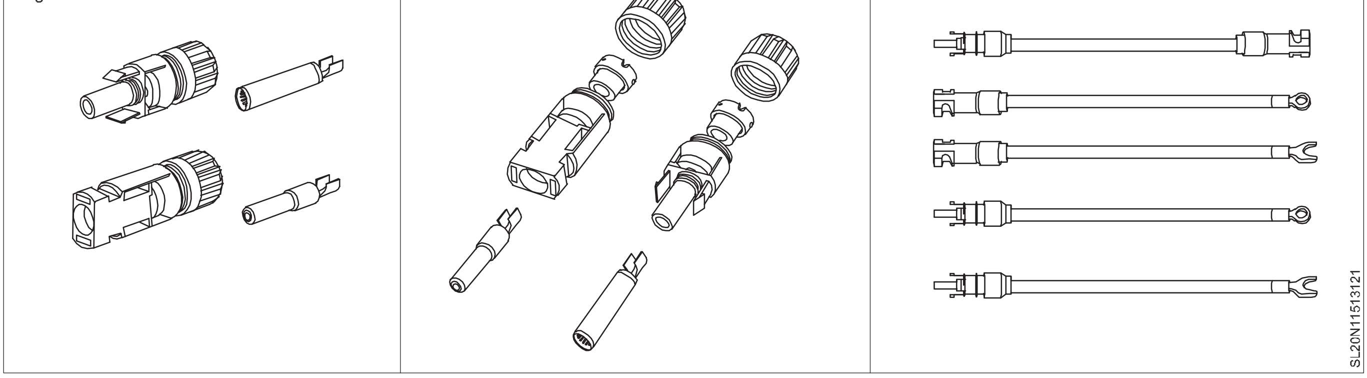
Connecting MC 4 connectors require materials such as MC 4 connectors, DC cables and Wires as well as Tools kit with crimping tool.

Caution: Keep all the circuit breakers, switches in OFF position and all fuses removed &stored separately till commissioning starts. DC volt more than 70 volts prove very dangerous. Once solar panels are exposed to sunlight they start generating DC volt. Construction work continues for long period based on capacity of the plant.

Follow the pictures and practice connecting the MC4 connectors for extension of Solar panel output wires

Fig 1 MC4 connectors

Fig 1

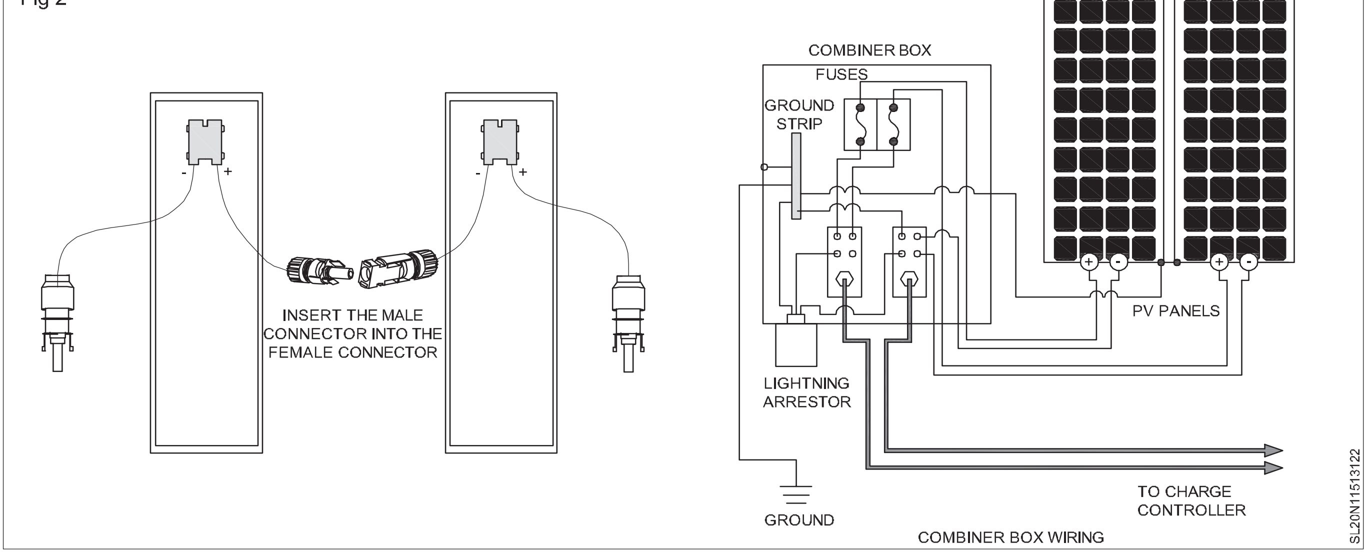


Then inter connect solar PV panels and wire the Array Junction Box.

People connect as shown for series connection of solar PV panels.

Fig 2 Connecting Solar panels using MC4

Fig 2



Steps to connect MC4 connector to the DC cable

Requirements are male and female MC4 connectors, 4mm solar cable, wire strippers and wire crimps (Crimping tool)

1 **Set Up The Connectors**

Mark the distance and decide on the length of cable so as to join all MC4 connectors together.

2 **Crimp Male Connector**

Start by passing the screw nut over your metal crimp and then make sure the plastic housing has a non-return clip inside it. If you didn't put the nut on the cable first, you won't be able to get the plastic housing off.

3 **Insert 4mm Cable**

After crimping the 4mm solar cable right, push in the connector till a "click" sound is heard, which indicates it is secured safely. Then lock the cable in the plastic housing.

4 **Secure Rubber Washer**

The seal washer, made of rubber, is flush at the end of the cable requires the nut to be tightened closely. This gives a solid grip for a 4mm solar cable. Otherwise the connector may spin around the cable and damage the connection. This completes the connectivity for the male connector.

5 **Crimp Female Connector**

Take the cable and put a small bend on it to ensure better surface contact within the crimp. Strip the cable insulation by a small amount in order to expose the wire for crimping. Crimp the female connector the same way as it was done for the male connector.

6 **Connect the Cable**

At this stage, you only have to insert the cable. Pass the screw nut over the cable and check the rubber washer again. Then you need to push the crimped cable into the female housing. You should hear a "Click" sound here as well to know it is locked it in place.

7 **Test Connectivity**

The final state of the connecting process is to test the connectivity. Test the MC4 connectors exclusively before connecting them to the main solar panels or the charge controller in order to verify everything is working properly.

Mount solar panels on the mounting structure

Objective: At the end of this exercise you shall be able to
- **mount solar panels on mounting structure.**

Requirements

Tools and Instruments/equipment

- Modem - 1 No
- Pillar mounts Qty - 2 Nos
- Connecting frames Qty - 2 Nos
- Swinging rod Qty - 2 Nos
- Angle adjusting rod Qty - 2 Nos
- Panel fitting arms Qty - 8 Nos
- Solar panels 4 x 250 W
- Mounting screws, bolts and nuts, washers, anchor bolts
- Tools, drilling machine
- Magnetic compass
- Marking pen and nail
- Thread
- Measuring tape
- Ruler

PROCEDURE

TASK 1: **Mount solar panels on the mounting structure**

1 Wear the PPE necessary.

2 Use the finished structure for pillar mount on rooftop.

3 Assemble the panels over the frames with the panels facing south at desired angles.(4x250Wp)

4 Check all fittings for correctness.

5 Check the wind gap between solar panels.

6 Secure tightness on base to roof and pillar to frame, bolt and nuts.

7 Secure tightness on the panels to frame fitting points.

— — — — — — — —

Solar batteries

Objectives: At the end of this lesson you shall be able to
- **Explain the specification details of the various component of PV system**
- **State the connection and operation of the solar PV system.**

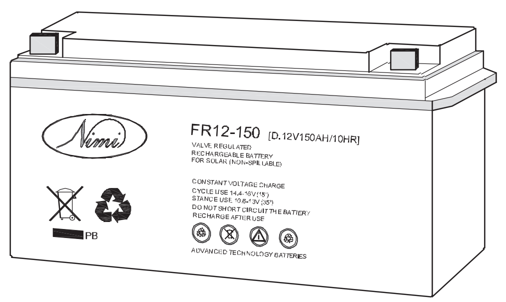
Solar batteries

Various types of Batteries- Lead acid battery, nickel cadmium battery, lithium ion battery are discussed here. Their construction, working, handling, selection, installation and maintenance are also elaborately discussed here. The tools and equipment required for use with solar batteries are dealt in the end.

Solar Batteries (Fig 1)

1 Maintenance free Solar Battery (High Efficient Deep Discharge)

Fig 1



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2 Maintenance battery (With and Without Level indicator)

Fig 2

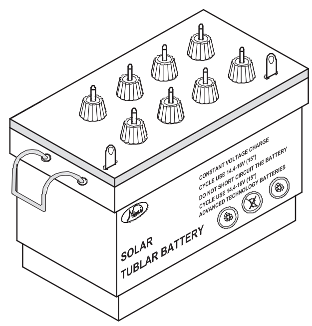

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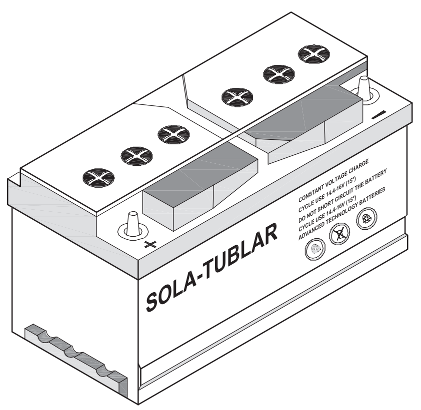
Fig 3



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A battery is an electrochemical cell which stores energy in chemical bonds. Chemical energy is converted to electrical energy when a battery is connected to a load.

Battery Functions in PV systems are to Store energy produced by the PV array and supply it to electrical loads as needed, to power electrical loads at stable voltages, suppressing transients, to supply surge currents to electrical loads or appliances.

Battery Classifications and Types

Primary Battery: Can store and deliver energy, but cannot be recharged. Primary batteries are not used in PV systems.

Batteries (Fig 4)

Fig 4

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Secondary Battery: Can store and deliver electrical energy, and can also be recharged.

