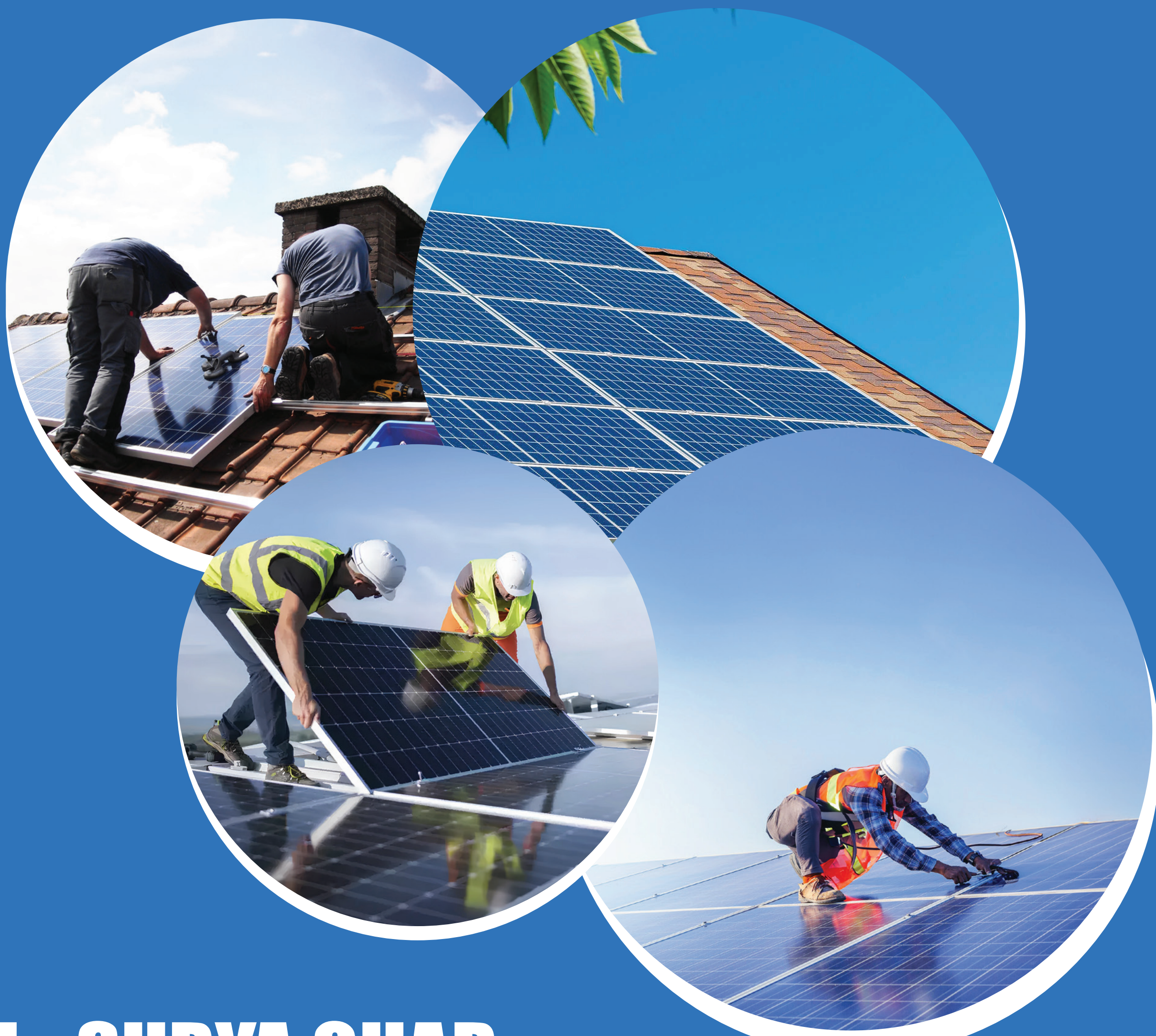
कौशल विकास
और उद्यमशीलता मंत्रालय
MINISTRY OF
SKILL DEVELOPMENT
AND ENTREPRENEURSHIP

MINISTRY OF
NEW AND
RENEWABLE ENERGY
GOVERNMENT OF INDIA

Directorate General of Training

Skill India
कौशल भारत - कुशल भारत

PMKVY
प्रधानमंत्री कौशल विकास योजना



PM - SURYA GHAR : MUFT BIJLI YOJANA

Rooftop Solar PV (Installation & Maintenance) - Trainer

NSQF LEVEL - 4

सत्यमेव जयते

कौशल विकास और उद्यमशीलता मंत्रालय

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ROOFTOP SOLAR PV
(INSTALLATION & MAINTENANCE) - TRAINER

NSQF - 4

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

Sector : Power

Duration : 15 Hours

Trades : Rooftop Solar PV (Installtion & Maintenance) - Trainer (Trade Theory & Trade Practical)- NSQF - 4

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FOREWORD

In our pursuit towards sustainable energy solutions, the Government of India has embarked on a transformative initiative through the PM Surya Ghar: Muft Bijli Yojana. This visionary program aims not only to increase the adoption of solar rooftop systems but also to empower communities by enabling them to generate their own electricity. As we strive to install 1 crore rooftops across residential sectors, the need for skilled technicians becomes paramount.

These technicians will form the backbone of the initiative, ensuring qualityinstallations and reliable maintenance, thereby enhancing consumer satisfaction. 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 Trainer Manual, designed under NSQF - 4 for the Power sector, represents a significant milestone in vocational education. It provides comprehensive guidance to trainers who will impart essential skills to our future solar technicians. 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 Trainer Manual will be instrumental in shaping the future of rooftop solar installation and maintenance in India. I encourage all trainers 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)-Trainer. This Trainer Manual, designed under NSQF - 4 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 Trainer Manual has been meticulously crafted to provide comprehensive guidance to trainers who will impart essential skills to 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 Trainer Manual. 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 trainers 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.

TRAINER COURSE INFORMATION

GENERAL

During the 15 hours duration of **Rooftop Solar PV (Installation & Maintenance) -Trainer** course, a candidate is trained on professional skills & knowledge related to job role. The Broad components covered during the course are given below:

The course will equip candidates to effectively demonstrate the installation and maintenance activities of solar rooftop systems. The curriculum emphasizes best practices for the installation, testing, operation and maintenance of rooftop solar panels to ensure optimal performance and longevity.

COURSE STRUCTURE

Table below depicts the distribution of training hours across various course elements:

S.No.	Course Element	Notional Training Hours
1	Professional Skill (Trade Practical)	10
2	Professional Knowledge (Trade Theory)	05
	Total	15

ASSESSMENT & CERTIFICATION

The trainee will be tested for his skill, knowledge and attitude through summative assessment at the end of the course as notified by the DGT from time to time.

The assessment will be conducted by Controller of examinations, DGT as per the guidelines. There will be a computer based summative test of 30 marks (15 questions each of 2 marks) with 30 minutes duration or as being notified by DGT from time to time.

The learning outcome and assessment criteria will be basis for setting question papers for final assessment.

TRAINEE COURSE INFORMATION

GENERAL

During the 60 hours duration of **Rooftop Solar PV (Installation & Maintenance)** trade a candidate is trained on professional Skill and professional Knowledge. The components covered related to the certificate course are categorized below.

The trainees learn about characteristics of Photovoltaic cells and modules, Batteries, Charge Controllers. Learns connections and testing of Solar Panel, Charge Controller, Battery Bank and Inverter. Prepare bill of material for rooftop solar projects. Installation, testing and commissioning of Rooftop Solar system. The Trainee learns about preventive and breakdown maintenance of rooftop solar system.

COURSE STRUCTURE

Table below depicts the distribution of training hours across various course elements:

S.No.	Course Element	Notional Training Hours
1	Professional Skill (Trade Practical)	30
2	Professional Knowledge (Trade Theory)	15
3	On the Job Training (OJT)	
	Total	15

ASSESSMENT & CERTIFICATION

The trainee will be tested for his skill, knowledge and attitude through summative assessment at the end of the course as notified by the DGT from time to time.

The assessment will be conducted by Controller of examinations, DGT as per the guidelines. There will be a computer based summative test of 30 marks (15 questions each of 2 marks) with 30 minutes duration or as being notified by DGT from time to time.

The learning outcome and assessment criteria will be basis for setting question papers for final assessment.

GUIDE LINES FOR CONDUCTING EFFECTIVE TRAINING

As technology advances and workplace strategies evolve, there comes a need for professionals to align with these changes in terms of knowledge and skills. One of the best ways to enhance knowledge and skills is through training.

In order to conduct effective training following are the key points to be considered for the conduct the theory and demonstrations.

The theory has to be effectively involves several steps and considerations to ensure that students understand and engage with the material. Here are some guidelines to help you conduct a successful theory class.

Preparation

1 Know your material

- Thoroughly understand the theory you will be teaching
- Prepare notes, examples, and explanations in advance.

2 Create a Lesson Plan

- Outline the topics to be covered in the class.
- Allocate time for each section.
- Plan for breaks if the class is long

3 Gather Resources

- Prepare any handout slides, or multimedia resources you will use
- Ensure all equipment (e.g., projector, whiteboard) is working.

4 Set Learning Objectives

- Define what students should know or be able to do by the end of the class.
- Share these objectives with the students at the beginning of the session.

Delivery

1 Start with a Hook

- Begin with an interesting fact, question, or problem to capture attention.
- Relate the topic to real-world applications or current events.

2 Clear and Structured Presentation

- Present the material in a logical order.
- Use clear, concise language
- Break down complex concepts into manageable parts.

3 Engage Students

- Encourage participation through questions and discussions.
- Use different teaching methods (e.g., lectures, group work, case studies).

4 Use Visual Aids

- Incorporate diagrams, charts, and videos to illustrate key points.
- Ensure that visual aids are clear and relevant

5 Check for understanding

- Regularly ask questions to gauge comprehension.
- Be open to questions and provide thorough explanations.

Interaction

1 Encourage Interaction

- Foster a supportive and inclusive classroom environment.
- Encourage students to share their thoughts and questions.

2 Be approachable

- Show enthusiasm and interest in the subject.
- Be patient and approachable, making students feel comfortable asking for help.

2 Provide Examples and Analogies

- Use real-life examples and analogies to explain abstract concepts.
- Relate theory to practical applications.

Assessment and Feedback

1 Assess Understanding

- Use quizzes, short tests, or in-class activities to assess comprehension.
- Provide immediate feedback on these assessments.

2 Solicit Feedback

- Ask for feedback on your teaching methods and materials.
- Be open to suggestions and willing to adjust your approach.

3 Summarize Key Points

- At the end of the class, summarize the main points covered.
- Highlight the most important takeaways.

4 Provide Follow-up

- Offer additional resources for students who want to develop deeper.
- Be available for questions after class or during office hours.

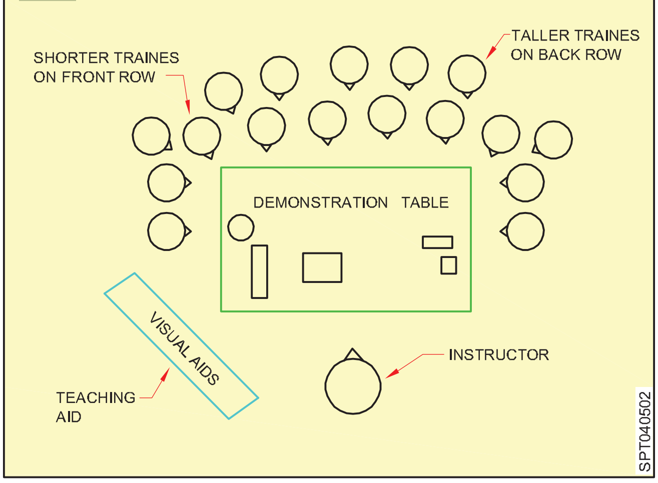
Conducting a successful demonstration for a skill requires careful planning, clear communication, and engagement with your audience.

1 Following are the Key points for conducting effective demonstration

- In order to ensure the success of demonstration, the instructor must prepare the plan minutely and very seriously, collection of material related to the demonstration needs to be well-planned in advance.

- The demonstrator must rehearse the activity several times before the real demonstrations for a smooth sequencing of the steps as well as accuracy of the result.
- Arrange the learners around the demonstration area of at a distance where they will be able to observe fully what is going on as shown in Fig 1.

Fig 1



- Arrange the tools, instruments, raw materials etc. required for the demo on the table in sequential order systematically according to the step of its use as per the demo plan.
- The place must be quite in order to sustain the observes attention and interest during the activity; Remove irrelevant items from demo area if any, to avoid distractions.
- During the demonstration, the clear language should be used so that learners may understand the instructional step easily.
- They are allowed to take down short notes or record some data which may be analysed afterwards.
- The instructor can use various teaching aids lime models, chalkboard, graphs etc. during demonstration. It helps learning easier, and quicker for permanent learning.
- After the demonstration learners should be involved to do imitate the simple or complex part of the step of activity demonstrated by the instructor.
- Depending on the kind of demonstration to be undertaken, pointers or questions may be used to be undertaken, pointers or questions may be used to focus learner's attention and avoid distractions.

i **Points to be considered while planning to teach skill**

- Be specific in the objectives as to what you expect from the learner to learn or to acquire proficiency in the skill.
- The main points to be explained during the demonstration should be listed out in order.
- Availability of the time according to the steps to be covered.
- Check in advance the materials, tools, equipments, etc., to ensure that they are in good working condition.

- Check up the space availablility for the demonstration, so as to accommodate the learners to observe the demonstration properly.

ii Points to be followed during the demonstration

- We should use such tools and equipments during the demonstration that will be used by the trainees for their practice after the demonstration.
- Observe all safety precautions and emphasize their importance.
- Perform the demonstration step by step in a sequential order.
- Provide immediate participation by the learner.
- Adopt only one method of demonstration at a time.
- Clear the doubts if any in the minds of the learners.

iii Points to be followed after the demonstration

- Providing materials for immediate practice under your close supervision.
- Correcting the doubts of the learners or wrong method of doing work during your supervision.
- Paying more attention to individual differences if necessary, re-demonstration has to be done to weaker trainees.
- Check/Observe the progress of each trainee in learning the skill.
- Let the trainees know the mistakes committed by them and explain.
- Show interest in each individual.

Shop talk

Shop talk is also another type of teaching method. But by this precise information very much relevant to develop skills only presented to the learners at shop floor situations.

Regarding the teaching cycle, shop talk can be differentiated according to the purpose they serve in the teaching cycle. They are

- Introductory shop talk
- Related shop talk
- Final shop talk as shown in Fig 5.

Types of Shop talk

Introduction Shop talk

- Introduction into a new skill
- Precise description of the skill (Working steps and drawing of the exercise).
- Skill related knowledge is taught (Skill information working steps and drawing of the exercise)
- Demonstration of materials, tools machines.
- Demonstration of skills.

ACKNOWLEDGEMENT

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) - Trainer (Trade Theory & Trade Practical) - NSQF- 4** 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.