Another way of classifying batteries is Starting, Lighting and Ignition (SLI) Batteries. They are:

- Designed for shallow cycle service, damaged by deep discharges.
- Designed for automobile starting.
- Large number of thin plates per cell, provide high discharge currents for short periods, but lack the mechanical strength to sustain deep discharges.
- **NOT SUITABLE FOR PV SYSTEMS**

Finally Motive Power or Traction Batteries are:

- Designed for deep discharge cycle service, typically used in electric vehicles and equipment
- Fewer number of thicker plates than SLI batteries
- Thick lead-antimony grids provide good deep cycle high temperature performance, but are not well suited for high discharge rates.

Battery Operation includes:

Discharge: The process when a battery delivers current, quantified by the discharge current or rate.

Charge: The process when a battery receives or accepts current, quantified by the charge current or rate.

Specification of a solar battery: mainly Voltage rating and AHr.

Ampere-Hour (Ah)

- Common measure of a battery's electrical storage capacity.
- An Ampere-hour is equal to the transfer of one amp over one hour
- A battery which discharges 5 amps for 20 hours delivers 100 ampere-hours
- A measure of a battery's ability to store and deliver electrical energy.
- Commonly expressed in ampere-hours at a specified temperature,discharge rate and cut-off voltage.

Battery Load Testing

- Battery load testing applies very high discharge rates for a few seconds, while measuring the decrease in battery voltage.
- Weak or failed cells are indicated by significantly greater voltage drop.
- Battery capacity testing involves discharging the battery at nominal discharge rates to a prescribed depth-of-discharge.
- Evaluates available energy storage capacity for the system.

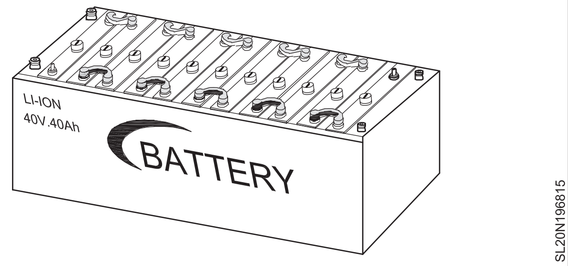
Battery Test Equipment

- DC voltmeters are used to measure battery and cell voltages.
- DC ammeters (clamp-on type) are used to measure battery currents.
- Hydrometers are used to measure electrolyte specific gravity.
- Load testers discharge the battery at high rates for short periods while the voltage drop is recorded.
- Impedance and conductance testers may be used on some VRLA batteries
- Periodic battery maintenance should include checks of all terminals for corrosion and proper torque

Lithium Battery (Fig 5)

Li-ion batteries are almost everywhere. They are used in applications from mobile phones and laptops to hybrid and electric vehicles. Lithium-ion batteries are also increasingly popular in large-scale applications like Uninterruptible Power Supplies (UPSs) and stationary Battery Energy Storage Systems (BESSs).

Fig 5



Lithium-ion batteries conform to this generic battery definition. Other examples include lead-acid and nickel cadmium (Ni-Cad).

Working of a lithium-ion battery:

Most Li-ion batteries share a similar design consisting of a metal oxide positive electrode (cathode) coated onto an aluminum current collector, a negative electrode (anode) made from carbon/graphite coated on a copper current collector, a separator and electrolyte made of lithium salt in an organic solvent.

While the battery is discharging and providing an electric current, the electrolyte carries positively charged lithium ions from the anode to the cathode and vice versa through the separator. The movement of the lithium ions creates free electrons in the anode which creates a charge at the positive current collector. The electrical current then flows from the current collector through a device being powered (cell phone, computer, etc.) to the negative current collector. The separator blocks the flow of electrons inside the battery.

During charging, an external electrical power source (the charging circuit) applies an over-voltage (a higher voltage than the battery produces, of the same polarity), forcing a charging current to flow within the battery from the positive to the negative electrode, i.e. in the reverse direction of a discharge current under normal conditions. The lithium ions then migrate from the positive to the negative electrode, where they become embedded in the porous electrode material in a process known as intercalation.

Primary batteries, or cells, are not rechargeable, and must be discarded once their charge is exhausted. By contrast, secondary types can be recharged using an external electric charger.

Today, most attention is given to secondary types, particularly Li-ion batteries, because of their widespread application in cell phones and electric vehicles. However, primaries still play an important role, especially when charging is impractical or impossible, such as in military combat, rescue missions and forest-fire services.

Regulated under IEC 60086, primary batteries are also used for pacemakers in heart patients, tire pressure gauges in vehicles, smart meters, intelligent drill bits in mining, animal-tracking, remote light beacons, as well as wristwatches, remote controls, electric keys and children's toys.

Alkaline is the most popular primary battery chemistry, while lithium-metal is used for heavier loads.The three most common form factors are prismatic (rectangular), pouch, and cylindrical.

However, one battery cell is not always enough to power a practical load. Instead, battery cells are connected in series and parallel, into a so-called battery pack, to achieve the desired voltage and energy capacity. An electric car for example requires 400-800 V while one single battery cell typically supplies 3-4 V.

A battery pack is a complete enclosure that delivers power to a final product, such as an electric car. The pack contains battery cells, software (battery management system) and often a cooling and heating system, depending on where and how the battery pack is to be used. In large battery packs, the battery cells are arranged in modules to achieve serviceable units.

Lithium-ion battery applications

Lithium-ion batteries are popular because of their high energy density and other properties – and as the technology improves and prices reduce, they are proliferating in many applications. Here are some examples for Li-ion battery applications:

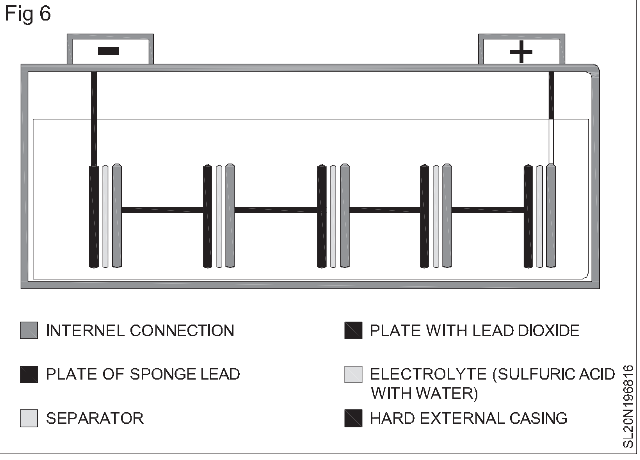
- Portable power packs
- Uninterruptible Power Supplies (UPSs)
- Electric vehicles
- Marine vehicles
- Personal mobility
- Renewable energy storage

Construction of Lead Acid Battery

Lead is a chemical element (symbol is Pb and the atomic number is 82). It is a soft and malleable element. We know what Acid is; it can donate a proton or accept an electron pair when it is reacting. So, a battery, which consists of Lead and anhydrous plumbic acid (sometimes wrongly called as lead peroxide), is called as Lead Acid Battery.

Lead acid battery - construction (Fig 6)

Fig 6



A Lead Acid Battery consists of Plates, Separator, and Electrolyte, Hard Plastic with a hard rubber case.

In the batteries, the plates are of two types, positive and negative. The positive one consists of Lead dioxide and negative one consists of Sponge Lead. These two plates are separated using a separator which is an insulating material.This total construction is kept in a hard plastic case with an electrolyte. The electrolyte is water and sulfuric acid.

The hard plastic case is one cell. A single cell store typically 2.1V. Due to this reason, A 12V lead acid battery consists of 6 cells and provide 6 x 2.1V/Cell = 12.6V typically.

Charge storage capacity

It is highly dependable on the active material (Electrolyte quantity) and the plate's size. You may have seen that lithium battery storage capacity is described in mAh or milliamp-hour rating, but in the case of Lead Acid battery, it is Amp hour. We will describe this in later section.

Working of the Lead Acid battery

This is all about chemistry and it is very interesting to know about it. There are huge chemical process is involved in Lead Acid battery's charging and discharging condition.

The diluted sulfuric acid H2SO4 molecules break into two parts when the acid dissolves. It will create positive ions 2H+ and negative ions SO4-. The two electrodes are connected as plates, Anode and Cathode. Anode catches the negative ions and cathode attracts the positive ions. This bonding in Anode and SO4- and Cathode with 2H+ interchange electrons and which is further react with the H2O or with the water (Diluted sulfuric acid, Sulfuric Acid + Water).

The battery has two states of chemical reaction, Charging and Discharging.

Lead Acid Battery Charging

To charge a battery, we need to provide a voltage greater than the terminal voltage. So to charge a 12.6V battery, 13V can be applied.

When we charge a Lead Acid Battery, the same chemical reactions happens which were described before. Specifically, when the battery is connected with the charger, the sulfuric acid molecules break into two ions, positive ions 2H+ and negative ions SO4-. The hydrogen exchange electrons with the cathode and become hydrogen, this hydrogen reacts with the PbSO4 in cathode and form Sulfuric Acid (H2SO4) and Lead (Pb). On the other hand, SO4- exchange electrons with anode and become radical SO4. This SO4 reacts with PbSO4 of anode and create the lead peroxide PbO2 and sulfuric acid (H2SO4). The energy gets stored by increasing the gravity of sulfuric acid and increasing the cell potential voltage.

As explained above, following chemical reactions takes place at Anode and Cathode during the charging process.

At cathode

$PbSO_4 + 2e^- => Pb + SO_4^{2-}$

At anode

$PbSO_4 + 2H_2O => PbO_2 + SO_4^{2-} + 4H^- + 2e^-$

Combining above two equation, the overall chemical reaction will be

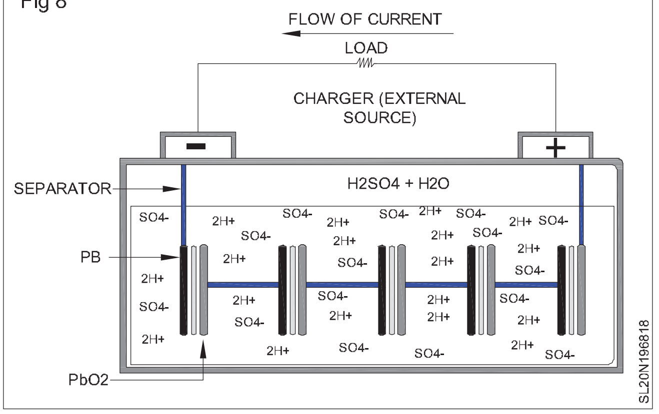
$PbO_2 + Pb + 2H_2SO_4 => 2PbSO_4 + 2H_2O$

Discharge action ina Lead Acid battery (Fig 8)

Due to the electron exchange across anode and cathode, electron balance across the plates is affected. The electrons then flow through the load and the battery gets discharged.

During this discharge, the diluted sulfuric acid gravity decrease. Also, at the same time, the potential difference of the cell decrease.

Fig 8



Wire solar panels and connect the array junction box to the above installation and draw wires up to PCU

Objective: At the end of this exercise you shall be able to
- **perform AJB wiring and PCU wiring.**

Requirements

Tools and Instruments/equipment

- Pillar mount with solar panels 4 X 250W solar panels mounted on it
- Array junction box or combiner box
- Pre-installed with surge protector, DC MCB, connectors, link and fuses
- Wires and tool

PROCEDURE

TASK 1: **Wire the Array Junction Box for series wiring**

1 Fix the AJB in the centre of the Mounting structure or in the end as per convenience in the site to draw the output wire to PCU.

2 Extend positive wires from solar panels to DC (positive) input connectors of AJB.

3 Extend negative wires from solar panels to DC (negative) input connectors of AJB.

4 Link inside the DC input connectors (positive and negative) of AJB provides parallel connection.

5 Remove the link.

6 Provide loops of wires on to the connector for serial wiring.

AJB wiring (Fig 1)

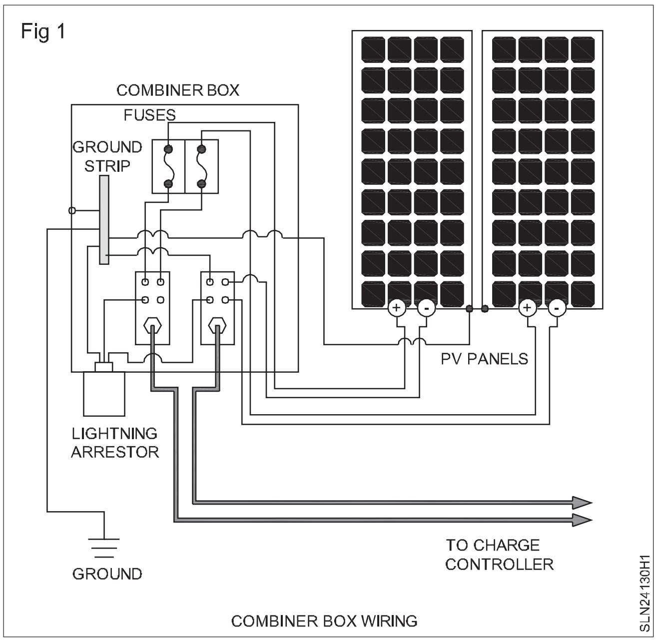
6 Internally the connectors outputs are taken to Surge Protecting Device (SPD), DC MCB and DC fuses (Factory built).

7 Take out Combined DC output from AJB and extend till solar DC IN of PCU.

8 Earth wire (Green) is connected to chassis or box cover.

Parts of AJB

Fig 1



TASK 2: **Wire the Array Junction Box for parallel wiring**

1 Fix the AJB in the centre of the Mounting structure or in the end as per convenience in the site to draw the output wire to PCU.

2 Extend positive wires from solar panels to DC (positive) input connectors of AJB.

3 Extend negative wires from solar panels to DC (negative) input connectors of AJB.

4 Link inside the DC input connectors(positive and negative) of AJB provides parallel connection.

5 Check for link available in position; if not provide link there. Check for parallel connection and confirm.

6 Internally the connectors outputs are taken to Surge Protecting Device (SPD), DC MCB and DC fuses (Factory built).

7 Take out Combined DC output from AJB and extend till solar DC IN of PCU.

8 Earth wire (Green) is connected to chassis or box cover.

After completion of AJB wiring record your experience in Observation column

Observations

Sl.No	List the observation

— — — — — — — —

Combiner Box and Protective Devices

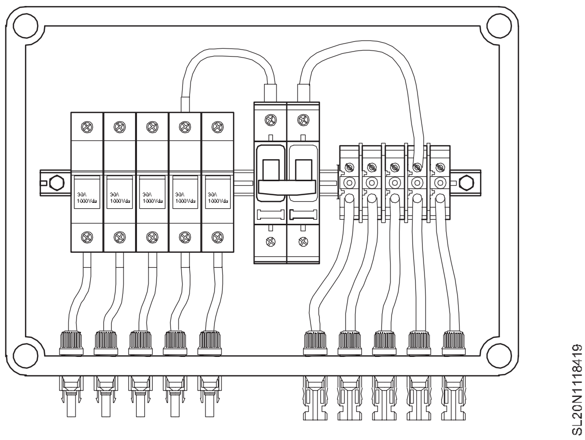
Objectives: At the end of this lesson you shall be able to
- **briefly about array junction box**
- **briefly about PV fuse**
- **briefly about surge protection device**
- **briefly about DC disconnetion isolator.**

Array Junction Box or Combiner Box (Fig 1)

An Array Junction Box, AJB, is used to connect the photovoltaic strings in parallel. The combined DC power is fed to the photovoltaic inverter. It includes photovoltaic string protection, overvoltage protection and a DC output switch isolator.

The AJB can be customized for different configurations, based on the number of strings of solar panel modules used in the layout.

Fig 1



AJB have the following components

1 Enclosure

2 PV fuses

3 Surge Protection Device

4 DC Disconnect/Isolator and

5 Cable Glands/Connectors

These are the Protection devices in an AJB.

1 Enclosure

The combiner box enclosures are usually made of thermoset (eg. GRP or polyester), or thermoplastic (polycarbonate) material, and come with IP65 protection. Enclosures come in various sizes, based on the number of input strings. The protection features required also contribute to the changes in the enclosure needed. Enclosure should be fire-resistant with self-extinguishing property. It should be UV-resistant and halogen-free and should also have a good mechanical impact resistance.

2 PV fuse

PV fuse or photovoltaic fuse of the range from 1A to 32A is easily available in market. The PV fuses are used for overcurrent protection.

PV fuse selection:-

N_s= No. of PV modules in series per PV string

N_p = No. of PV strings in parallel per PV sub-array

I_{sc} = Short-circuit current of one module at Standard Test Conditions (STC)

V_{oc}= Open circuit voltage of one PV module at STC

Calculations to verify volts and amps:

Fuse voltage rating = 1.20 x V x Ns

Fuse amp rating = 1.56 x I_{sc}

For Example:-

Let's assume that

N_s = 20, N_p = 16, I_{sc} = 8.6 A and Voc=37.2 V

Then Fuse amp rating = 1.56x8.6 A = 13.41 A

As per the standard fuse available in market, a 15A fuse should be used here.

And Voltage rating of Fuse = 1.2x37.2x20 = 892.8 V

As per the standard fuse available in market, a 1000 V DC fuse should be used to meet this requirement.

3 Surge Protection Device:

SPD or Surge Protection Device is used in the AJB/SCB. It protects electrical and electronic equipment from the power surges and voltage spikes. SPD diverts the excess voltage and current from transient or surge into ground through earthing system.

Selection Of SPDs according to the voltage protection level Vp : Every SPD has a maximum voltage protection level specified for operation & diverts the excess energy in ground. The protection voltage level of SPD is usually kept at 20% less than dielectric strength & greater than operating voltage of PV system.

4 DC Disconnect /Isolator:

DC Disconnect/Isolator is a switch used to disconnect the power supply between PV string & inverter. It is recommended to be placed before the inverter, to disconnect the DC side of the system when required.

Selection criteria for PV isolator:

Initial conditions for specifying PV disconnect:

N_s = No. of PV module in series per PV string

N_p= No. of PV string in parallel per PV sub-array

I_{sc} = Short-circuit current of one PV module at Standard Test Conditions

Voc = Open circuit voltage of one PV module at STC

Circuit breaker voltage rating = 1.20 x Voc x N_s Volt

PV Output current rating = 1.56 x I_{sc} x N_p Amp

For example:-

Let's we assume that Ns = 20, Np= 16, Isc = 8.6 A and Voc=37.2 V

Circuit breaker voltage = 1.20 x 37.2 x 20 = 892.8 Volt

As per standard available circuit breakers in market, it should be 1000 V DC Disconnect.

Current rating of isolator = 1.56 x Isc x Np A = 1.56 x 8.6 x 16 = 214.65 A

As per standard available circuit breakers in market, it should be 225 A isolator.

5 Cable Glands/Connectors

Every solar system is outdoor type, so AJB component should be IP65 protected & UV protected. There are two options with cable entry in AJB.

1 Cable Gland

2 MC4 connector.

Cable glands require the sealing arrangement after the connection inside AJB to outside systems is done. MC4 Connectors have the male-female socket for connection, and hence do not require sealing to maintain the IP protection. MC4 connectors have the limitation of current capacity. In low rating, 30 A for string level MC4 is the best option. In case of AJB, output rating of more than 30A cable gland is suitable.

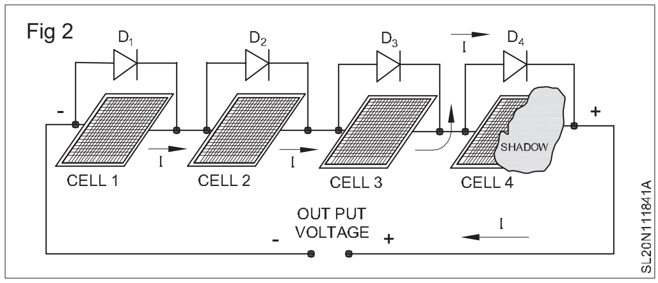
By pass diode

We should know about shading in PV Cells to understand the role of bypass diode. According to Kirchhoff's current law all the cells connected in series in a string will have the same current.When one cell is shaded the individual current in this cell drops. The cell tries to increase its current output to equal the current in the network, and goes into reverse bias in the process. The cell operating in reverse bias requires more energy. This produces a negative voltage and increased heat dissipation.

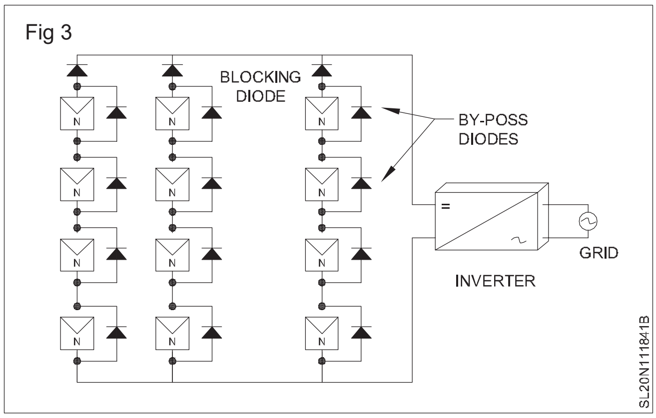
Due to imperfections in the cell the temperature increases in some parts of the cell.This leads to a hotspot in the cell, thus damaging the cell.