CONTENTS

Power 1.1.01
Rooftop Solar PV (I & M) - Trainer - Sun 's Path and Irradiance

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

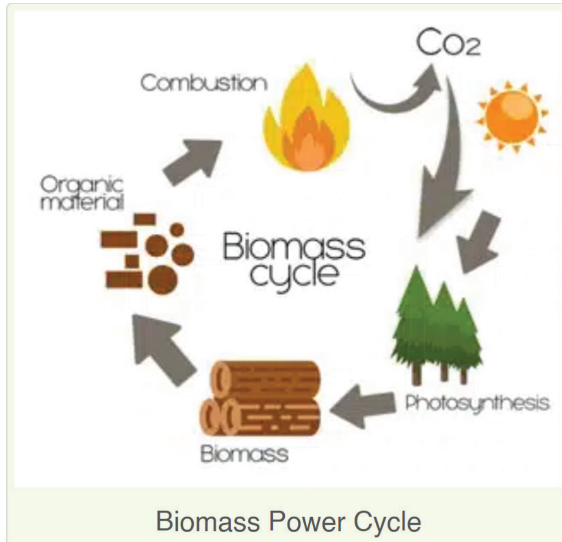
Hydro Energy: Converting energy of water flow into electricity. (Fig 3)

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)

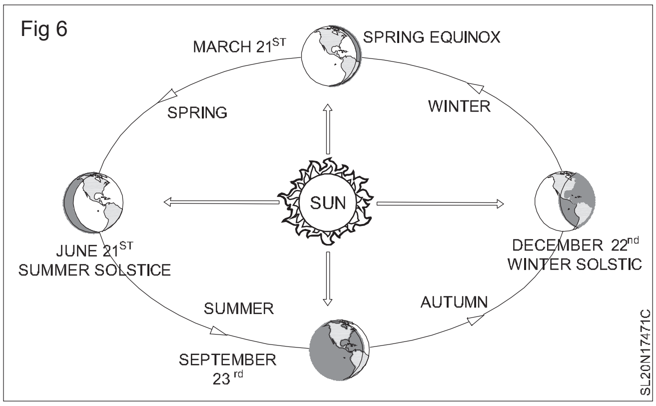


Fig 6

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)

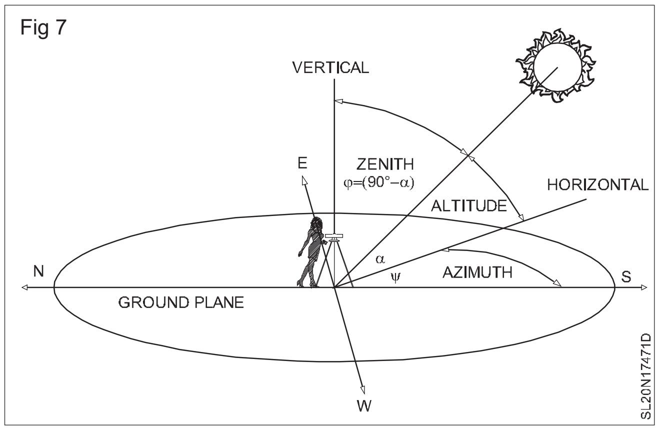


Fig 7

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)

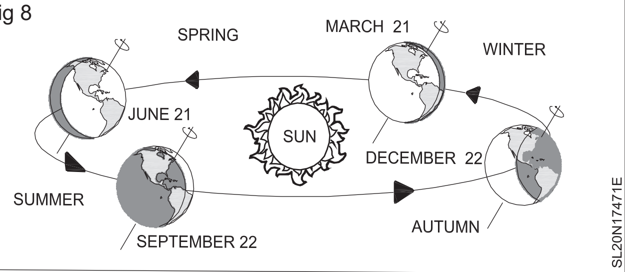
Zenith angle of the sun is defined as the angle measured from vertical downward.

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.

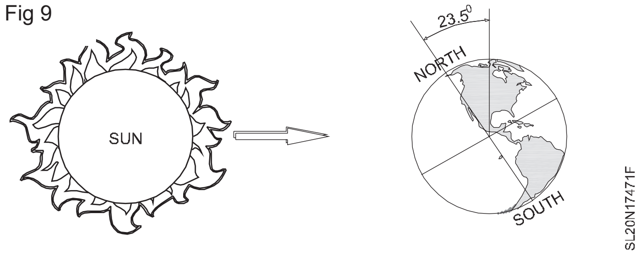
The 23.5º inclination of the earth’s axis also has an influence as can be seen from Illustration above. The all-important factor is the change of the angle of incidence during the different times of the day.

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

Fig 9



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)

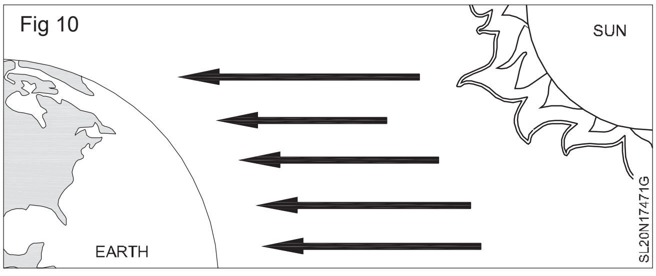
The all-important factor is the change of the angle of incidence during the different times of the day and throughout the year for a given location on earth. Based on these Solar collectors’ installation varies place to place.

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
- **measure solar intensity**
- **use solar irradiance meter**

Requirements

Trainer has to arrange the required tools, equipments and materials for this exercise.

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

Sun's Path

Objective: At the end of this lesson you shall be able to
- **describe the equation time & solar constant**
- **define irrediance 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.

Fig 1

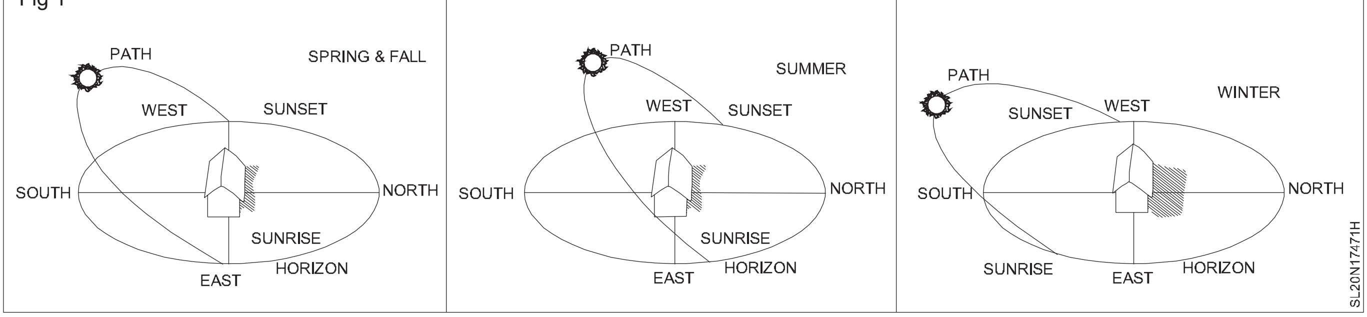
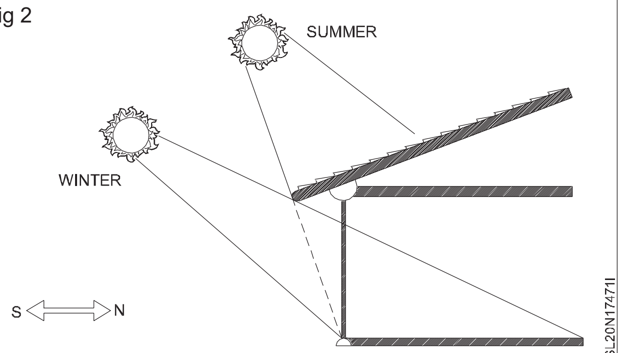


Fig 2

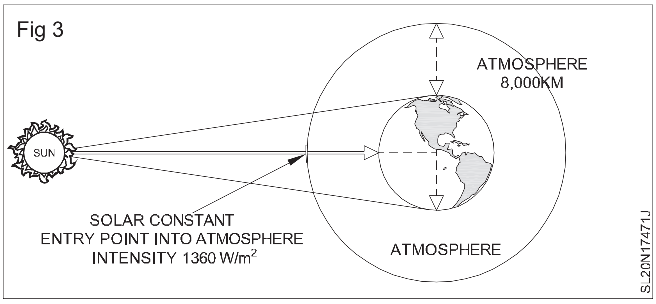


Solar constant is the rate at which energy reaches the earth's surface from the sun, usually taken to be 1,388 watts per square meter.

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.

Fig 3



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.

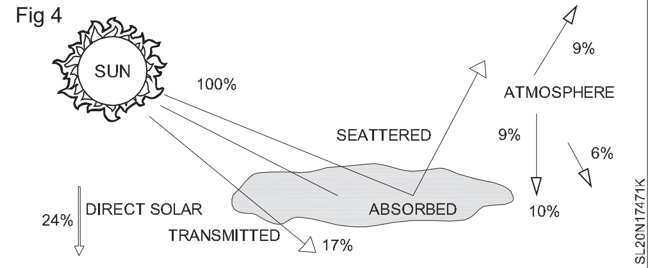
Diffuse Horizontal Irradiance (DHI) is the amount of radiation received per unit area by a surface (not subject to any shade or shadow) that does not arrive on a direct path from the sun, but has been scattered by molecules and particles in the atmosphere and comes equally from all directions

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).

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).

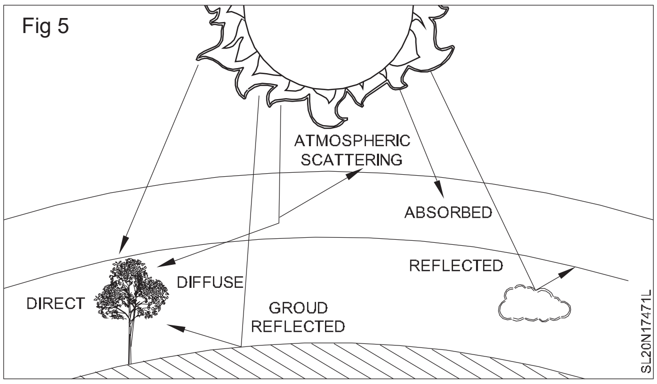
Minimum GHI – 1000 kwh/m^2

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

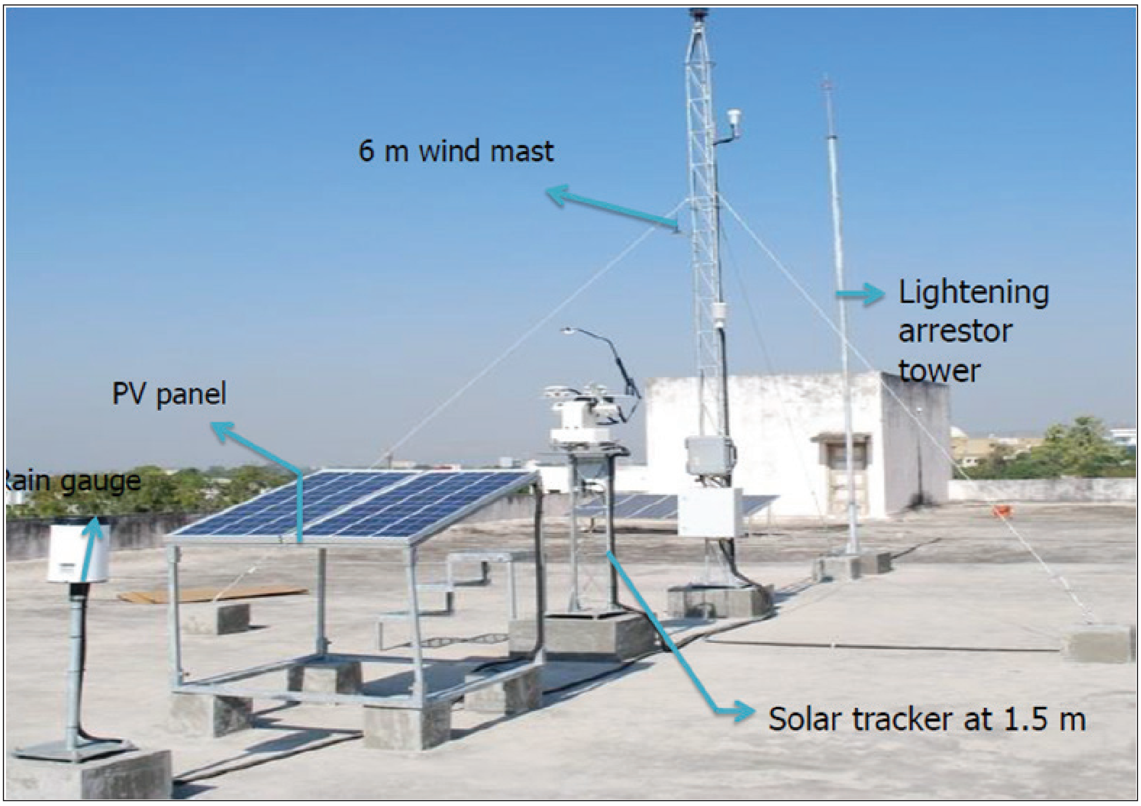
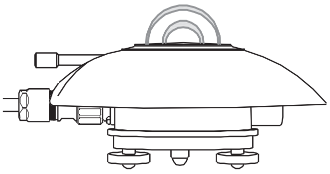
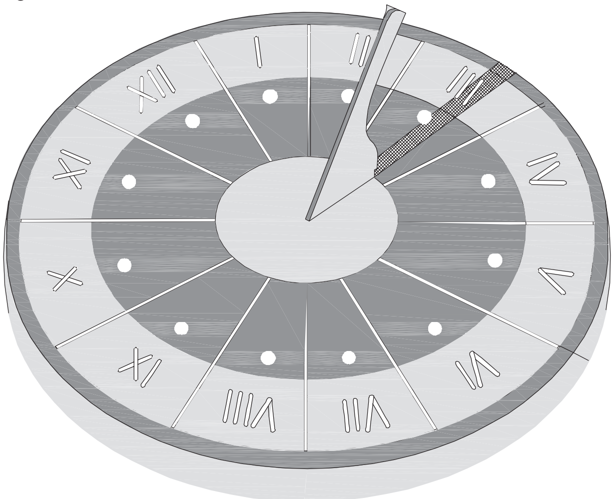


Fig 7



SL20N17471N

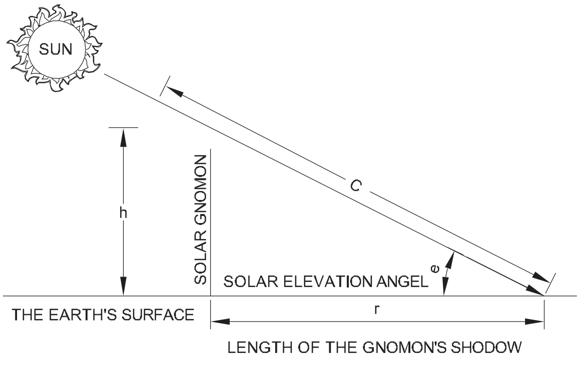
Fig 8



SL20N17471O

Sunlight spectrum. (Fig 9)

Fig 9



SL20N17471P

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.