Diodes used to minimize the effect of shading. Diodes are used in parallel with the with a string of cells. Current flows through the forward biased diodes, when the cells are switched to reverse bias due to shading. This reduces the effect of shading.

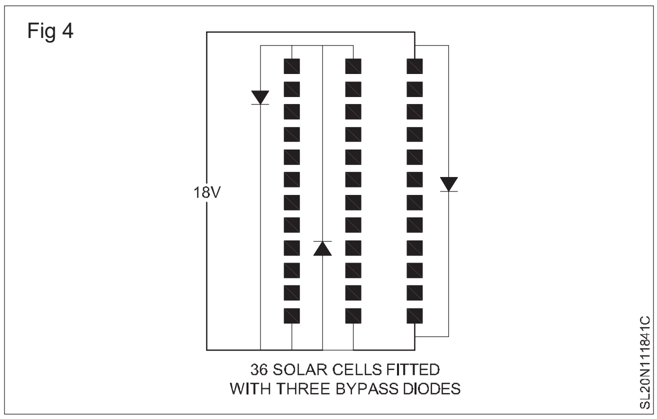
Effect of Shadow on one cell in a string (Fig 2)



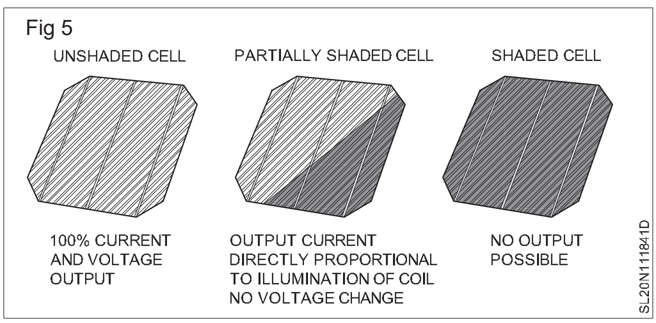
Bypass diodes across each Solar panel in an array (Fig 3)



Diodes per cell string within a panel (Fig 1)



Shading stages over a cell (Fig 5)



Power reduction from a solar panel due to shading (Fig 6)

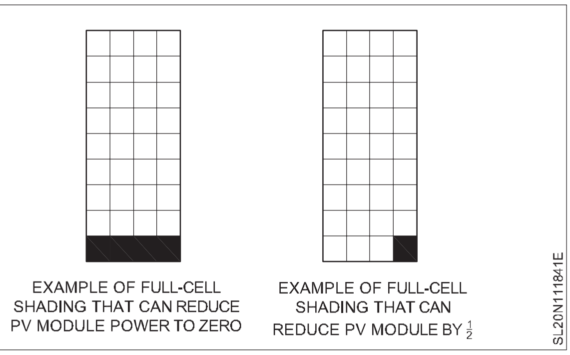
- CIS (Copper Indium Selenium)
- CIGS (copper indium gallium di-selenide)

Charge controllers

The need for a charge controller

Though abundant, solar insolation is an unreliable source of energy, in the sense,it fluctuates as a function oftime and is not available during the nights or in cloudy sky. Therefore when the PV systems are usedfor stand –alone applications, a backup source of energy is necessary to compensate for the balancepower demand of the load.

Fig 6



Batteries are used as generally backup source in such applications. Toreduce the cost of system, the ratings of batteries are designed optimally. Battery feeds the loadwhen the PV output power is less than load demand and is charged when PV output power is morethan load demand. In applications where batteries are used, it is critical to prevent overcharging ordeep discharging of the batteries to preserve their life and to ensure good performance. This isachieved using Charge controllers.

The block diagram of a stand –alone PV system with batterybackup and a charge controller is shown in fig. 38. This shows the solar energy is received from the solar panel by the charge controller. The energy received is either used for charging the battery or delivered to the load based on energy level in the battery and the requirement by the load. Battery delivers out or receives in the energy.

A charge controller (an electronic circuit) is basically a voltage and/or current regulator to keep batteries gets charged and prevent from overcharging. It regulates the voltage and current coming from the solar panels and going to the battery.

Standalone solar PV electrical system

The Solar charge controller performs the following major functions:

- Charges the battery.
- Gives an indication when battery is fully charged.
- Connect/disconnect the load
- Monitors the battery voltage and when it is minimum disconnects the load
- Connects or disconnects solar panel to circuit
- Protects the battery from over charging
- Prevents battery from deep discharge
- Monitors the reverse current flow and block
- Indications for charging ON, Battery connect, Solar ON etc
- Commercial charge controllers have 10amp to 40amp of charging current

As a common application, the Solar Street lights use photovoltaic modules to convert sunlight into DC electric charge and use a solar charge controller to store DC in the batteries and automatically switch ON street light in the evening after sunset.

Home systems use PV module for house-hold applications in which charge controller plays important role.

Charge Controller

Basically there are three types of charge controller

1 On/Off (bang-bang) type controller

- Disconnects module when high battery voltage is reached
- Reconnects module when battery voltage lowers
- Control may be relay or solid state

2 PulseWidth Modulation (PWM)

- When desired battery voltage is reached (≈14V) output turns on/off quite rapidly (100Hz -50KHz)
- Battery voltage held constant, producing a more fully charged battery

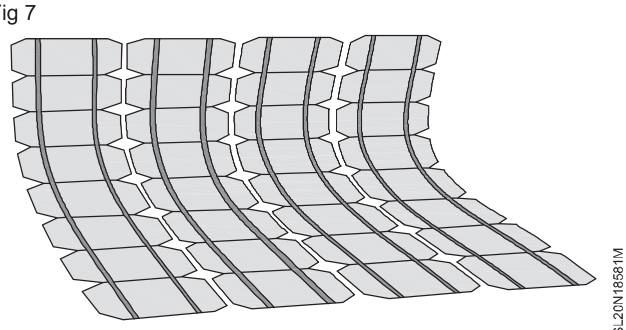
3 Maximum Power Point Tracking (MPPT)

- Provides PWM type battery voltage control
- Extracts all available power from the PV module
- MPPT technology can increases charge current up to 30% or more compared to traditionalcharge controllers

The solar charge controllers are necessary for most solar power system that uses batteries. The solar charge controller functions to control the power as it moves from the solar panels to batteries. Ifovercharged, the life of battery is reduced. The simple type of charge controller functions to monitor the battery voltage and opens the circuit to stop the charging process once the voltage reaches acertain level. Older charge controllers accomplished this through the use of a mechanical relay.

Charge controller and its connections with other components in Solar PV electrical system (Fig 7)

Fig 7



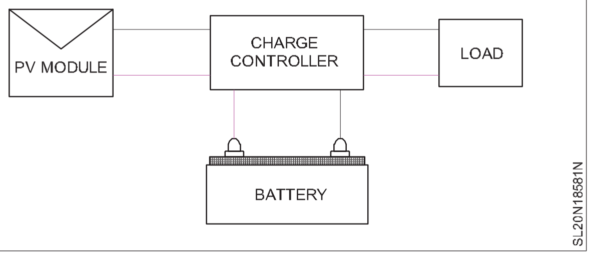
PWM solar charge controller

More charge controllers make use of pulse width modulation. This is a process in which, asthe battery starts to reach a fully charged state, the amount of power being transferred to it graduallydecreases.

Block diagram of a PWM type charge controller (Fig 8)

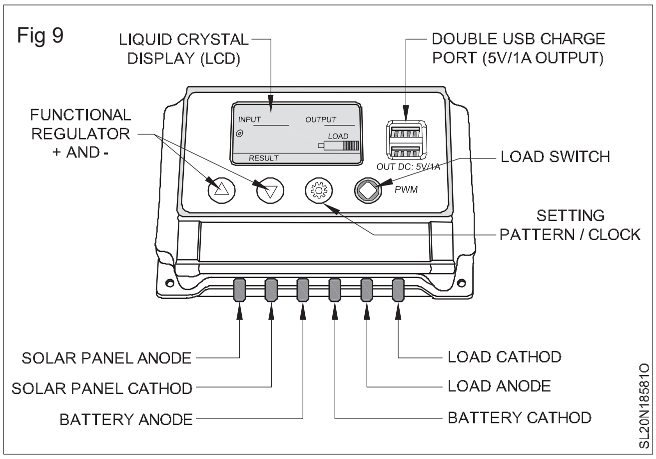
PWM extends the battery life even more, as it decreases stress on battery. It can also keepbatteries in a completely charged state, or floating, indefinitely. PWM chargers are more complex,but they tend to be more durable as they do not use any breakable mechanical connection.

Fig 8



Graphical representation of functions of a charge controller (Fig 9)

Fig 9

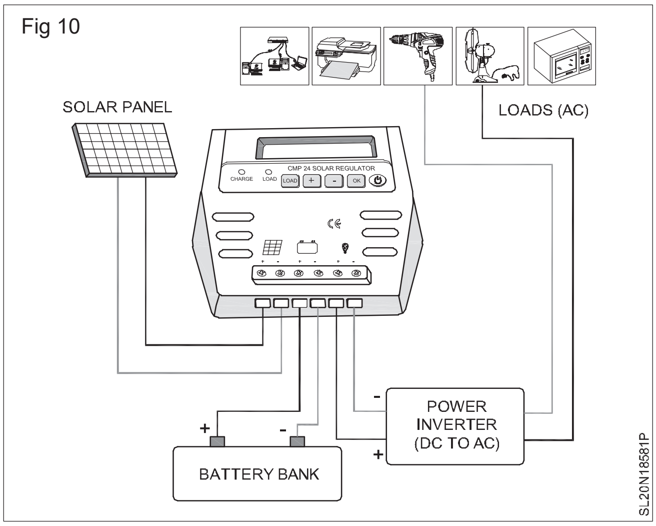


Control by duty cycle in a PWM controller (Fig 10)

MPPT solar charge controller

The most recent type of solar charge controllers use maximum power point tracking, or MPPT. Thisis an electronic tracking system that continuously compares the battery charge level with the outputof solar panel. It will then adjust the voltage and current to be applied to the battery, conserving thesame power from the solar panel, but charging the battery more efficiently.