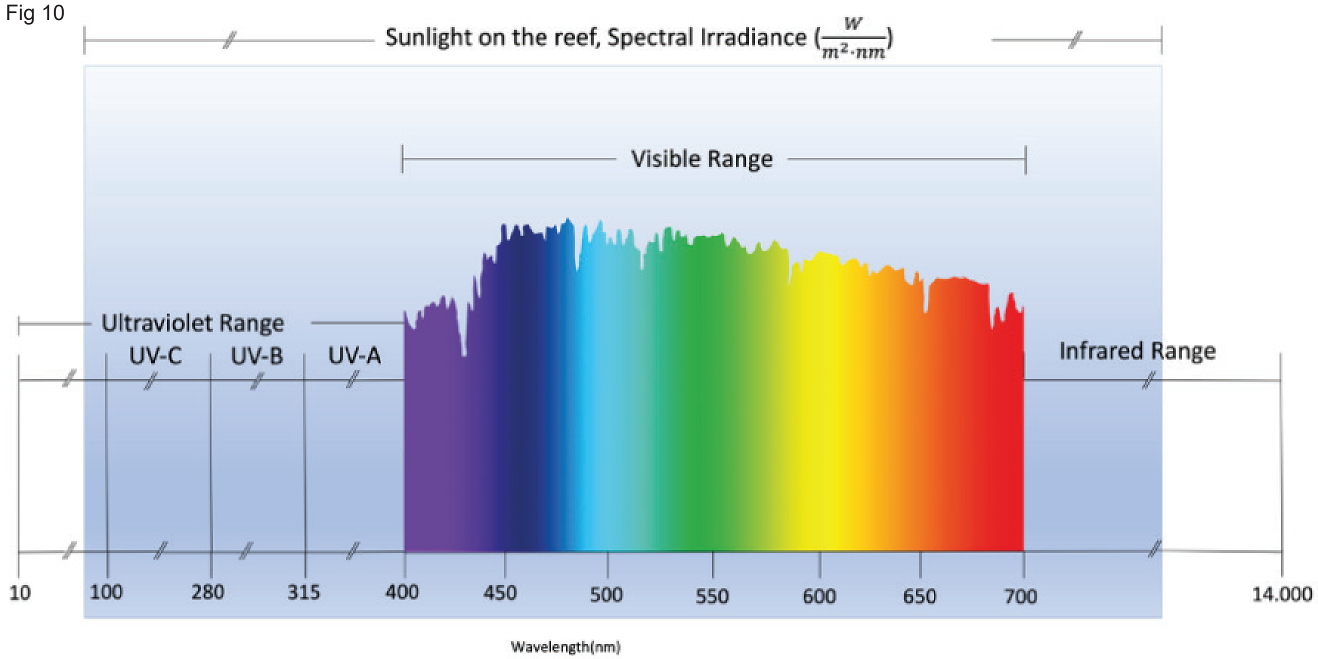
Solar Electrical Application

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



Analyze shadow effect on incident solar radiation and find out contributors

Objective: At the end of this exercise you shall be able to
- **understand shadow effect in different places**

Requirements

Trainer has to arrange the required tools, equipments and materials for this exercise

PROCEDURE

1 Take a Pyranometer or solar 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 Use opaque, transparent, semitransparent and reflecting plates to create shadow effects.

5 Measure the Solar irradiance under different shadow.

6 Record your observations.

7 Discuss on the results.

No shadow effect		Shadow effects							
Inside room	Outside room	Using opaque		Using transparent plate		Using semitransparent plate		Using reflecting plate	
		Inside room	Outside room	Inside room	Outside room	Inside room	Outside room	Inside room	Outside room

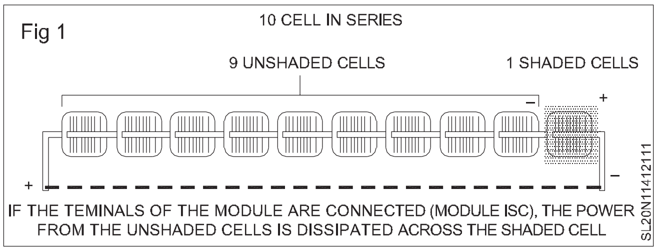
Observations:

Hot spot on modules and method to detect them at site

Objective: At the end of this lesson you shall be able to
- **acquire specific information on installation in fixed or variable angle of inclination of solar panels.**

Hot spot heating occurs in a PV module when its operating current exceeds the reduced short-circuit current (Isc) of a shadowed or faulty cell or group of cells. When such a condition occurs, the affected cell or group of cells is forced into reverse bias and dissipates power, which can cause local overheating.

Fig 1 Hot spot in a group of cells



One shaded cell in a string reduces the current through the good cells, causing the good cells to produce higher voltages that can often reverse bias the bad cell.It is a typical degradation mode in PV modules.

Causes of shading might include Bird or Leaf, Dirt or Snow, Building Shadow etc

Common Causes of Hotspots due to manufacturing process:

Cell Manufacture

- Incomplete edge isolation
- Crystalline defects intersecting junction
- Metal-decorated cracks
- Overfiring: pn junction "punchthrough"
- Scribeline shunts- incomplete removal or redeposition
- Metal particles & bridges on backside
- Print alignment errors

Module Manufacture

- High resistance or "cold" solder points
- Current mismatch between cells

Hotspot defects are known to cause reliability problems in both thin-film and conventional c-Si modules. Detection of hotspots in completed modules can identify potential failures before the module is installed in the field.

Module Measurement Method

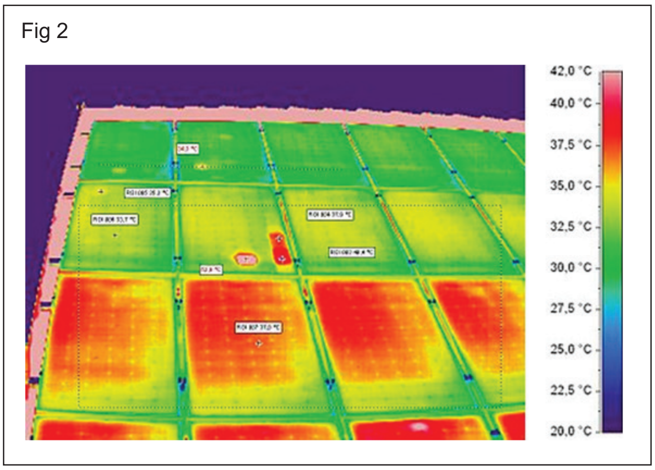
Quick detection is possible with infrared camera, performing thermography imaging. A hot spot can also lead to browning in the glass plane of the PV module, if it is present for long time. Thus, the hot spot can become visible for the human eye.

To prevent emergence of hot spots, the different causes have to be considered. Cell mismatches are prevented by measuring the maximum power point of produced cells and then combining similar cells into one module. To ensure a homogeneous irradiation on the module, shadow-casting structures are considered and avoided during PV plant construction. And to avoid severe damage from dirt, periodic cleaning is necessary. Finally, bypass diodes are integrated in PV modules to shortcut a cell string, if the voltage drop becomes too high.

Thermography is the method used to measure hotspots based on Lock-in & Time-resolved techniques. This uses a Camera like LWIR (8-12 micron) which has speed of ~20 seconds / module or above. R&D is going on for 30ms- 5 min.

Using this technique, hotspots may beconclusively identified before or during fieldinstallation with IRIS inspection machinescapable of >25 modules per hour. The techniqueworks in ambient light and directly measures thelocal heating due to defects.

Fig 2 Thermography image of a PV module with visible hot spot in centered cell



Measure insulation resistance and wet leakage current solar panel

Objective: At the end of this exercise you shall be able to
- **measure about the insulation resistance and leakage current of a solar PV panel.**

Requirements

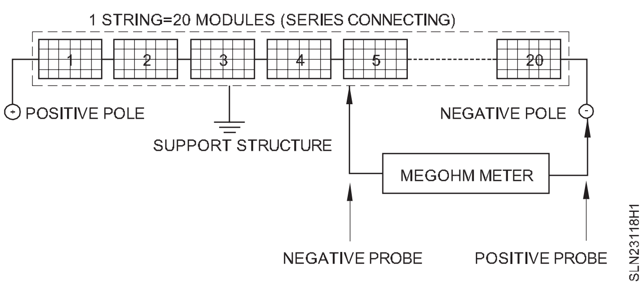
Trainer has to arrange the required tools, equipments and materials for this exercise.

PROCEDURE

TASK 1: **Measure insulation resistance**

1 Select the megger according to the system voltage
2 Wrap the solar panel under test with thick block cloth or sheet
3 Short the positive and negative terminates of the solar panel under test
4 Connect the megger between the shorted terminal and the grounded support structure as shown in the figure below.
5 Set the megger to the system voltage.
6 Operate the megger for 2 minutes without the irradiance on solar panel
7 Measure the insulation resistance value and record.
8 Measure and Record the insulation resistance of each solar panels of the spring.
9 Repeat the test under hot and humid climatic conditions to compare the results.
10 Record the observations.

Fig 1



Observation:

S.No.	Panel No.	Insulation resistance value in meg ohm	
		Dry	Wet

Possible results

The average value of the insulation resistance of a PV module an average value can be assumed:

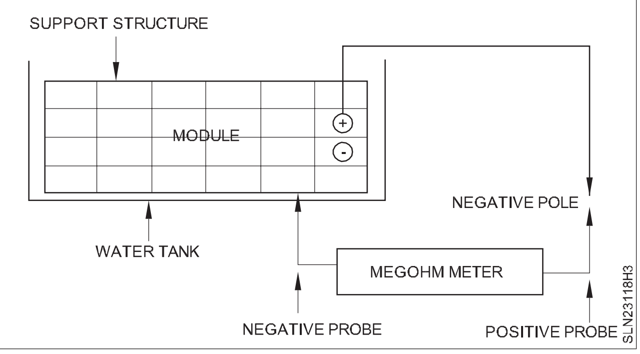
- for thin-film PV modules approximately 40 Meg ohm per PV module.
- for polycrystalline and mono-crystalline PV modules approximately 50 Meg ohm per PV module.

— — — — — — — —

TASK 2: **Measure wet leakage current of a PV module**

Note: The leakage current test result is normally presented in the insulation resistance form for the easier testing and monitoring.

Fig 1



1 Put the PV module inside the water tank.

Seal the junction box to prevent the entering water.

2 Short the positive and negative terminator of a solar panel

3 Connect the positive probe of the megger to the negative pole of the module. (Fig 1)

4 Connect the negative probe of the megger to the support structure.

5 Operate the megger for 2 minutes without the irradiance on solar panel.

6 Measure the insulation resistance to estimate wet leakage current.

7 Record the observation.

8 Measure the wet league current of each solar panel of the string.

— — — — — — — —

Perform bypass diode test - P_{max} at STC and P_{max} at low irradiance

Objective: At the end of this exercise you shall be able to
- **perform testing of solar panel for status of bypass diode.**

Requirements

Trainer has to arrange the required tools, equipments and materials for this exercise.

PROCEDURE

TASK 1: **Test the bypass diode at STC of a solar panel by measuring P_{max}**

1 Set the conditions as per STC (Normally 1000 W/m^2, 25°C, AM1: or 1.5 at the angle of incidence at 0°).

2 Connect the solar panel for performing test for I-V curve plotting.

3 Measure simultaneously all parameters (P_{max}, V_{oc}, I_{sc}, V_m, I_m).

4 Perform 'Batch measurements' of open-circuit voltage, short-circuit current, and bypass route resistance for panels in array.

5 Discover open faults.

6 Discover short-circuit faults.

7 Find out the difference between the measured value and the reference value.

8 Record the observation.

9 Compare your findings with the results.

Observation

STC (Normally 1000 W/m^2, 25°C, AM1: or 1.5 at the angle of incidence of 0°

Tested parameter	Specified value	Measured value
P_{max}		
V_{oc}		
I_{sc}		
V_m		
I_m		

No.of cells per panel:

No.of bypass diodes:

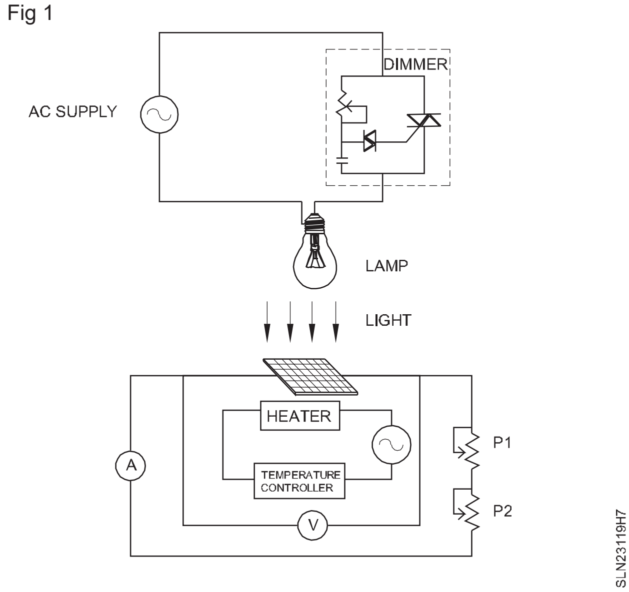
Conditions of Bypass diodes:

Reasons for difference in specified and measured values:

Conclusions:

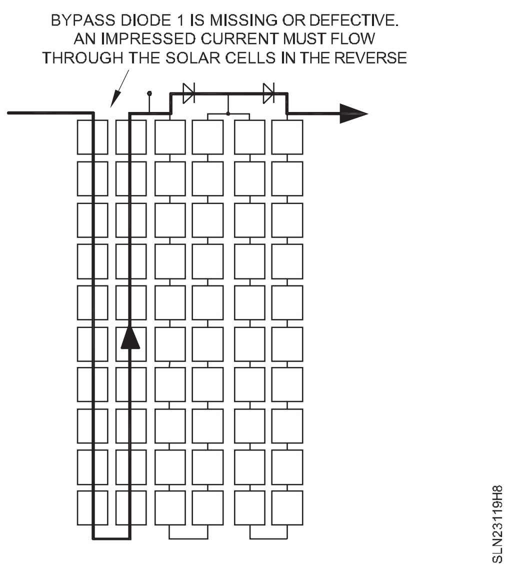
Standard set up required for setting STC for conducting I-V & P-V curves tests. (Fig 1)

Fig 1



Effect of open bypass diode on solar panel. (Fig 2)

Fig 2



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TASK 2: **Test the bypass diode at low irradiance on a solar panel by measuring P_{max}**

1 Repeat task 1 above with low irradiance and measure the same values.

2 Record your observations and inference from the testing.

Observations

Irradiance: 200 W/m²

Tested parameter	Measured value
P_{max}	
V_{oc}	
I_{sc}	
V_m	
I_m	

No. of cells per panel:

No. of bypass diodes:

Conditions of Bypass diodes:

Reasons for difference in specified and measured values:

Conclusions:

Note: Commercially in the field batch testing of bypass diodes can be done by using bypass diode tester and defective ones can be screened out. Since open diodes can result in hot spots thermography methods using drone cameras are also in use to expedite the testing for mega projects.