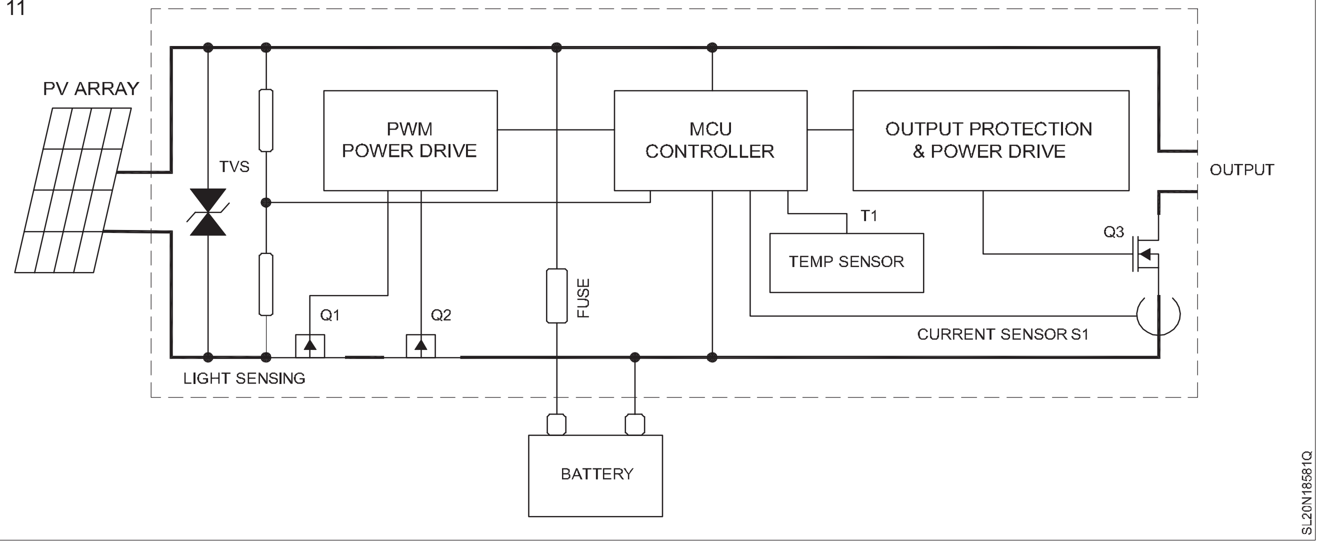
Fig 10



Block diagram of a MPPT type charge controller (Fig 11)

MPPT Solar Charge Controller is a battery charger and load controller for standalone PVsystems. This controller features a smart tracking algorithm that maximizes energyharvest from solar panels.

Fig 11



Maximum power point in a solar panel characteristic (Fig 12)

The controller also prevents over charge or deep discharge. It providesautomatic load control for the external load connected to the controller board. This optimized batterycharging process increases battery life, minimizes battery maintenance, and improves system performance.

The advantage of MPPT (Fig 13)

Maximum power point tracking, referred to as MPPT, is an electronic system thatoperates the photovoltaic modules to produce maximum power. MPPT varies the electrical operatingpoint of the modules and enables them to deliver maximum available power. The additional powerharvested increases the current available for battery charging. MPPT can be used in conjunction witha mechanical tracking system, but the two systems are completely different. In comparison to PWM controllers, MPPT charge controllers are more expensive, but theirperformance is significantly enhanced.

Fig 12

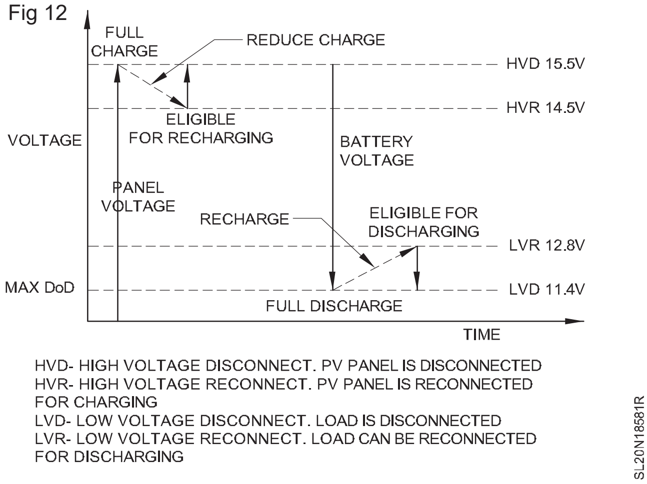
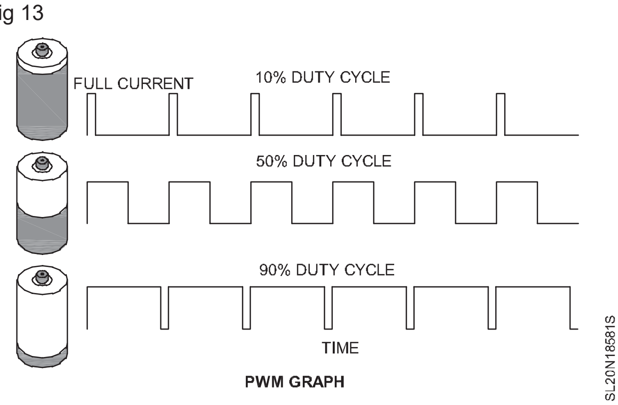
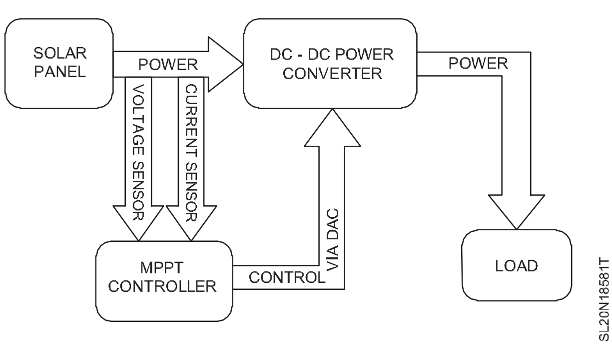


Fig 13



PWM charge controller and MPPT charge controller (Fig 14)

Fig 14



Besides the type, charge controllers are characterized by thecurrent they can control (5, 10, 15, …….. 50 A….) and the voltage under which they can control it,generally 12, 24 or 48 V which is the voltage of the solar module or array. They can be dual voltagewith automatic switch, as 12/24 V.

They also feature the operating temperature and efficiency,almostalwaysabove95%.Mostpowercontrollers for 12V applications will control a maximumunder 50A. Generally high power photovoltaic systems are based on higher voltages (24, 48V…..).

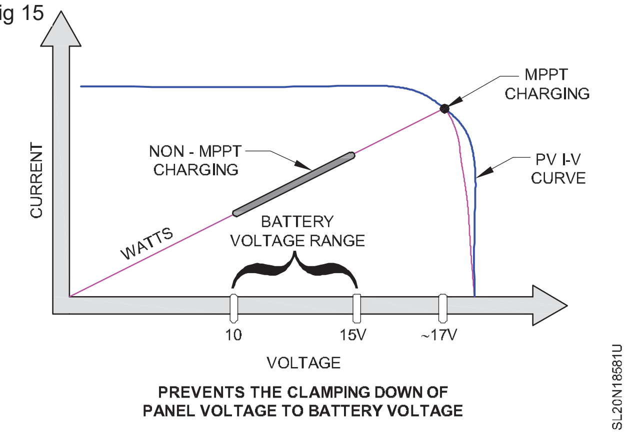
Further in modern inverters used in Solar PV electrical system, three levels of charging required by the solar batteries are accomplished by MPPT charge controllers. They are Bulk charging, absorption charging and float charging.

Three stages of charging required for battery by charge controller (Fig 15)

Another way of classification is by the way application i.e., Day lighting with manual control and dusk to dawn with automatic control. Day lighting control is preferred in Solar PV DC electrical system which can be totally independent of AC mains supply.

The dusk to dawn is used by the street light that requires automatic turn ON at subset.

Fig 15



Installs test AC, DC & Lightening arrestor

Objectives: At the end of this exercise you shall be able to
- **to understand assembly of lightning arrestor**
- **to practice erection of the lightning arrestor.**

TASK 1 : **Visit actual substations or solar plants and learn or practice with the help of field executives the installation and maintenance of the lightning arrestor**

> **Note: Instructor and institute authorities should arrange necessary MoU or tie ups with suitable industry stake holders.**

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Quality certification, Standards and testing for Grid-connected Rooftop Solar PV Systems/Power Plants

Objectives: At the end of this lesson you shall be able to
• **become informative on Quality standards.**

Quality certification and standards for grid-connected rooftop solar PV systems are essential for the successful mass-scale implementation (in-order to achieve 40 GW of rooftop solar target under 'National Solar Mission' programme) of this technology.