— — — — — — — —

Safety related to solar panel installation

Objective: At the end of this lesson you shall be able to
- **acquire specific information on installation in fixed or variable angle of inclination of solar panels.**

When we plan to get the solar panels installed on rooftop and power the home or office, there are many things to be considered. Apart from how much power each panel can produce how many panels are needed, what size, and how well they'll work with your rooftop, and also we have to consider the best direction for solar panels to face.

The direction the solar panels face can be a major factor in how much energy the rooftop solar system produces. Solar panel positioning based on the rate structures at different utility companies is to be discussed.

The traditional advice is to position solar panels to be north – facing or south-facing, depending on the location in southern or northern hemisphere respectively. This is because, for those living in the Northern Hemisphere, the sun is always along the southern part of the sky as we complete our yearly orbit around it.

Similarly, for those living in the Southern Hemisphere, the sun is always along the northern part of the sky as we complete our yearly orbit around it.

This being the case, the general best practice to date has always been to position solar panels facing south for places in northern hemisphere in order to capture the maximum amount of sunlight overall.

While the pitch or angle is important to your solar panel's efficiency, what truly matters most is the direction your home faces. Pointing your solar panels in the direction with the most direct sunlight is imperative to producing the most energy.

For homes in the northern hemisphere, panels should face true south. For southern hemisphere homes, your solar panels should face true north. If your southern facing roof has too much shade due to surrounding trees or buildings, you still have options. The eastern sun in the morning and western sun in the afternoon will still provide a good amount of energy for your solar panels to use. If that's the case, keep in mind that the solar panels you install may not produce the full wattage they say they will.

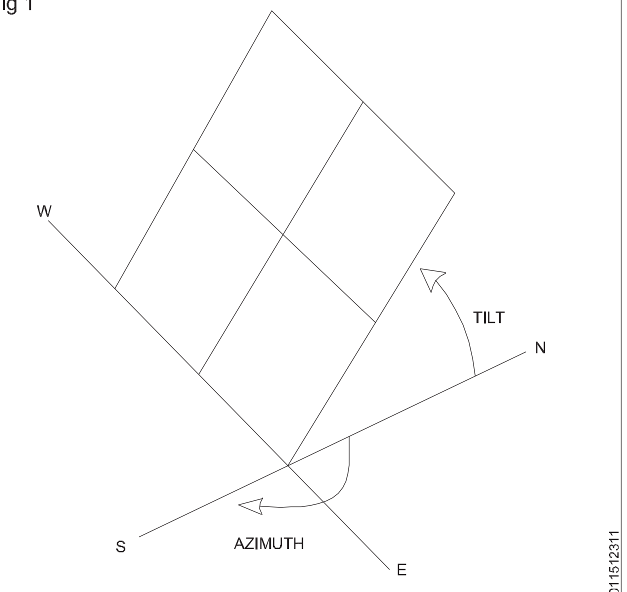
However, you will still notice a significant decrease in the amount of energy you need from your city's power grid—and therefore a lower electricity bill each month.

Generally, it's common knowledge in the solar industry that these south-facing panels should be tilted between a 30- and 40-degree angle. But, this angle varies and is just about equal to the latitude of your home (how far north you are in relation to the equator).

Fig 1 PV array tilt and azimuth

The reasoning behind this angle specificity is to ensure sunlight hits panels at a perpendicular angle, which produces the most energy.

Fig 1



PV ARRAY FACING SOUTH AT FIXED TILT

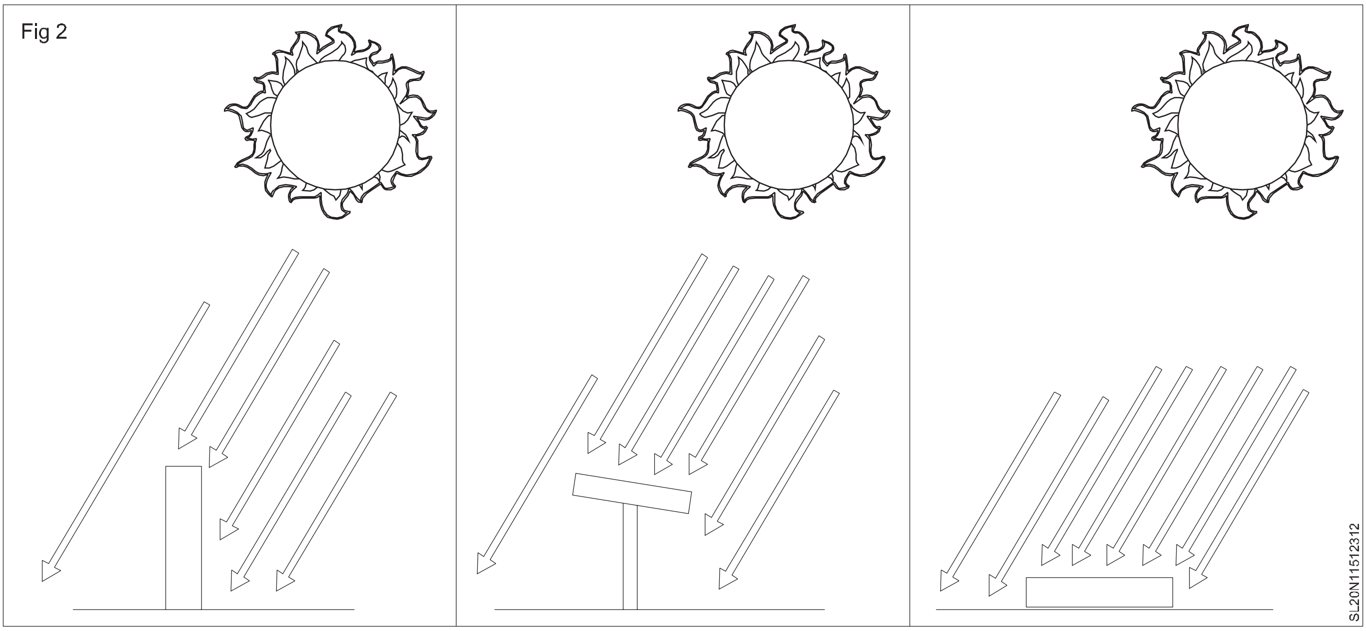
Some rooftops slope just about perfectly in a way that lets installers secure the panels flush against them and still be at a great angle for capturing the sun's energy. Other rooftops might be steeper, or some others are flat. Depending on the type of roof you have, there are different mounting systems to help position your solar modules so that they can produce at their best. The angle of slope of the roof to be considered and compared with the tilt requirement and accordingly the mounting system's dimensions are calculated.

Fig 2 Effect of Tilt angle while mounting Solar panel

Different Solar Panel Sizes and Dimensions

The average dimensions for solar panels are 65 inches (1651 mm) long by 39 inches (991 mm) wide. This is more common standard.

Some manufacturer's solar panels may be smaller, making them a great choice if we have a smaller home or don't need to convert as much solar energy into power for the customer. First Solar's panels are a good option if we have more space to hold solar panels— like a large roof— or plan on installing solar panels on the land instead of the roof.



The depth dimensions vary a little more widely than the length and width because they are impacted by the base of the solar panels and any mounting equipment installed underneath the solar panels.

The reasoning behind having most solar panels be about the same size is that it creates an industry standard. That means that you'll know what to expect, in terms of potential power, from a solar panel of a certain size. This also makes it easier to know how many solar panels you will need, or how many solar panels fit on your roof.

Horizontal vs. Vertical Solar Panel Installation

Solar panels are mounted to the roof using the rafters in the roof as anchors for the solar panel mounts—generally utilizing steel bolts to attach mounts to the home. Solar installation companies mount their solar panels on rails attached to the steel bolts, specifically for added security and stability. There are a few reasons why most solar panels are installed vertically:

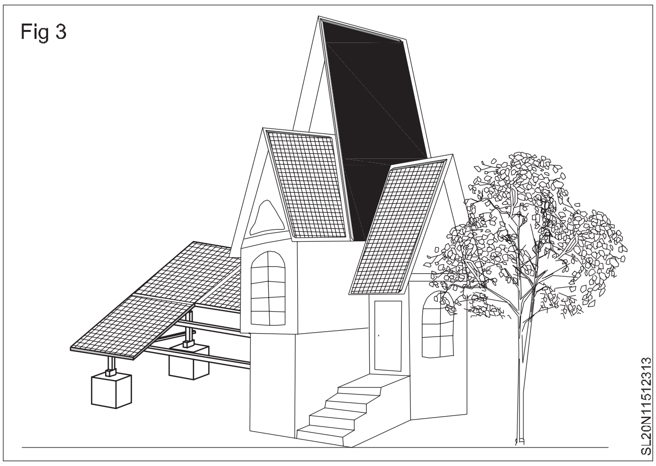
- Fewer rails are required to mount a solar panel vertically instead of horizontally.
- It is easier to have a continuous row of solar panels if they are installed vertically.
- The size of solar panels makes them well suited to be installed vertically on most roofs.

Of course, not every home—or roof—is designed the same. Depending on the climate, the roof's construction, and the solar energy needs, horizontal solar panel installation may be the right choice for the home or office.

The amount of direct sunlight could impact the direction in which your solar panels are installed. Depending on how your home is situated, your solar panels may actually receive more sunlight if they are installed vertically.

It's important to note that horizontal solar panels require about twice as many railings and mountings to be installed. However, the benefits of having more efficient solar panels outweigh the cost of using twice as many railings to install the solar panels. The Solar technician as an installer must discuss the options before planning the mounting systems.

Fig 3 Horizontal mounting of Solar panels



If horizontal solar panel installation is considered the best option, then we need not worry about taking any extra steps for their maintenance, because it requires the same care as vertically installed solar panels. In fact, depending on your home's location and the amount of sunlight it receives, the pitch (angle) and direction of your horizontal solar panels will be nearly identical to what they would be if oriented vertically.

It is also important to note that you don't have to install all of your solar panels in one direction/orientation. Panel orientation also has no effect on the number of panels that can be installed. Homeowners have the option to install them using differing orientations, depending on the shape of your roof. However, it is more efficient to have a consecutive block of solar panels installed using the same orientation— either vertical or horizontal. If there is a break in your roof, or you have room for one more solar panel, then the solar technician can install the solar panel to fit the space.

There are several factors in your control when it comes to finding the ideal pitch/angle for your solar panels. Solar technician shall recommend using the latitude of the site's location as the degree of tilt. For example, the latitude of Delhi, India is 28.7 degrees North, so the tilt of the solar panels would be 28 degrees. Whereas, if you live in Bangalore, Karnataka, India your latitude is 12.9716 degrees North, meaning your solar panels would be at an angle 13 degrees. As most roofs are not flat, the solar technician will factor the pitch/angle of the roof into the equation.

Fixed or Tracking Solar Panels

There are two types of solar panel mounting options: fixed or tracking solar panels. Fixed panels are stationary and remain at the same pitch throughout the day and year. Tracking panels live up to their name— they track the sun as it moves through the sky each day. Depending on the pitch of the roof, tracking panels may not be an option for certain home. In that case, the solar technician must work to find the optimal pitch/angle for the solar panels. (More details later)

Measure ground continuity, impulse voltage, reverse current and partial discharge

Objective: At the end of this exercise you shall be able to
- **check the quality of the encapsulation of the solar PV panel.**

Requirements

Trainer has to arrange the required tools, equipments and materials for this exercise.

PROCEDURE

TASK 1: **Check the PV system for ground faults by measuring the voltage (Check Ground continuity)**

Only use measuring devices with a DC input voltage range of 600 V or higher.

1 Disconnect the inverter from any voltage sources (see the inverter installation manual). (Danger to life due to high voltages).

2 Select a string.

3 Measure the voltage between the positive terminal and the ground potential (PE).

4 Measure the voltage between the negative terminal and the ground potential (PE).

5 Measure the voltage between the positive and negative terminals.

6 Check each string in the PV system for ground faults.

— — — — — — — —

TASK 2: **Perform impulse voltage test on a solar PV panel**

1 Connect the positive and negative terminals of the solar panel and extend the connection outward.

2 Wrap the solar panel, completely covered with one or two layers of 0.001-in. or 0.0015-in. thick copper foil so the total buildup is 0.002 in. to 0.003 in.

This foil is not available in widths large enough to cover the module, so the pieces are joined together using conductive glue.

3 Connect the negative lead of the impulse voltage tester to the foil after the module is successfully wrapped,

4 Connect the positive lead of the impulse voltage tester to the shorted output terminals of the module.

5 The impulse voltage is based on the maximum voltage of the module.

For systems with a maximum voltage from 100 V to 150 V, Class A modules will see a 2,500-V peak impulse while Class B modules will see 1,500-V peak.

6 Set the impulse tester to deliver a 1.2-μs x 50-μs pulse and apply impulses.

7 Repeat the test three times

8 Then conduct three more times with the polarity reversed.

9 Disconnect and unwrap the module.

10 Perform visual inspection on the module tested.

If there is no tracking or breakdown and the module survives the visual inspection, the test is considered passed.

11 Record your observation.

— — — — — — — —

TASK 3: **Measure reverse current in a string**

1 Connect the solar panels in three strings with equal number of panels per string.

2 Connect Ammeters in series with each string.

3 Connect One ammeter in the output of the combiner box (consider rating of ammeter is greater than 3 times of Im of solar panel.

4 Connect Voltmeter in the output of the combiner box.

5 Measure the readings when luminance is around 1000 W/m^2.

6 Record the observations.

7 Select any string and create short circuit on output terminals of one or more modules.

8 Measure the currents simultaneously and quickly and their direction.

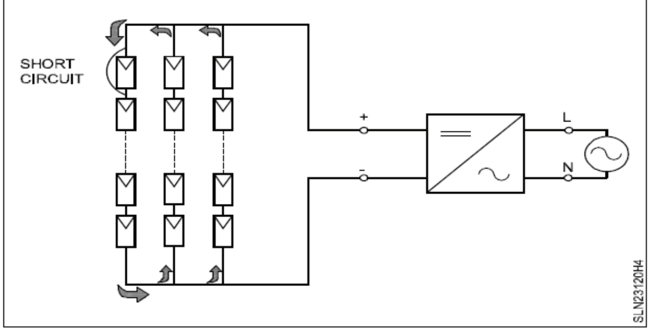
9 Remove the shorts immediately to avoid the damage to cells.

You have observed the reverse current from other strings flowing into string which has lost modules due to short.

10 Record your observations.

Flow of reverse current (Fig 2)

Fig 2



Observations

S.No.	Voltage	Current	Direction

Note: To prevent the reverse current into any string, we use blocking diodes or fuses in series with the each string in a group of strings connected in parallel. This can be tested in above task.

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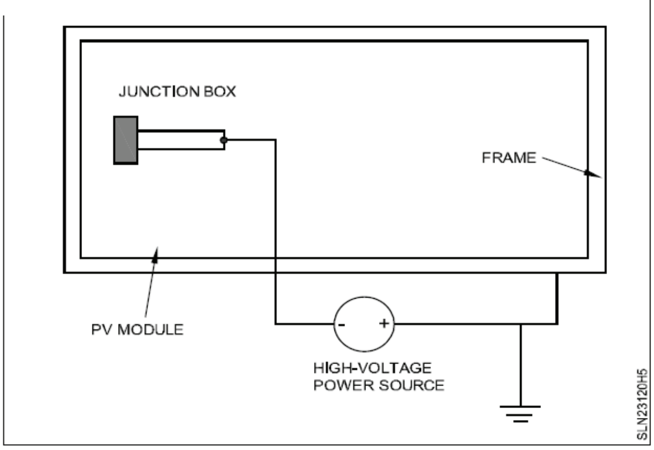
TASK 4: **Measure the partial discharge**

Schematic diagram for PD test (Fig 1)

Fig 1



1 Apply starting from a value below the maximum system voltage, up to the point at which partial discharge takes place (inception voltage), the test voltage shall be further increased by 10 %.

2 Lower the voltage to the point at which the partial discharge extinction voltage is reached.

3 The extinction voltage shall be considered to be reached once the charge intensity has dropped to a value of 1 pC. This voltage shall be measured with accuracy better than 5 %.

4 The partial discharge extinction voltage may be influenced by environmental conditions. These influences are taken into account by a basic safety factor F1 of 1,2.

5 The hysteresis factor is reduced to 1. The additional safety factor for reinforced insulation F3 = 1,25 is required for safety class A. The initial value of the test voltage is therefore 1,5 VOC (system voltage given by the module manufacturer).

Note: The solid insulation has passed the test if the mean value minus the standard deviation of the partial discharge extinction voltage is greater than 1.5 times the given maximum system voltage.

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Safety at rooftop

Objectives: At the end of this lesson you shall be able to
- **analyze the issues based on type of roof and its age etc.**

A well-conducted assessment of the roof requires developers to answer the following questions:

- Is the roof suitable for installation of solar PV?
- Is the solar resource high enough?
- How much installed capacity could fit on the roof?
- How much energy could that system deliver?

A rooftop solar PV installation comprises of PV panels assembled in arrays, mounting frames to support the panels and secure them to the roof, wiring, inverters, and other components depending on the type of installation. The roof site must be able to accommodate all of these components, which requires examining the following aspects:

Accessibility: The roof must be accessible to carry out installation and maintenance. It must be possible to lift the solar system components onto the roof and for personnel to physically access the site to install and maintain the system.

Roof configuration: A roof plan can help quantify the roof area available for the PV power plant. The plan should indicate the location (including longitude and latitude), height, and slope of the roof itself, as well as any additional structures present on the roof. Identify any possible conflicts in usage of the roof, (just a possibility!) such as a helipad or communication antennae, and contact relevant bodies to ascertain if any special permission is required to use and/or alter usage of the roof space.

Roof materials and structure: For existing buildings, first find out when the roof would need replacement. If a roof is nearing the end of its life span, it is more cost-effective to install the rooftop PV system once the new roof is in place. It is also easier to integrate a system into the design of a new roof.

.**Aesthetics:** Check that the solar PV modules would not negatively affect the aesthetics of the building. From street level, solar modules will be more visible on a sloped roof than on a flat roof. If they will be seen, find out if there are any local building restrictions preventing a visible rooftop solar PV installation. With growing support for the use of renewable energy, guidelines are being modified, where necessary, to allow rooftop solar installations.

Roof leasing: If planning to lease the roof space to the owner of the rooftop PV system, consult a legal advisor who would be able to confirm whether that type of arrangement is permissible.

Electrical load: Obtain the current and expected electrical load of the building or facility. Should the load be comparable to or less than the electricity generated through solar PV, plan a smaller system or plan to use the excess energy—either store the energy in batteries, send it to another building within the facility, or feed it into the grid.

Demonstrate hot spot on modules through audio visual aids

Objectives: At the end of this exercise you shall be able to
- **trouble shoot a solar plant reported to generate much lesser than installed capacity, by taking thermal image of the array**
- **interpret the findings from thermal image with defects of the solar panel and take remedial actions.**

Requirements
Trainer has to arrange the required tools, equipments and materials for this exercise

PROCEDURE

Verify the performance of thermal camera for the features discussed here

1 Study thoroughly about the digital thermal imager/ camera for its utility, handling and methods of fault finding in field.

2 Carry the thermal camera in early morning or in the evening.

3 Visit the solar PV plant.

4 Capture pictures of the solar panels in operation.

5 Transfer images to the computer tag them.

6 Analyse the defective modules and tabulate probable reasons.

7 Suggest remedies for the defective panels.

8 Record your observations and prepare a report.

Possible damages

Nature of defect noticed by image (shape and the location of their thermal patterns)	Indications (Identification of defects)
An entire module warmer than others	it is open circuited
On the scale of a module, a patchwork pattern	the whole module is short-circuited
One cell clearly warmer than the others	a shadowing effect or a defective or delaminated cell
A warmer part of a cell indicates	the presence of cracks
A pointed heating	a partly shadowed area due to a bird dropping (e.g.)

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Customer requirement to install solar PV systems

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

Demonstrate mounting grouting and installation of Solar system

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

Requirements
Trainer has to arrange the required tools, equipments and materials for this exercise.

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.

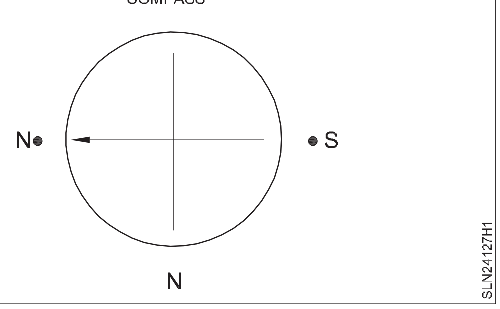
3 Collect all elements of Pillar mount on the roof top.

4 Collect all tools on the rooftop.

5 Use compass and mark true north and south poles.

Marking magnetic poles (Fig 1)

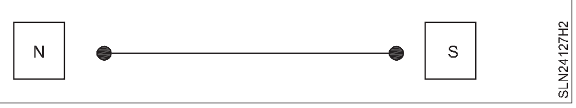
Fig 1



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.

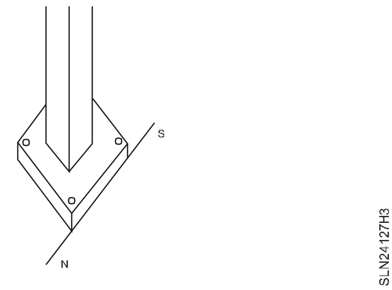
11 Mark the holes of second base on ceiling.

12 Remove the pillar mounts.

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

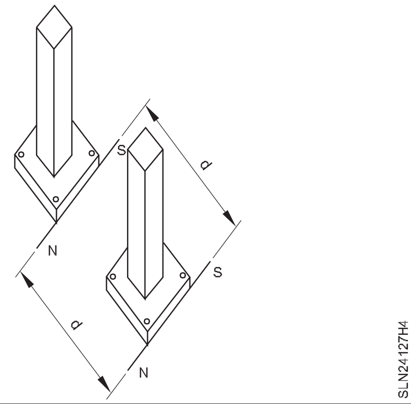
Marking Pillar base (Fig 3)

Fig 3



Marking second pillar parallel to first (Fig 4)

Fig 4



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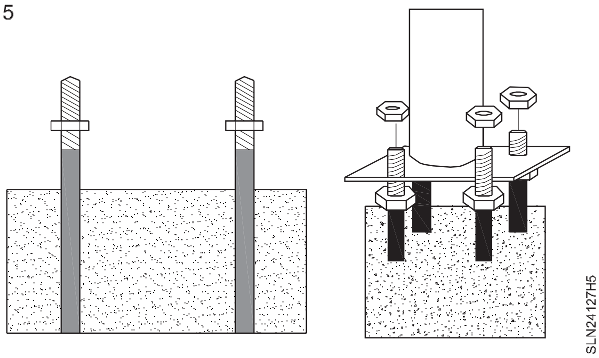
TASK 2: **Drilling on rooftop for pillar mount base**

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.

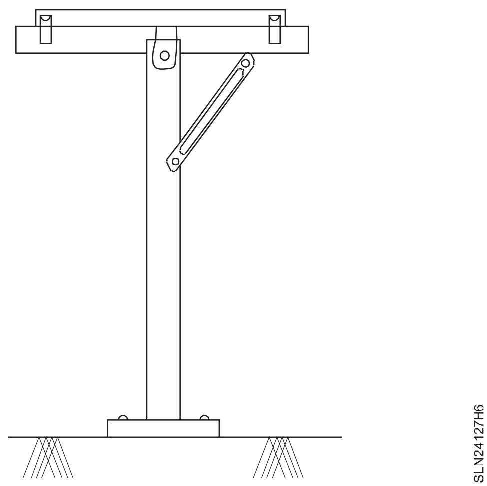
2 Assemble angle adjustment link rod between Pillar and swinging rod.

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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Importance of Earthing

Objectives: At the end of this lesson you shall be able to
- **explain the reasons for system and equipment earthing**
- **define the terminology related to earthing**
- **explain the procedure for reducing the resistance of earth electrodes to an acceptable value.**

Earthing:

Connecting the non-conductive metal body/parts of an electrical equipment and system to the earth through a low resistance conductor is called as **earthing**.

Earthing of an electrical installation can be brought under two major categories.

- System earthing
- Equipment earthing

System earthing: Earthing associated with current-carrying conductors is normally essential to the security of the system, and is generally known as system earthing.

System earthing is done at generating stations and substations.

The purpose of system earthing is to:

- maintain the ground at zero reference potential, thereby ensuring that the voltage on each live conductor is restricted to such a value with respect to the potential of the general mass of the earth as is consistent with the level of the insulation applied
- protect the system when any fault occurs against which earthing is designed to give protection, by making the protective gear to operate and make the faulty portion of the plant harmless.

In most cases such operation involves isolation of the faulty main or plant by circuit breakers or fuses. Earthing may not give protection against faults which are not essentially earth faults.

Equipment earthing: Earthing of non-current carrying metal work and conductor which is essential for the safety of human life, animals and property is generally known as equipment earthing.

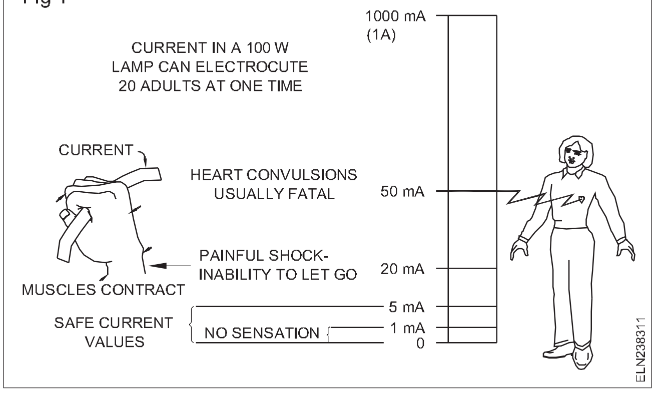
Terminology

> **Trainees can be instructed to refer the international electro technical commission (IEC 60364-5-54) website for the standard safety rules related with earthing installation for the further details.**

Dead: Dead' means at or about earth potential and disconnected from any live system.

Earth: A connection to the general mass of earth by means of an earth electrode. An object is said to be `earthed' when it is electrically connected to an earth electrode; and a conductor is said to be `solidly earthed' when it is electrically connected to an earth electrode.

Fig 1



Earth-continuity conductor (ECC): The conductor which connect the non-conductive metal part/body of an electrical system/equipment to the earth electrode is called as earth contained conductor.

Earth electrode: A metal plate, pipe or other conductor electrically connected to the general mass of the earth.

Earth fault: Live portion of an electrical system getting accidentally connected to earth.

Leakage current: A current of relatively small value, which passes through the insulation of conductive parts/ wire.

Step potential: The maximum value of the potential difference possible of being shunted by a human body between two accessible points on the ground separated by the distance of one step, which may be assumed to be one metre.

Touch potential: The maximum value of potential difference between a point on the ground and a point touched by a person.

Reasons for earthing: The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock. The reason for having a properly earthed metal part in an electrical installation is to provide a low resistance discharge path for earth leakage currents which would otherwise prove injurious or fatal to a person or animal touching the metal part.

An electric shock is dangerous only when the current through the body exceeds beyond a certain milliampere value. In general, any current flow through the body beyond 5 milliamperes is considered dangerous. Fig 1 shows the magnitude of current and its effect.

However, the degree of danger is also dependent on the time during which it flows, and resistance of the body. In human beings, the resistance between hand and hand or between hand and foot can easily be as low as 400 ohms under certain conditions. Table 1 shows the body resistance at specified areas of contact.

Table 1

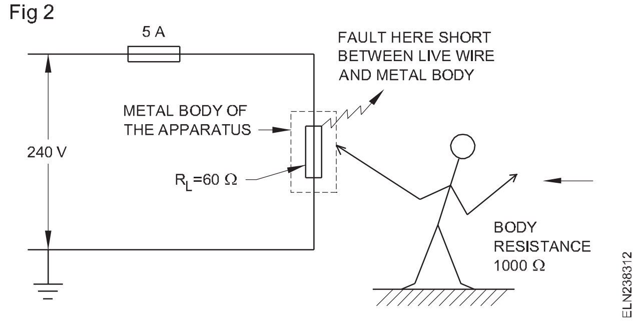
Skin conditon or area	Resistance value
Dry skin	100,000 to 600,000 ohms
Wet skin	1,000 ohms
Internal body-hand	400 to 600 ohms to foot
Ear to ear	about 100 ohms

CASE 1: **Metal body of apparatus when it is not earthed**

Let us consider a 240V AC circuit connected to an apparatus having a load resistance of 60 ohms. Assume that the defective insulation of cable makes the metal body live and the metal body is not earthed.

When a person, whose body resistance is 1000 ohms, comes in contact with the metal body of the apparatus which is at 240V, a leakage current may pass through the body of the person (Fig 2).

Fig 2



The value of current through the body = $\frac{V}{R_{Body}}$

$= \frac{240}{1000}$ = 0.24 amps or 240 milliamps.

This current, as can be judged from Table 1, is highly dangerous, and might prove to be fatal. On the other hand, the 5 amps fuse in the circuit will not blow for this additional leakage current of 240 milliamperes. As such the metal body will have 240V supply and may electrocute any person touching it.