It is also imperative to put in place an efficient and rigorous monitoring mechanism, adherence to these standards. In-addition, a few standards which are still under development/draft need to be introduced in the ongoing rooftop solar PV programmes at the earliest. The relevant standards and certifications for a grid-connected rooftop solar PV system/plant (component-wise, upto LV-side) are given below: [currently, all applicable standards (International and Indian) are listed, and bifurcation of mandatory and advisory is done]

Solar PV Modules/Panels

IEC 61215/ IS 14286	Design Qualification and Type Approval for Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
IEC 61646/ IS 16077	Design Qualification and Type Approval for Thin-Film Terrestrial Photovoltaic (PV) Modules
IEC 62108	Design Qualification and Type Approval for Concentrator Photovoltaic (CPV) Modules and Assemblies
IEC 61701- As applicable	Salt Mist Corrosion Testing of Photovoltaic (PV) Modules
IEC 61853- Part 1/ IS 16170 : Part 1	Photovoltaic (PV) module performance testing and energy rating –: Irradiance and temperature performance measurements, and power rating
IEC 62716 IEC 61730-1,2	Photovoltaic (PV) Modules – Ammonia (NH3) Corrosion Testing (Advisory - As per the site condition like dairies, toilets) Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction, Part 2: Requirements for Testing
IEC 62804 (Draft Specifications) IEC 62759-1	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation (PID). IEC TS 62804-1: Part 1: Crystalline silicon (Mandatory for system voltage is more than 600 VDC and advisory for system voltage is less than 600 VDC) Photovoltaic (PV) modules – Transportation testing, Part 1: Transportation and shipping of module package units

Solar PV Inverters	
IEC 62109-1, IEC 62109-2	Safety of power converters for use in photovoltaic power systems Safety compliance (Protection degree IP 65 for outdoor mounting, IP 54 for indoor mounting)
IEC/IS 61683	Photovoltaic Systems – Power conditioners: Procedure for Measuring Efficiency (10%, 25%, 50%, 75% & 90-100% Loading Conditions)
(For stand Alone System) BS EN 50530 (Will become IEC 62891) (For Grid Interactive system)	Overall efficiency of grid-connected photovoltaic inverters: This European Standard provides a procedure for the measurement of the accuracy of the maximum power point tracking (MPPT) of inverters, which are used in grid-connected photovoltaic systems. In that case the inverter energizes a low voltage grid of stable AC voltage and constant frequency. Both the static and dynamic MPPT efficiency is considered.
IEC 62116/ UL 1741/ IEEE 1547	Utility-interconnected Photovoltaic Inverters - Test Procedure of Islanding Prevention Measures
IEC 60255-27	Measuring relays and protection equipment - Part 27: Product safety requirements
IEC 60068-2 (1, 2, 14, 27, 30 & 64)	Environmental Testing of PV System – Power Conditioners and Inverters
IEC 61000- 2,3,5	Electromagnetic Interference (EMI), and Electromagnetic Compatibility (EMC) testing of PV Inverters (as applicable)

Fuses	
IS/IEC 60947 (Part 1, 2 & 3), EN 50521 IEC 60269-6	General safety requirements for connectors, switches, circuit breakers (AC/DC) Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems
Surge Arrestors	
IEC 61643-11:2011 / IS 15086-5 (SPD)	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods
Cables	
IEC 60227/IS 694, IEC 60502/IS 1554 (Part 1 & 2) BS EN 50618	General test and measuring method for PVC (Polyvinyl chloride) insulated cables (for working voltages up to and including 1100 V, and UV resistant for outdoor installation) Electric cables for photovoltaic systems (BT(DE/NOT)258), mainly for DC cables
Earthing /Lightning	
IEC 62561 Series(Part 1,2 & &) (Chemical earthing)	IEC 62561-1 Lightning protection system components (LPSC) - Part 1: Requirements for connection components IEC 62561-2 Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes IEC 62561-7 Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds

Junction Boxes	
IEC 60529	Junction boxes and solar panel terminal boxes shall be of the thermo plastic type with IP 65 protection for outdoor use, and IP 54 protection for indoor use
Energy Meter	
IS 16444 or as specified by the DISCOMs	a.c. Static direct connected watt-hour Smart Meter Class 1 and 2 — Specification (with Import & Export/ Net energy measurements)
Solar PV Roof Mounting Structure	
IS 2062/IS 4759	Material for the structure mounting

SOP (Standard Operation Procedures) of PV system

Objectives: At the end of this lesson you shall be able to
- **execute SOP in a SPV plant.**

Safety Preparation at Work Area

Solar technician must understand essential safety norms to be followed at field and be able to prepare documentation of safety procedures. The main purpose of the Health and Safety policies and procedures is to instruct and follow all workers to prevent injury, to themselves and others. Every worker has to participate in developing, implementing, and enforcing Health and Safety policies and procedures.

The separate instruction manual is prepared for health and safety at work area at solar PV project. The structure and usage of the manual is supported by the following two document sets.

1 Standard Operating Procedures (SOP) applicable for different tasks, business processes or risk areas.

2 Documentation Formats for preparation and maintenance of important records.

The manual should be read in conjunction with the most updated versions of the standard operating procedures (SOPs) and documentation formats (DF) for different sub-tasks at all times, as applicable.

The manual is intended to provide guidance on the basic framework for health & safety management and its continual improvement across all our operations. These standards are to be followed along with SOPs as good practise and mitigate Health & Safety risks in operations.

The list of SOPs and documentation formats is prepared and recorded.

For Example: SOPs with versions

1 Risk Management

2 Waste Management

3 Fire and emergency procedures

4 Electrical safety

5 Work at height and fall prevention

6 Tools and equipment

7 Traffic safety

8 Personal protective equipment

9 Work permit system

10 Safe lifting operations

11 Health & Safety audit procedure

For example Documentation formats

1 Health & Safety checklist

2 Accident/Incident Reporting

3 Risk mitigation plan

Personal Protective Equipment (PPE)

Objectives: At the end of this lesson you shall be able to
- **handle PPE for use in SPV plant.**

Solar technician shall be able to

- Place personal safety equipment properly at work area.
- Identify and segregate good personal safety equipment.
- Inspect visually wear and tear of safety equipment.
- Verify expiry date of personal protection equipment.
- Arrange protective equipment as per instruction from supervisor.
- Arrange required test devices as per required site work.

We should first understand the importance of PPE and select suitable equipment to protect different part of the body.

PPE is equipment that will protect the user against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses. It also includes respiratory protective equipment (RPE).

Making the workplace safe includes providing instructions, procedures, training and supervision to encourage people to work safely and responsibly. Even where engineering controls and safe systems of work have been applied, some hazards might remain.

These include injuries to:

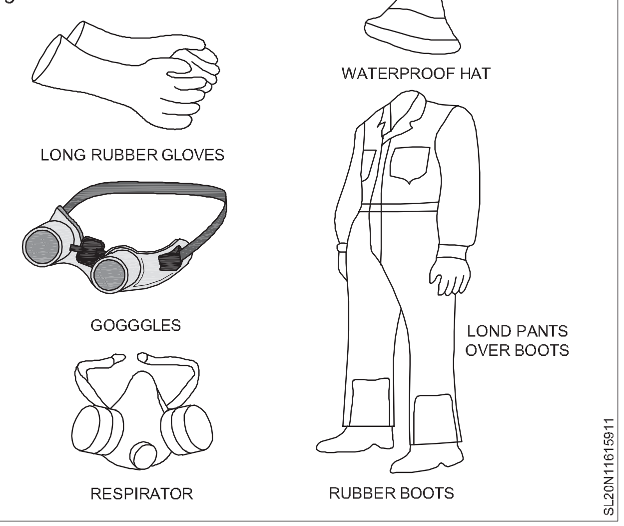
- the lungs, example from breathing in contaminated air
- the head and feet, example from falling materials
- the eyes, example from flying particles or splashes of corrosive liquids
- the skin, example from contact with corrosive materials
- the body, example from extremes of heat or cold

PPE is needed in these cases to reduce the risk.

Fig 1 Types of PPE

You must choose the equipment carefully and ensure employees are trained to use it properly, and know how to detect and report any faults. When selecting and using PPE:

Fig 1



Types of PPE

Personal safety for	Hazards	Options	Remarks
Eyes	Chemical or metal splash, dust, projectiles, gas and vapour, radiation	Safety spectacles Goggles face screens face shields visors.	Make sure the eye protection chosen has the right combination of impact/dust/ splash/molten metal eye protection for the task and fits the user properly.
Head and neck	Impact from falling or flying objects, risk of head bumping, hair getting tangled in machinery.	Industrial safety helmets bump caps, hairnets fire fighters' helmets.	Helmet protects the head from injury. The neck protection is also very important. Replace head protection if it is damaged.
Ears	Noise - very high-level sounds are a hazard even with short duration	Earplugs earmuffs semi-insert/ canal caps	Provide the right hearing protectors for the type of work, and make sure workers know how to fit them.
Hands and arms	Abrasion, temperature extremes, cuts and punctures, impact, chemicals, electric shock, radiation, vibration, biological agents and prolonged immersion in water.	Gloves gloves with a cuff gauntlets sleeving that covers part or all of the arm.	Wearing gloves for long periods can make the skin hot and sweaty, leading to skin problems. Using separate cotton inner gloves can help prevent this.
Feet and legs	Wet, hot and cold conditions, electrostatic build-up, slipping, cuts and punctures, falling objects, heavy loads, metal and chemical splash, vehicles.	Safety boots shoes with protective toecaps mid-sole wellington boots	Footwear can have a variety of sole patterns and materials to help prevent slips in different conditions, including oil - or chemical-resistant soles. It can also be anti-static, electrically conductive or thermally insulating.
Lungs	Oxygen-deficient atmospheres, dusts, gases and vapours	Respiratory protective equipment (RPE)	Only use breathing apparatus - never use a filtering cartridge.
Whole body	Heat, chemical or metal splash, spray from pressure leaks or spray guns, contaminated dust, impact or penetration.	boiler suits aprons Chemical suits.	The choice of materials includes flame-retardant, anti-static, chain mail, chemically impermeable, and high-visibility.

Verify the checklist carryout final test of commission the rooftop solar system

Objectives: At the end of this exercise you shall be able to
- **issue a clearance certificate for first switch ON.**

Note: Verified check list signed by the inspector (Technician).

PROCEDURE

TASK 1: **Grant permission to first switch ON**

1 Complete information about the installation.
2 Verify important points as an in - charge of team.
3 Consider risk blocks.
4 Have a verbal check up with the technician signed.
5 Rectify any loose connection or short comings reported.
6 On satisfactory completion sign the document and release it for 'First Switch On'.

Observations

Sl.No	Checklist parameter	Remarks

Battery maintenance and Safety precaution

Objective: At the end of this lesson you shall be able to
- **work safely at heights.**

Follow Instructions for Work at Height, such as:

1 Arrange fall protection materials and devices as per supervisor instructions
2 Arrange perimeter protection material and devices to work area.
3 Assist in plan fall protection and perimeter protection.
4 Verify tools and materials as per list.
5 Remove the tools and materials from work area.
6 Verify protection equipment as per list.
7 Remove the protection equipment from work area.
8 Dispose the scrap material from work area.

Fall protection at workplace

Objectives:

1 identify tools essential for working at height
2 handle various safety gadgets

The solar PV panels are often installed at heights, the following safety precautions should be kept in mind.

Solar technician should:

- Use proper ladder safety techniques when accessing all elevated areas.
- Hoist materials instead of trying to take them up ladders manually.
- Evaluate the height and the roof pitch to determine if fall protection or safety barriers are required.
- Stay away from elevated edges.