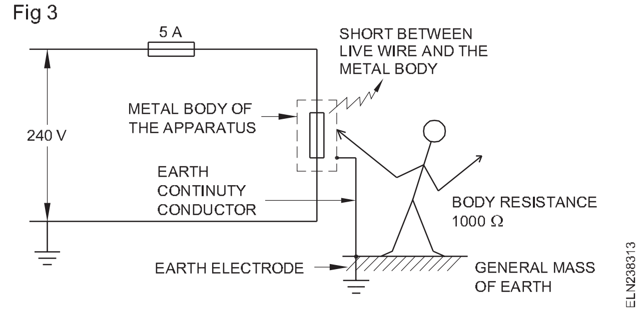
CASE 2: **Metal body of apparatus when earthed**

In case the metal body of the apparatus is earthed (Fig 3), the moment the metal body comes in contact with the live wire, a higher amount of leakage current will flow through the metal body to earth.

Assuming that the sum of the resistance of the main cable, metal body, earth continuity conductor and the general mass of earth is to the tune of 10 ohms

the leakage current = $\frac{V}{R_{Total}}$ = 240/10 = 24 amps.

Fig 3



This leakage current is 4.8 times higher than the fuse rating, and, hence, the fuse will blow and disconnect the supply from the mains. The person will not get a shock due to two reasons. Before the fuse operates, the metal body and earth are in the same zero potential, and across the person, there is no difference of potential. Within a short (milli-seconds) time the fuse blows to open the defective circuit, provided the earth circuit resistance is sufficiently low.

By studying the above two cases, it is clear that a properly earthed metal body eliminates the shock hazards to persons and also avoids fire hazards in the system by blowing the fuse quickly in case of ground faults.

Types of earth electrodes

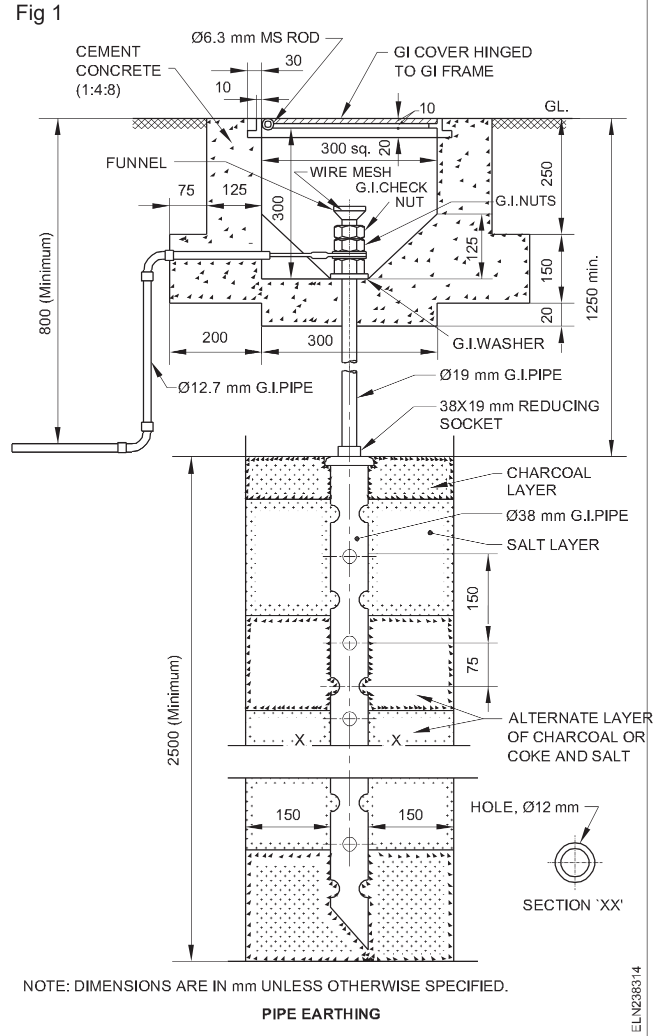
Rod and pipe electrodes: These electrodes shall be made of metal rod or pipe having a clean surface not covered by paint, enamel or other poorly conducting material.

Rod electrodes of steel or galvanised iron shall be at least 16 mm in diameter, and those of copper shall be at least 12.5 mm in diameter.

Earthing installation in solar PV system

Objectives: At the end of this lesson you shall be able to
- **explain pipe earthing**
- **explain plate earthing**
- **explain the methods of reducing earth resistance.**

Fig 1



PIPE EARTHING

Pipe electrodes shall not be smaller than 38 mm internal diameter, if made of galvanised iron or steel, and 100 mm internal diameter if made of cast iron.

Electrodes shall, as far as practicable, be embedded in earth below the permanent moisture level.

The length of the rod and pipe electrodes shall not be less than 2.5 m.

Except where rock is encountered, pipes and rods shall be driven to a depth of atleast 2.5 m. Where rock is encountered at a depth of less than 2.5 m, the electrodes may be buried, inclined to the vertical. In this case too, the length of the electrodes shall be atleast 2.5 m, and the inclination not more than 30^0 from the vertical.

Deeply driven pipes and rods are, however, effective where the soil resistivity decreases with depth or where a sub-stratum of low resistivity occurs at a depth greater than those to which rods and pipes are normally driven.

Pipes or rods, as far as possible, shall be of one piece.

For deeply driven rods, joints between sections shall be made by means of a screwed coupling, which should not be of a greater diameter than that of the rods which it connects together.

Plate electrodes (Fig 2): Plate electrodes, when made of galvanised iron or steel, shall not be less than 6.3 mm in thickness. Plate electrodes of copper shall be not less than 3.15 mm in thickness. Plate electrodes shall be of a size, at least 60 cm by 60 cm.

Plate electrodes shall be buried such that the top edge is at a depth not less than 1.5 m from the surface of the ground.

Fig 2

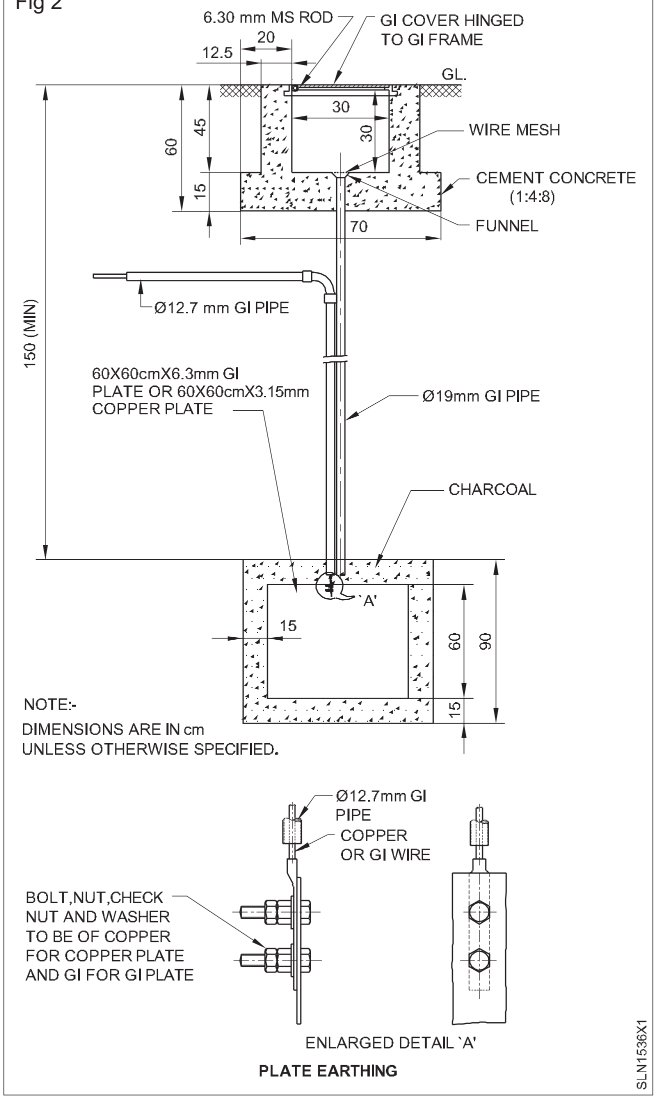


PLATE EARTHING

Where the resistance of one plate electrode is higher than the required value, two or more plates shall be used in parallel. In such a case, the two plates shall be separated from each other by not less than 8.0 m.

Plates shall preferably be set vertically.

Use of plate electrodes is recommended only where the current-carrying capacity is the prime consideration; for example, in generating stations and substations.

If necessary, plate electrodes shall have a galvanized iron water pipe buried vertically and adjacent to the electrode. One end of the pipe shall be atl east 5 cm above the surface of the ground, and it need not be more than 10 cm. The internal diameter of the pipe shall be at least 5 cm and need not be more than 10 cm. The length of pipe, if under the earth's surface, shall be such that it should be able to reach the centre of the plate. In no case, however, shall it be more than the depth of the bottom edge of the plate.

Methods of reducing the resistance of an earth electrode to an acceptable value:

To achieve efficient operation of the protective devices, under fault condition the earth electrode resistance should be lower than an acceptable value which could be calculated from circuit details.

However, the earth electrode resistance is found higher in rocky or sandy areas where moisture is very low.

The following methods are suggested to bring down the earth electrode resistance to an acceptable value.

1 After installing the rod or pipe or plate in earth, the earth pit (the area surrounding the rod / pipe / plate) should be treated with layers of coke and common salt to get a lower value of earth resistance.

2 Pouring water in the earth pit at repeated intervals lowers the earth electrode resistance.

3 Connecting a number of earth electrodes in parallel reduces the earth electrode resistance. (Distance between two adjacent electrodes shall be not less than twice the length of the electrodes.)

4 Soldering the earth connections or using non-ferrous clamps lowers the earth electrode resistance.

5 Avoiding rust in the earth electrode connections lowers the earth electrode resistance.

Demonstrate Earthing Installation

Objectives: At the end of this exercise you shall be able to
- **prepare the pipe for earthing**
- **dig the pit in the ground**
- **install the earth pipe and test it.**

Requirements
Trainer has to arrange the required tools, equipments and materials for this exercise.

PROCEDURE

1 Collect G.I.pipes and the accessories.

2 Make a slant cut of 30° in the 38mm dia. G.I.pipe to have sharp edge as shown in Fig 1.

3 Make threads in the other end of 38mm dia. G.I.pipe to a length of 25mm.

4 Make threads in both ends of 19mm dia. G.I.pipe to a length of 25mm on one side and 75mm on the other side.

5 Fabricate the 38mm and 19mm dia. G.I. pipes as shown in Fig 1.

6 Select an earth pit site at least 1.5 meters away from the building foundation.

An earth electrode should not be installed in proximity to a metal fence to avoid the possibility of the fence becoming live. If the metal fence is unavoidable, it should be earthed.

7 Dig an earth pit of dimensions 1 m width x 1 m breadth x 3.75 m depth.

The depth given here is the minimum recommended. However, the depth may be increased till moist soil is reached.

8 Place the fabricated pipe in an upright position as shown in Fig 1 and position the pipe with the help of bamboo sticks.

9 Place the wooden box around the pipe and fill it to a height of about 15cm with charcoal, and fill the surrounding outer space of the box with soil.

It is difficult to dig a pit 150mm square. A pit of dimension 1 metre square is therefore suggested to be dug. The area sufficient to be filled with salt and charcoal is about 150mm square. Hence fill the surrounding extra area with the soil which was taken out earlier.

10 Lift and place the wooden box above the coke layer. Fill up with salt to a height of about 15cm and to an area of 150 x 150mm area around the pipe.

Fill up the surrounding area with soil.

11 Repeat the above steps 10 and 11 up to 2.5 meters as shown in Fig 1.

12 Place the G.I.pipe 12.7 mm dia. meter with G.I. bends in proper position for E.C.C. connection.

13 Prepare the concrete mixture and build the structure as shown in Fig 1.

14 Fix the G.I. cover also.

Atleast allow one day for curing the concrete structure. Pour water every 2 hours. (A wetted gunny sack will hold the moisture for several hours.)

15 Insert the G.I.wire No.8 SWG through the 12.7mm dia. G.I.pipe.

The size of the earth wire depends upon the incoming supply cable size.

16 Use the ladle and the blowlamp and melt the solder.

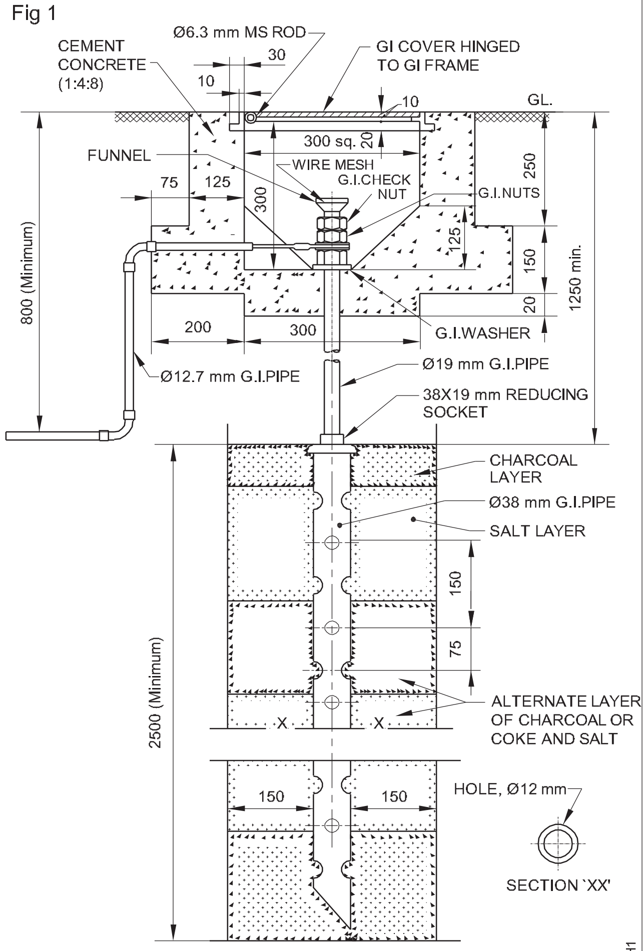
17 Solder the lug in the G.I. wire.

18 Insert the lug in the 19mm dia. G.I.pipe and tighten it with the G.I.nut and check-nut.

19 Pour three or four buckets of water through the funnel.

Allow an hour for the water to be absorbed in the earth.

Fig 1



NOTE: DIMENSIONS ARE IN mm UNLESS OTHERWISE SPECIFIED.

PIPE EARTHING

20 Test the earth electrode resistance with an earth Megger.

The earth continuity conductor (E.C.C.) should not be connected to the earth electrode while measuring the earth electrode resistance.)

21 Enter the value of the earth electrode resistance in Column 5 of Table 1. Fill up the other particulars also. The acceptable value of the earth electrode resistance has been given earlier. Check the value if it.

22 Check the value of the earth resistance is found higher than the acceptable value, make one more pipe earth electrode at a distance of 8 meters from the earlier one and connect both of them in parallel.

23 Measure the earth electrode value and enter it in Column 6 of Table 1.

The second reading with two electrodes will be approximately half the first reading which was taken with one electrode. The measured value should be within the recommended value.

Table - 1

S.no	Date	Climate	Earth Electrode Location	Earth Resistance in Ohms		Remarks
				Single	Double	
1	2	3	4	5	6	7

Wire (cable) requirement/ estimation

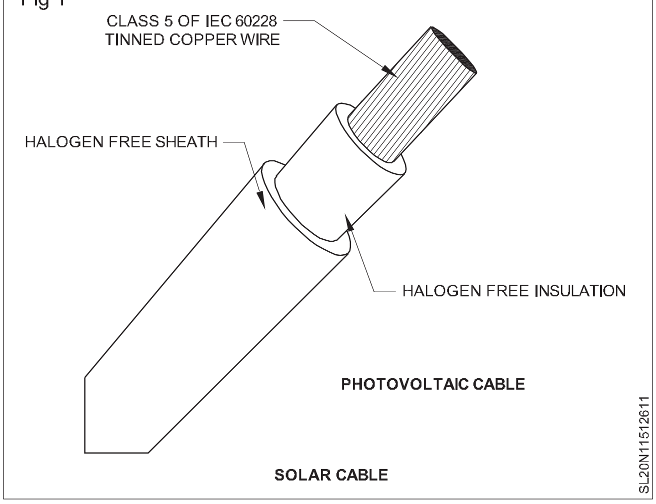
Objectives: At the end of this lesson you shall be able to
- **elaborate on selection of solar cables**
- **brief about size and current ratings of wire.**

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.

Fig 1



SOLAR CABLE

The following is an introduction to correct sizing and terminology.

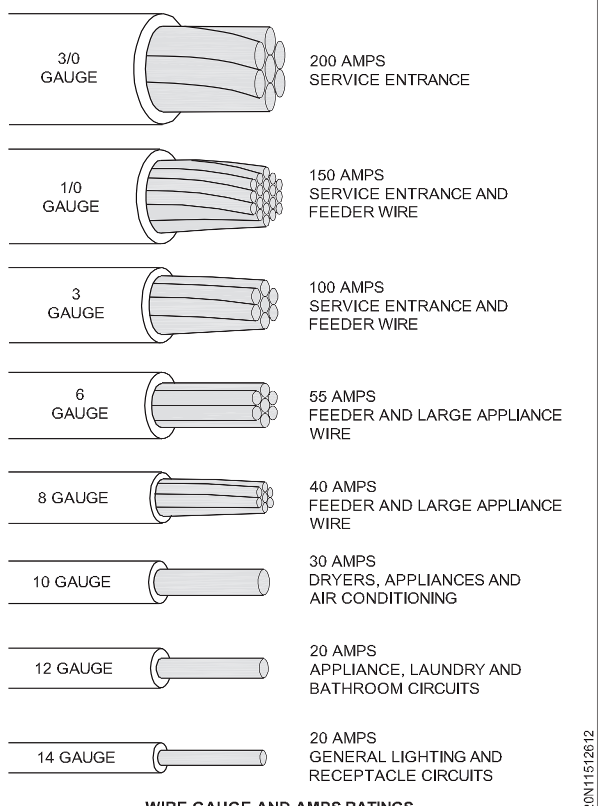
To start with, the most common size for solar wires is "AWG" or 'American Wire Gauge'. If you have a low AWG, this means it covers a large cross-sectional area and hence has lower voltage drops. The solar panel manufacturer supplies the charts that showcase connecting basic DC/AC circuits. They should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

Fig 2



WIRE GAUGE AND AMPS RATINGS

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.

Connect solar panels to an Array Junction box

Objectives: At the end of this exercise you shall be able to
- **connect solar panels to array junction box.**

Requirements

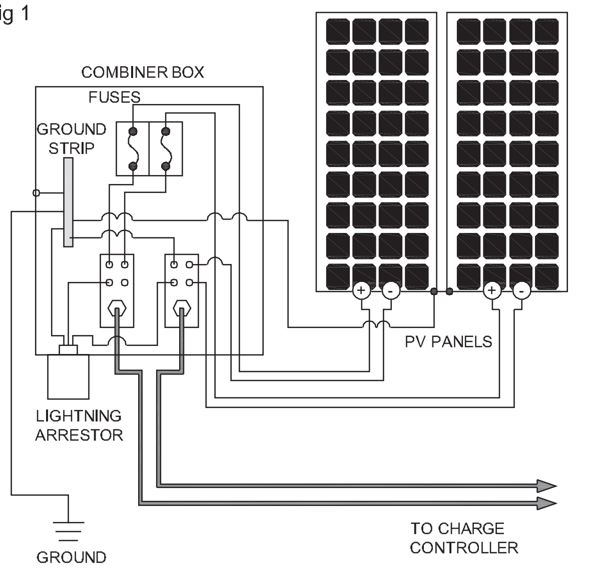
Trainer has to arrange the required tools, equipments and materials for this exercise.

PROCEDURE

- Open the AJB and understand the inside features
- Verify the circuit diagram below and compare
- Draw wires from Solar Panels and connect to input connector in AJB
- Wire the input connector for series connection
- Connect fuse, DC MCB and surge protectors
- Connect the output circuit
- Test the output voltage and current using multi meter
- Remove the above connections and repeat for parallel connection
- Record the observations
- Try connecting inside AJB for series or parallel connection for solar panels

Combiner box /AJB wiring (Fig 1)

Fig 1



COMBINER BOX WIRING

— — — —

Charge controller

Objectives: At the end of this exercise you shall be able to
- **listout types of charge connection**
- **brief about PWM, MPPT, Charge Controller.**

Charge Controller

Basically there are three types of charge controller

1 Pulse Width 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

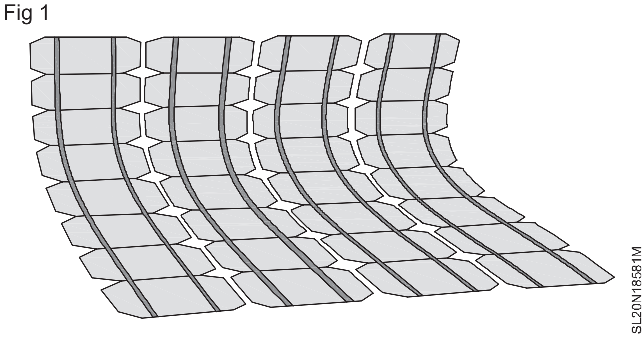
2 Maximum Power Point Tracking (MPPT)

- 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 traditional charge 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. If over charged, 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 a certain 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 1)

Fig 1



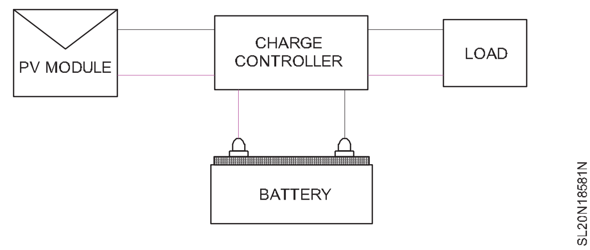
PWM solar charge controller

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

Block diagram of a PWM type charge controller (Fig 2)

PWM extends the battery life even more, as it decreases stress on battery. It can also keep batteries in a completely charged state, or floating, indefinitely. PWM chargers

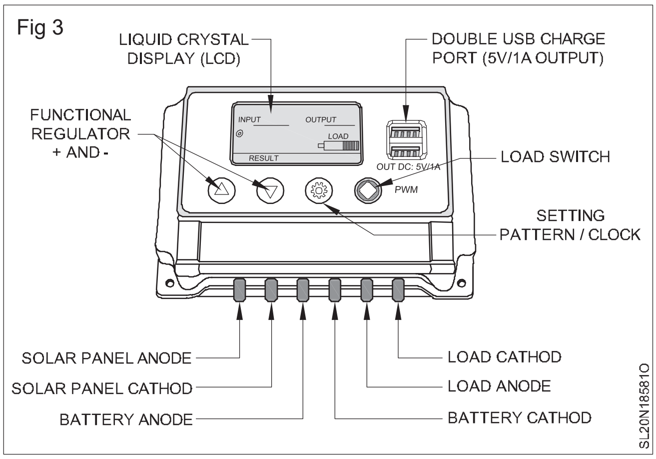
Fig 2



are more complex, but they tend to be more durable as they do not use any breakable mechanical connection.

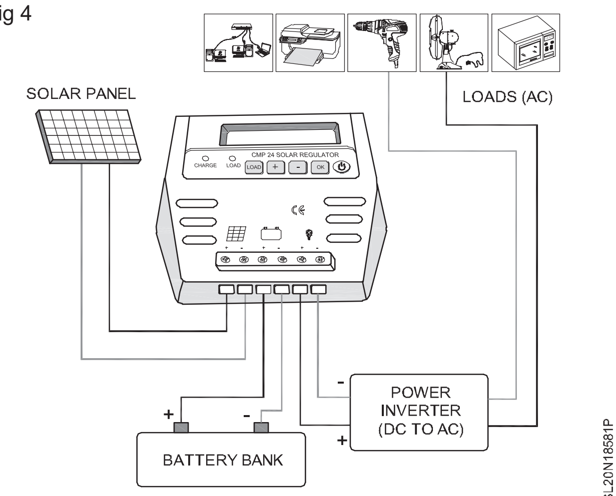
Graphical representation of functions of a charge controller (Fig 3)

Fig 3



Control by duty cycle in a PWM controller (Fig 4)

Fig 4



MPPT solar charge controller

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

Block diagram of a MPPT type charge controller (Fig 5)

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

Maximum power point in a solar panel characteristic (Fig 6)

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

Fig 6

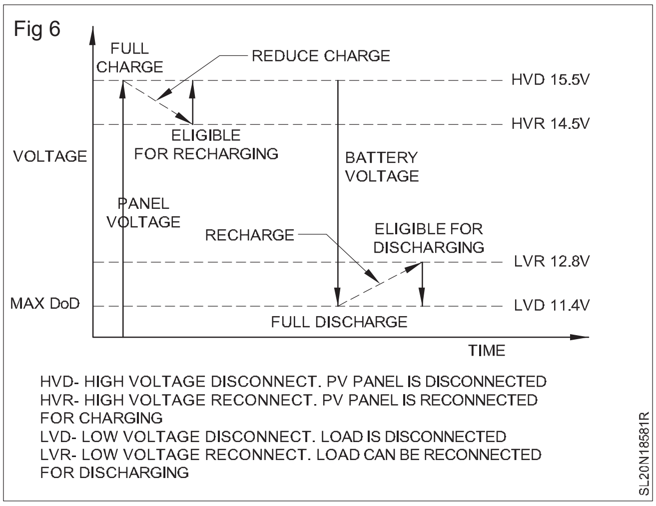
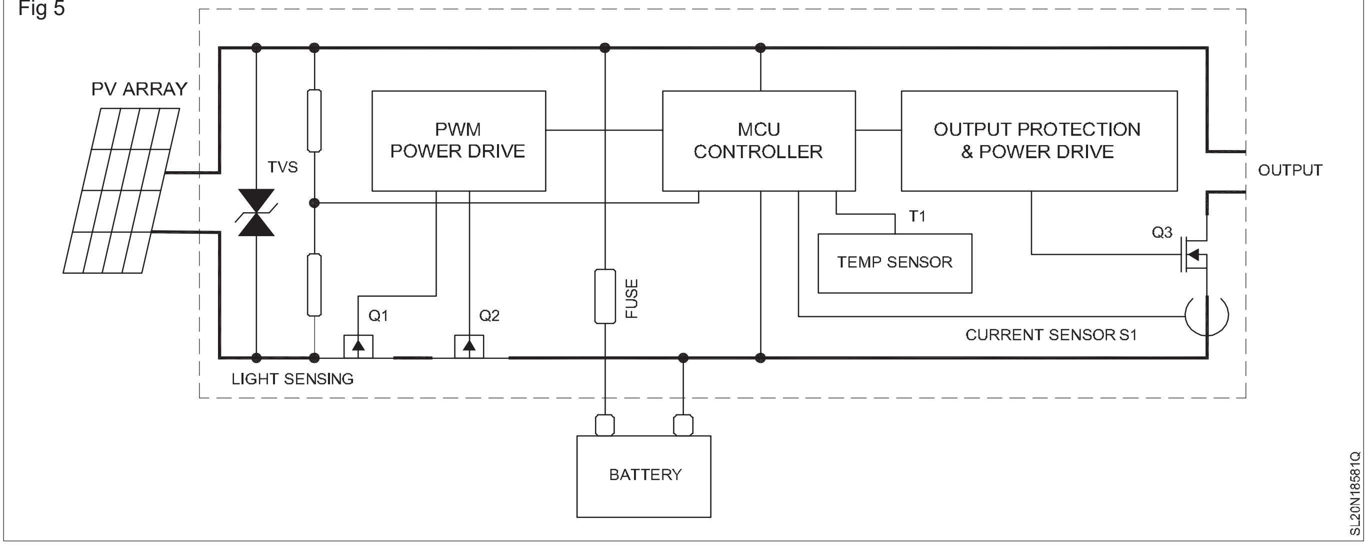
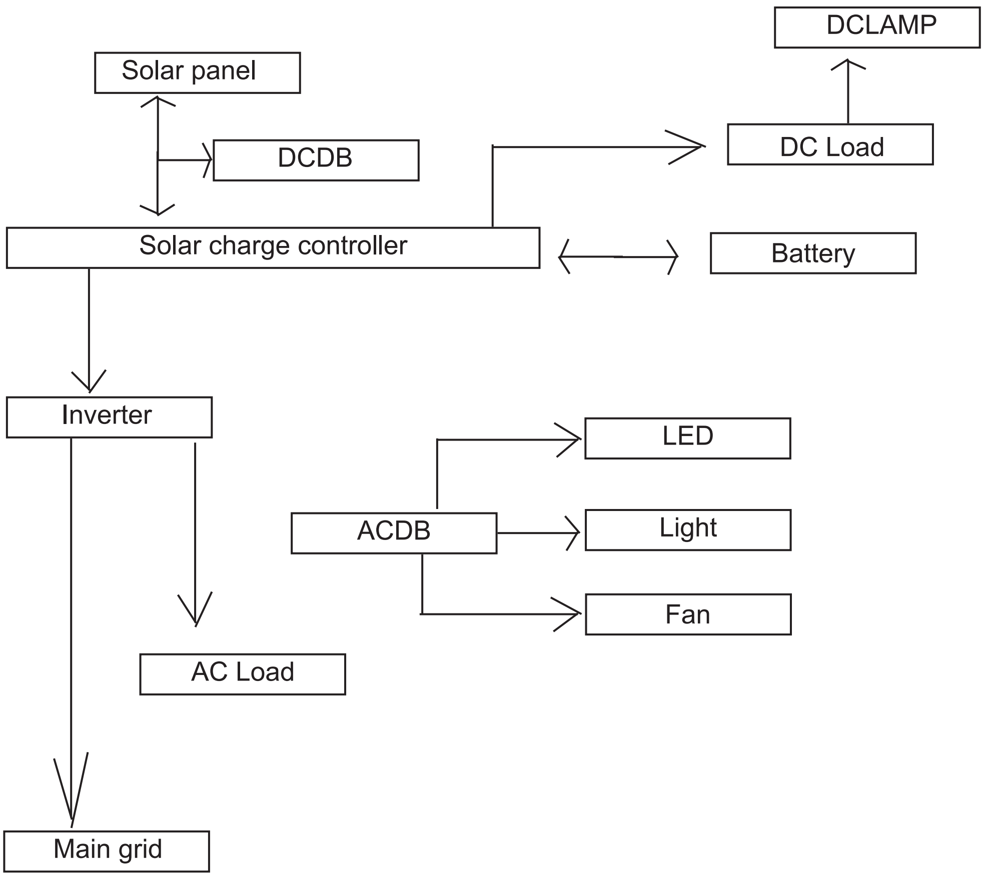


Fig 5



Overview of sequence of connection (stepwise) in an off grid system



Solar off grid system

Connect a Solar panel, Solar charge controller, Solar battery and a normal inverter and convert to a solar inverter

Objectives: At the end of this exercise you shall be able to
- **connect a normal inverter to function as a solar inverter by adding a solar panel and charge controller.**

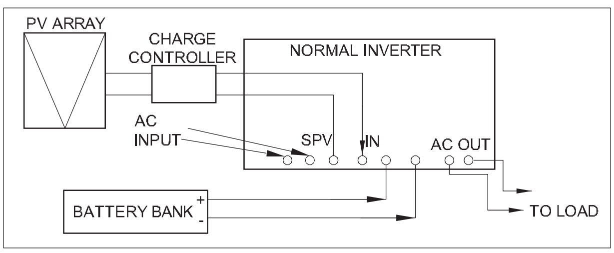
Requirements
Trainer has to arrange the required tools, equipments and materials for this exercise.