Fig 1 Fall Protection Equipment

Fig 1

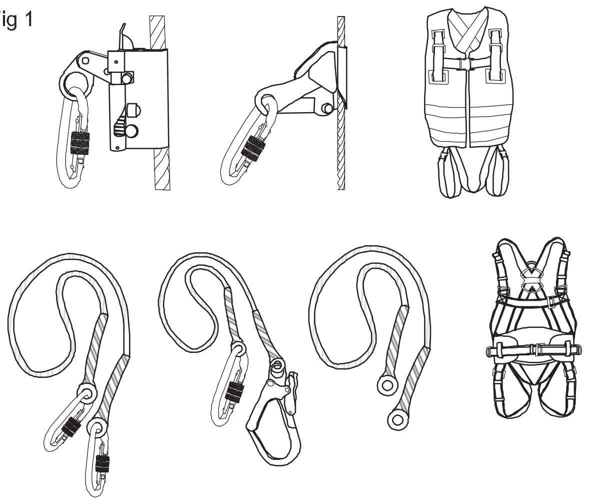


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Fig 2 Fall protection hazards

Fig 2

Ladder Safety

Solar construction often involves working on roofs and from ladders. Choosing the right ladder and using it properly are essential.

Safety measures for solar technicians:

1 Select the ladder that best suits the need for access – whether a stepladder, straight ladder or extension ladder. Straight or extension ladders should extend a minimum of three feet above the rung that the worker will stand upon.

2 Select the right ladder material. Aluminium and metal ladders are the most commonly used today and may have their place on the job, but they're a serious hazard near power lines or electrical work. Use a fibreglass ladder with non-conductive side rails near power sources.

3 Place the ladder on dry, level ground removed from walkways and doorways, and at least 10 feet from power lines and secure it to the ground or rooftop.

Trips and Falls Hazard

Trips and falls are a common hazard of all construction jobs, including solar. They can happen anywhere on the jobsite, especially off roofs or ladders. The solar installations on pole type structures are especially hazardous because the work space diminishes as more panels are installed, increasing the risk of falls.

Safety measures for solar PV technicians:

1 Keep all work areas dry and clear of obstructions.

2 For fall distances of six feet or more, take one of three protective measures: install guardrails around ledges, sunroofs or skylights; use safety nets; or provide each employee with a body harness that is anchored to the rooftop to arrest a potential fall.

3 Cover holes on rooftops, including skylights, and on ground-level work surfaces.

Fall hazard assessment checklist		
1 Can an employee enter the area without restriction and perform work?	Yes	No
2 Are fall prevention systems such as cages, guardrails, toeboards, and manlifts in place?	Yes	No
3 Have slipping and tripping hazards been removed or controlled?	Yes	No
4 Have visual warnings of fall hazards been installed?	Yes	No
5 Can the distance a worker could fall be reduced by installing platforms, nets, etc.?	Yes	No
6 Are any permanently installed floor coverings, gratings, hatches, or doors missing?	Yes	No
7 Does the location contain any other recognized safety and or health hazards?	Yes	No
8 Is the space designated as a Permit Required Confined Space?	Yes	No
9 Working near telecommunication or electric equipment?	Yes	No
10 Working near fume hood stacks?	Yes	No
11 Have anchor points been designated, tested, and inspected?	Yes	No
12 Is work being performed (above or below) power lines?	Yes	No
13 Are the weather conditions acceptable to work in: i.e. wind, wet footing, lightning, rain1:	Yes	No

Fall Assessment Tool/Checklist: Conditions to be checked

- Work Areas Associated with:
- Loading docks
- Balconies
- Galleries
- Landings
- Platforms
- Stairs
- Walkways
- Mezzanines
- Parking areas
- Sidewalks
- Working Surface Conditions: Oil, grease, wax Fluids Ice Irregular surfaces
- Working at heights with: Portable ladders, Fixed ladders, Elevated Platforms, Scaffolds, Cherry pickers, Catwalks and Other elevating devices

Factors for increased potential for electrical shock, tripping, slipping, and falling are highlighted below:

- The surface of PV modules is normally slippery. When installed on a peaked structure or when the modules are wet, they become extremely slippery. DO NOT walk on modules.
- Accidental contact with high-voltage PV components could cause involuntary muscle reaction and could result in a fall from the structure.
- Fire fighters should never attempt to place a ladder on PV modules.
- Do not attempt to break the glass covering PV modules, as this could expose high-voltage internal components within the module and increase the risk of electrical shock.
- The mounting racks, electrical conduit, and wires are sometimes partially concealed and are not always visible during the day. They become even more difficult to identify in the dark or in the presence of smoke.

Carryout of solar panel maintenance cleaning & DC array inspection

Objectives: At the end of this exercise you shall be able to
- **perform maintenance of solar PV panels.**

Requirements

Tools and Instruments/equipment

- Container
- Clean water
- Wiper
- Cleaning fluid

PROCEDURE

TASK 1: **Clean the solar PV array (manual)**

1 Do not sit, stand or walk on solar panel.

2 Even keeping palm on panel for resting for few moments also can damage internally the PV cell.

3 Ensure water used is free from dirt and physical contaminants. (De-ionized water is preferable).

4 Water with mineral content more than 200 ppm should NOT be used.

5 Cleaning agent must be mild, non-caustic and non-abrasive detergent may be used.

6 For normal cleaning where dirt is not visible only water or thinly diluted cleaning agent can be used.

7 Add more cleaning agent where dirt or dust level is more.

8 Pour the mix on the surface exposed to sun and gently brush with wiper to clean.

9 Do not brush or clean on the reverse side of the modules to avoid damage to the lead wires or the junction box.

10 For removing stubborn marks of bird droppings, insects, dirt etc. make use of a soft sponge, fiber cloth or non-abrasive brush.

11 Do not sit, stand or step on the modules for cleaning.

12 Do not use a metal brush to clean solar panel surface.

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Execute battery maintenance

Objectives: At the end of this exercise you shall be able to
- **maintain battery bank.**

Requirements

Tools and Instruments/equipment

- Preventive maintenance schedule
- Log book
- PPE

PROCEDURE

TASK 1: **Perform Preventive maintenance of Battery bank**

1 Verify the following common practice on batteries:
   - Check the tops of the batteries for clean and dry.
   - Check for caps in place and secure.
   - Check all wired connections are secure.
   - Confirm that there are no shelves, hooks, or hangers above the batteries.
   - Check the electrolyte level of every cell in every non-sealed battery. It should always be above the top of the plates, but below the tops of the battery cases.
   - Verify the ventilation systems are functional.
   - Label each battery with a number for the battery and numbers for each cell.

Sample Battery log sheet

Battery bank log sheet

	Date	**Date**	**Date**
Name			
Battery voltage			
Ambient temperature			
Cell 1			
S G			
Electrolyte temperature			
Corrected SoC			
Cell volts			
Water used in litres			
....			
Cell x			
S G			
Electrolyte temperature			
Corrected SoC			
Cell volts			
Water used in litres			
Interconnections OK?			
Battery cases OK?			
Comments			

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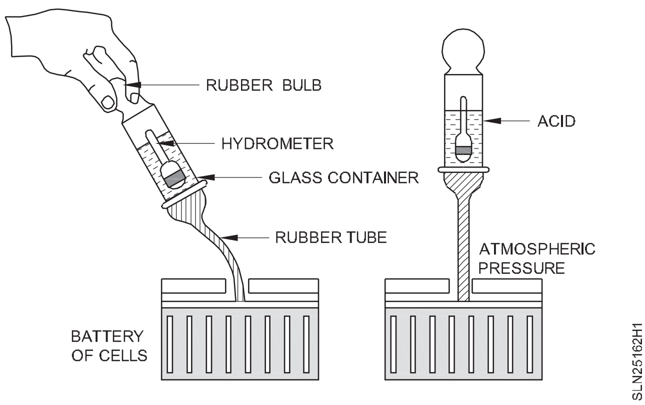
TASK 2: **Check for specific gravity of electrolyte in a battery**

Testing specific gravity (Fig 1)

Fig 1



1 If the battery has been charged within the last four hours, remove the Surface Charge. If the battery has been discharged within the last 15 minutes, wait for at least 15 minutes before testing it.

2 While holding a clean hydrometer vertically and wearing glasses, squeeze the rubber bulb, insert the nozzle into the electrolyte in the cell, and release the bulb. The electrolyte will be sucked up into the barrel or container allowing the float to ride freely. Start with the cell that is closest to the Positive terminal.

3 Squeeze the rubber bulb to release the electrolyte back into the battery's cell.

5 At eye level and with the float steady, read the Specific Gravity at the point the surface of the electrolyte crosses the float markings. The Specific Gravity reading should be between 1.100 and 1.300.

6 Release the electrolyte back into the cell from which it was taken and record the reading. Be sure to avoid spillage.

8 Thoroughly rinse the hydrometer with water after using it.

Specific gravity to corresponding battery state of charge

Electrolyte Temperature (°C)	Specific Gravity Reading and State of Charge				
	SG Reading at 100% SOC	SG Reading at 75% SOC	SG Reading at 50% SOC	SG Reading at 25% SOC	SOC SG Reading at 0% SOC
48.9	1.249	1.209	1.174	1.139	1.104
43.3	1.253	1.213	1.178	1.143	1.106
37.8	1.257	1.217	1.182	1.147	1.112
32.2	1.261	1.221	1.186	1.151	1.116
26.7	1.265	1.225	1.190	1.155	1.120
21.1	1.269	1.229	1.194	1.159	1.124
15.6	1.273	1.233	1.198	1.163	1.128
10.0	1.277	1.237	1.202	1.167	1.132
4.4	1.281	1.241	1.206	1.171	1.136
-1.1	1.285	1.245	1.210	1.175	1.140
-6.7	1.289	1.249	1.214	1.179	1.144
-12.2	1.293	1.253	1.218	1.183	1.148
-17.8	1.297	1.257	1.222	1.187	1.152

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TASK 3: **Perform monthly battery maintenance**

1 Check electrolyte level flooded lead acid batteries.

2 It should always be above the top of the plates, but below the tops of the battery cases.

3 Level monitors are also available in some batteries.

4 Top up if required.

5 Wipe electrolyte residue from the top of the battery top up of electrolyte.

6 Inspect all terminals for corrosion.

7 Check for loosened cable connections.

8 Clean the corroded terminals.

9 Tighten the loose connections.

10 After cleaning, add anti-oxidant/petroleum jelly to exposed wire and terminals.

Cleaning of terminals

11 Operate the system loads from the batteries for five minutes.

12 Turn off the loads.

13 Disconnect the batteries from the rest of the system.

14 Measure the voltage across the terminals of every battery using digital multimeter.

15 Verify in the table to check the open circuit voltages and corresponding states of charge for deep cycle lead acid batteries during this load test.

Overall maintenance check sheet

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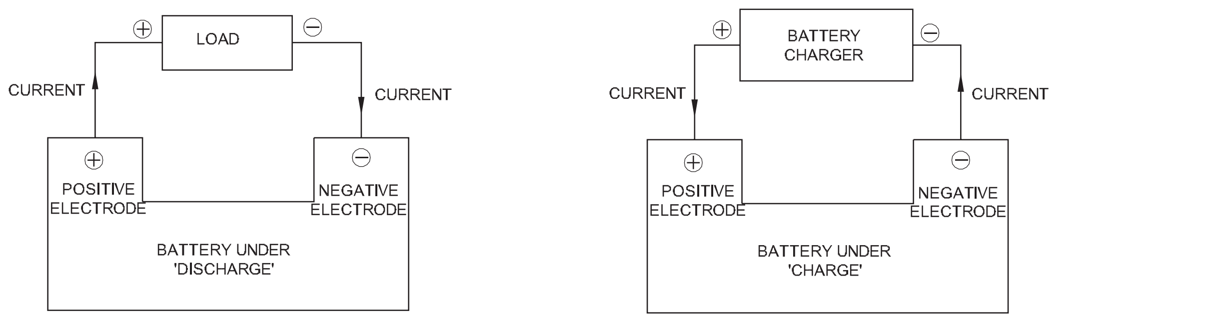
Safety aspects, maintenance, capacity, defects of batteries

Objectives: At the end of this lesson you shall be able to
- **describe the Safety and Maintenance of Battery**
- **explain the Battery Capacity.**

Fig 1



BATTERY MAINTENANCE

attery maintenance is well recognized as an important part of running an efficient and safe warehouse. However, the appropriate procedure for battery maintenance is often overlooked. Performing maintenance in the correct order is just as essential as the maintenance steps themselves when it comes to saving time, extending the lifespan of your battery and protecting your equipment.

Follow the correct maintenance order for your batteries:

1 **Charge battery once it is down to 20% capacity.**

Do not allow battery to drop below 20% power before charging. Discharging the battery's banks too far will harm the battery, permanently impacting the performance and endurance of the battery. It may also overheat, damaging electric circuits to the forklift.

Allow battery to charge to full power uninterrupted. A battery's lifespan is often proportional to the number of charges it receives. Undercharging, charging for short periods of time multiple times a day (this includes quick charging during a lunch break) or charging before battery has discharged more than 50% of its power can all lead to decreased performance rate and a shortened battery life.

2 **Deliver equalizer charge when necessary.**

This is a deliberate overcharge that many batteries require to function properly and efficiently. Chargers for batteries that need this will have button that must be manually pressed to turn on the equalizer charge. If you are uncertain about whether an equalizer charge is necessary, how often to deliver it or how to deliver an equalizer charge, consult your battery/charger manual for further instructions.

During the process of receiving an equalizer charge, batteries will charge for a longer period of time. This extended charge time may lead to overheating, and batteries should be monitored during this process.

3 **Turn power off and allow battery to cool before removing.**

Do not turn power off until after battery has reached 100% power. The battery will run more efficiently throughout the day if it has reached full power. This practice will also decrease the number of times the battery needs to be charged, thus increasing the battery's lifespan.

Battery must cool before being placed back into service or it may overheat, potentially damaging both the battery and electrical circuits

4 **When water/electrolytes are needed, be sure to water battery after charging and disconnecting.**

It is not safe to water battery at any other point in time. Charge before watering as heat of charging can cause changes in water levels (both as evaporation and overflow). If water levels are quite low before charging, you may add a small amount of water to prevent battery overheating during the charging process.

5. **If battery is overfilled, clean battery immediately following overflow.**

Overflow during this process will leak battery acid across the surface of the battery and will cause corrosion if not immediately cleaned. Corrosion and residual acid can deteriorate battery life and cause battery to overheat during charging and use.

6 **Clean battery with a neutralizing detergent solution on a regular basis.**

Surface cleaning will prevent grime build-up, corrosion and resulting problems.

Clean battery after watering. This will save you from repeating a step in the event of an overflow, water drips, etc. Always clean batteries in the designated washing area with the appropriate equipment and specialized neutralizing detergent. The neutralizing agent may be a specified cleaner or a simple sprinkling of baking soda. Whatever is used, this is a vital step that will neutralize any battery acid that has accumulated on the surface and prevent corrosion of the battery and surrounding electrical circuits.

Establishing the appropriate procedure for battery maintenance is a vital part of maintaining a productive and safe work environment. Charts and maintenance schedules are a good way to ensure that batteries receive the appropriate maintenance.

Your satisfaction and safety are very important to us. For battery maintenance needs contact your IBCI representative for options on scheduled maintenance programs to keep your fleet running efficiently and extend your battery life.

Inspect of mounting structure of solar modules

Objectives: At the end of this exercise you shall be able to
- **collect evidences for failure of mount possibilities in existing SPV plant**
- **repair the defective fixtures on module mounting structure.**

Requirements

Tools and Instruments/equipment

- Visit to existing SPV plant
- Solar array log sheet
- Layout of Solar PV array in a SPV plant
- Details of fixtures / MMS installed including dimensions and material
- Method of installation guidelines
- Spare parts
- PPE
- Material handling equipment

PROCEDURE

TASK 1: **Perform inspection of solar array mounting in existing SPV plant**

1 Follow the guidelines as per suggested log sheet.

2 Check for Cleaned modules.

3 Check for array structure.

4 Check for array cabling mechanical.

5 Check for array cabling electrical.

6 Check for array voltage.

7 Check for array current.

Activity done

Sl.No	

Sample solar module mount log sheet for maintenance

Solar array log sheet							
Date	**Name**	**Cleaned modules**	**Array structure OK**	**Array cabling mechanical**	**Array cabling electrical**	**Array output voltage**	**Array output current**
		☐	☐	☐	☐		
		☐	☐	☐	☐		
		☐	☐	☐	☐		
		☐	☐	☐	☐		
		☐	☐	☐	☐		
		☐	☐	☐	☐		
		☐	☐	☐	☐		
		☐	☐	☐	☐		
		☐	☐	☐	☐		

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TASK 2: **Structure of Solar Modules, Procedure of replacement of defective Fixtures**

1 Inspect the Solar PV array for mechanical faults.

2 Check the condition of the array mounting frame for defects such as bolts rusting, bent in connecting frames, loss of Galvanizing done, break or crack in frame, wind bearings, weakened foundation etc.

3 Report even any minor crack as it may lead to major accident damaging the entire structure. Even it may be thrown off in strong winds leading to great loss.

4 Check array mounting bolts to ensure that the frame and modules are firmly secured.

5 Prepare a chart for each defect with suitable suggested remedial action.

6 Tighten loose bolts.

7 Correct minor errors suitably.

8 For major defect like replacement a member of frame derive an action plan since the maintenance activity should not lead damage of structure.

9 Make a replacement member frame as per design originally made found from drawings and choosing right materials and processes.

10 Use proper material handling equipment and support structure for carrying out the remedy.

11 Record your activities done.

Activities done

S.No	List the observation

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Verify the inverters Panels & Devices to IEC standards

Objectives: At the end of this exercise you shall be able to
- **identify the parts/components of solar rooftop PV system**
- **record their IEC and IS standards**
- **verify the standards with IEC/IS.**

Requirements

Tools and Instruments/equipment
- Multi meter -1 No.
- Screw driver -1 No.
- Megger -1 No.

PROCEDURE

1 Identify the various components of solar roof top solar plants

2 Record the specification of each components along with its IEC/IS standards.

3 Confirm their standards conforming with relevant IEC/IS standards.

4 Record your observation.

Sl.no	Name of component	specification along with IEC and IS Standards	Relevant standards as per IEC/IS	Remarks
1	Panel			
2	AJB			
3				
4				
5				
6				

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Defects in Battery, fixture & Replacements Procedure

Objectives: At the end of this lesson you shall be able to
- **brief about capacity of battery**
- **listout common defects in battery**
- **brief about replacement of defective fixtures.**

Battery Capacity

The ampere-hour (AH) capacity is the unit used in specifying the storage capacity of a battery. While a battery that can deliver 10 A for 10 hours can be said to have a capacity of 100 AH, that is not how the rating is determined by the manufacturers. A 100 AH rated battery most likely will not deliver 10 A for 10 hours. Battery manufacturers use a standard method to determine how to rate their batteries. Their rating is based on tests performed over 20 hours with a discharge rate of 1/20 (5%) of the expected capacity of the battery per hour. So a 100 ampere-hour battery is rated to provide 5 A for 20 hours. The efficiency of a battery is different at different discharge rates. When discharging at 5% an hour, the battery's energy is delivered more efficiently than at higher discharge rates. To calculate the 5% discharge rate of a battery, take the manufacturer's ampere-hour rating and divide it by 20. C-rate C-rate is a measure of the rate at which a battery is discharged relative to its maximum capacity. 1C rate means that the discharge current will discharge the entire battery in 1 hour; 0.1C means 10% transfer in one hour, or full transfer in 10 hours; 5C means full transfer in 12 minutes, and so on.

Common Defects in Batteries

1 Short-circuited cell due to failure of the separator between the positive and negative plates.

2 Short-circuited cell or cells due to a build-up of shed plate material below the plates.

3 Sulfation after a long period of disuse in a low- or no-charge state.

4 Corrosion or damage to the positive and negative terminals.

5 Broken internal connections as a result of corrosion.

6 Broken plates due to corrosion and vibration.

7 Damage to the battery case.

8 Low electrolyte (fluid) level.

Procedure of replacement of defective fixtures. (Solar structure)

- Check the defective fixtures.
- Open the defective fixture from original place.
- Change with new fixtures

Verify & assess the earthing & Lighting protection of the rooftop solar system

Objectives: At the end of this exercise you shall be able to
- **to understand the earthing system**
- **to understand assembly of lightning arrestor**
- **to practice erection of the lightning arrestor.**

PROCEDURE

1 Visit actual rooftop solar plants and learn or practice with the help of field executives the system of earthing and the lightning protection.

Note: Instructor and institute authorities should arrange necessary MoU or tie ups with suitable industry stake holders.

2 Record your observation.

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