PROCEDURE

- Study the inverter wiring diagram and connect the components of the solar inverter

Normal to Solar Inverter wiring (Fig 1)

Fig 1



Wiring Sequence

- Wire the charge controller
- Connect charge controller to battery
- Connect battery to inverter
- Connect panel to charge controller
- Connect loads

> **In all the above steps wire or connect means only physical connection. But not energizing.**

- Keep all MCB in OFF position and fuses removed for safety.
- Follow the testing sequence of the inverter in 1.12.103 and test the solar inverter in a similar way for normal load, full load and overload conditions
- Record the observations

Observations:

— — — —

Type of inverters / Classification of inverters in SPV systems

Objectives: At the end of this lesson you shall be able to

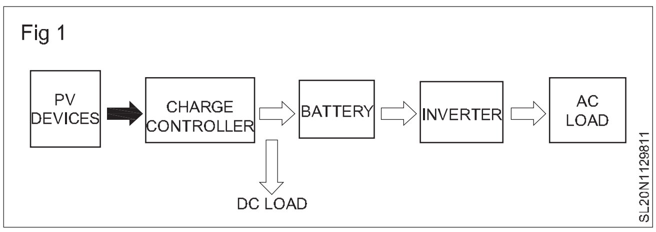
- **listout the types of SPV System**
- **differentiate between type stand alone hybrid, grid tied and grid interactive SPV System.**

Based on the necessity in a solar PV electrical system different types of inverters are in use. Quite often the type of Inverter used helps in naming the type of solar PV electrical system itself. Accordingly we have Standalone SPV system, Hybrid system, Grid tied SPV system and Grid interactive SPV system in use.

Stand alone or off-grid inverter

Standalone SPV system is normally preferred in places where electricity is not available. Hence it is suitable for remote areas, land or water bodies where Grid supply is not available. Examples: Border Military service camps, naval services, farm houses, mountains, forests, resorts etc. the main components include Battery backup and inverter. An AC main from Grid is not used. Solar energy, the only source is used to charge the battery bank and day lighting. During night Battery provides the energy input to inverter. Loads are normal AC loads and can be any. DC loads also can be used after charge controller. No AC output when battery bank voltage goes below its designed value.

Fig 1 Standalone SPV system

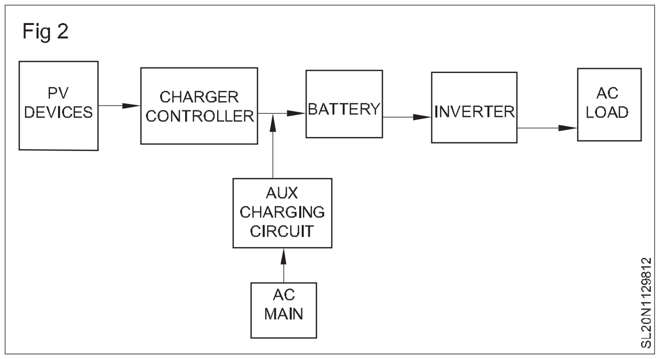


Hybrid inverter

When we add an option of additional source of charging to the standalone solar PV system, we get the Hybrid Inverter based SPV system. Solar energy is the main source for charging the battery. Additional energy requirement is supplemented by AC mains. An auxiliary charging circuit helps charge the battery in the absence of solar energy. In the absence of sunlight either partially or totally and while the system is not able to supply AC power to load, then the additional energy is drawn from AC mains.

AC mains power is converted to DC power by rectifiers to supply additional energy input to the battery. Diesel generator is also one of the choices, in the absence of AC mains power. Both AC mains and Diesel generator are Non-renewable.

Fig 2 Hybrid Solar PV electrical system

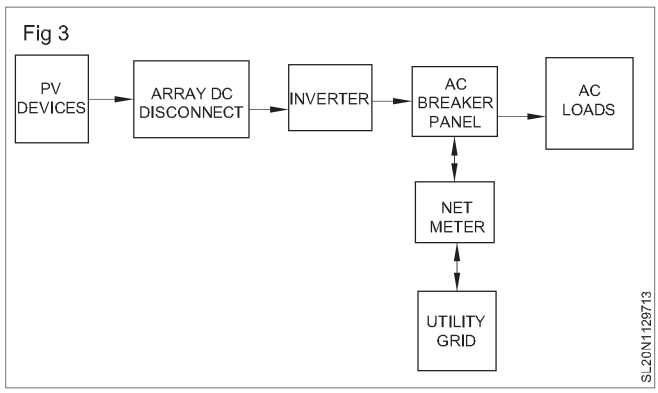


Other renewable energy sources such as wind or hydro may also be used to expand the scope of hybrid SPV systems. Priority of charging starting from 1 to solar energy, followed by other sources can be set by including electronic circuits in the input of battery bank.

Grid-tied inverter

No battery is used hence no back-up of solar energy is available. Generation is possible only when sun light is there.

Fig 3 Grid tied Solar PV system



Solar energy is directly converted to AC by a Grid-tied Inverter and supplied to the grid. When Grid is shut down solar input is disconnected and no output from the Grid tie inverter. Load shares the inverter output so that remaining is supplied to the grid. When load draws more than generated power the excess only is drawn from Grid. The normal AC energy meter in the Grid input point is replaced by a utility meter (also known as Bi-directional energy meter) to get the net usage of electricity by the customer.

This type allows the consumer as an electricity producer and government pays for it. Hence proper approval by government is to be taken before installation.

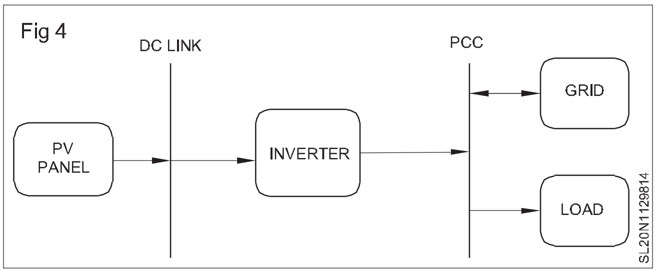
Grid interactive SPV system

This is a combination of Off grid battery backup SPV system and On grid/grid tied SPV system. Hence it has advantages of both. When grid power is available this functions similar to the On grid system. When grid shuts down this will work like off grid system by changeover of Solar array connections. An off grid system at the load end of an ON grid system also provide similar results.

A grid-interactive solar system generates clean power from the unlimited energy of sunlight. Grid-interactive inverters can also use other renewable sources such as wind or hydro power. When the sun shines, the PV system charges its deep cycle solar batteries and feeds all excess clean power into the electricity grid via the inverter.

When there is no solar power because it's night, the system can draw power from the electricity grid. When there is a power failure, the inverter draws clean power from the solar panels and batteries to meet the electricity needs of your home or business. Then it is a stand-alone system.

Fig 4 Grid interactive SPV system



A grid-interactive photovoltaic (PV) system uses solar energy to generate renewable power that charges batteries for use during power failures and feeds power into the electricity grid.

Grid-tied systems feed green energy into the electricity grid but must disconnect if the grid goes down. Tied systems receive credits and incentives for feeding green power into the grid but they can't generate energy for their own use when grid electricity is unavailable.

Grid-interactive systems also feed power into the grid but they can keep generating green energy from their PV modules and battery backup systems and use this electricity to meet their own needs.

Connect of solar PCU to solar panel installation using suitable battery bank & Test the performance

Objectives: At the end of this exercise you shall be able to
- **connect a normal inverter to function as a solar inverter by adding a solar panel and charge controller.**

Requirements
Trainer has to arrange the required tools, equipments and materials for this exercise.

PROCEDURE

TASK 1: **Study the block diagram of Off grid Solar PV electrical system**

1 Deeply go through the block diagram given below.

2 Observe the energy flow paths and type of energy.

3 Analyse level of energy at each point and describe the safety precautions to be taken while in that block.

4 Observe the DC and AC disconnects and appraise their importance.

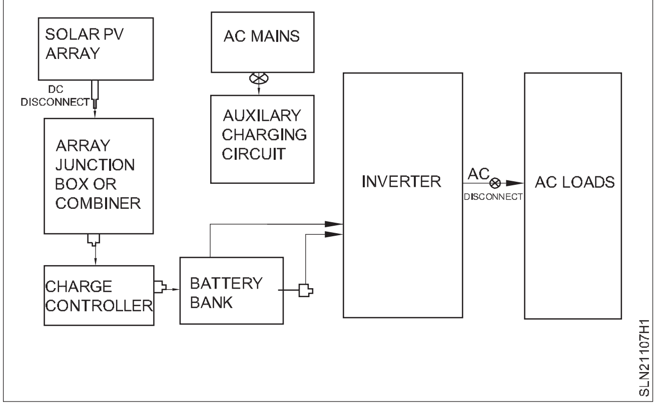
5 Assuming the entire connection is ready for use, describe a sequence of switching ON the Off grid Solar PV electrical system.

6 Write down the steps required for interconnecting blocks if individual blocks are already assembled, wired and kept ready.

7 Record your answers in observations column in sequence.

Block diagram of an Off grid Solar PV electrical

Fig 1



Observations

• **Energy flow paths**

• **Block wise safety precautions**
• **Sequence of switching ON**
• **Interconnecting blocks**

— — — — — — —

TASK 2: **Interconnect different blocks of an Off grid Solar PV electrical system**

1 Follow the wiring diagram.

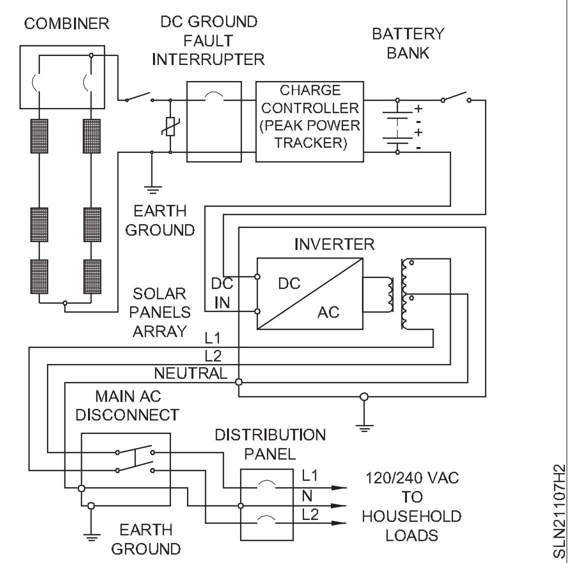
2 Keep all the MCBs and disconnects in OFF position.

3 Sequentially connect the different blocks.

4 Verify the connections made.

Wiring Diagram (Fig 2)

Fig 2



Suggested sequence of wiring

1 Wire the Charge controller.

2 Connect battery bank to charge controller or inverter as the case may be, through DC disconnect.

3 Connect solar array output from combiner box through dc disconnect to charge controller.

4 Connect charge controller output through dc disconnect to the input of the inverter.

5 Connect the AC mains to the inverter.

6 Connect the AC loads to the inverter output.

Observations

SI.No	List the observation

— — — — — — — —

TASK 3: **Test the performance of the 1 kW SPV off grid system**

1 Follow a sequence and switch ON the above connected system.

Suggested sequence:

1 Switch ON DC disconnect between combiner box and charge controller.

2 Measure and record the Solar array output reaching the input of charge controller.

3 Switch ON the DC disconnect between Battery bank and charge controller or inverter as the case may be.

4 Measure the input to the charge controller or inverter as the case may be from battery bank and record the observations.

5 Switch ON the AC mains disconnect to the input of Inverter.

6 Measure input AC to the inverter.

7 Switch on the inverter and observe normal functioning.

8 Measure the output AC and record the observation.

9 Connect the AC loads and measure load current and watts.

10 Record all observations.

Observations

Sl.No	List the observation

— — — — — — — —

Test solar panel, Charge controller, Battery bank and Inverter

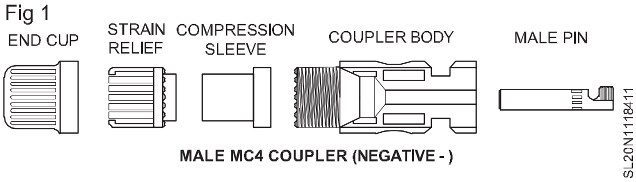
Objectives: At the end of this lesson you shall be able to
- **describe about component details of PV and Distribution System**
- **operation details of ON and OFF Grid PV System.**

Solar panel terminal wires and MC-4 connectors

The MC4 system consists of a plug and socket design. The plugs and sockets are inside plastic shells that appear to be the opposite gender - the plug is inside a cylindrical shell that looks like a female connector but is referred to as male, and the socket is inside a square probe that looks male but is electrically female. (Important to note)

MC 4 Male connector (Fig 1)

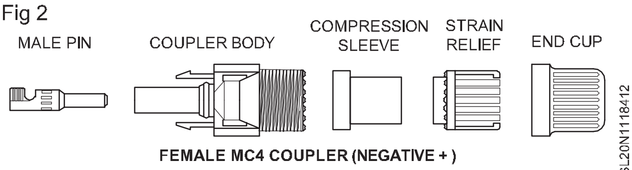
Fig 1



The female connector has two plastic fingers that have to be pressed toward the central probe, slightly to insert into holes in the front of the male connector. When the two are pushed together, the fingers slide down the holes until they reach a notch in the side of the male connector, where they pop outward to lock the two together.

MC 4 Female connector (Fig 2)

Fig 2



For a proper seal, MC4s must be used with cable of the correct diameter. The cable is normally double-insulated (insulation plus black sheath) and UV resistant (most cables deteriorate if used outdoors without protection from sunlight). Connectors are typically attached by crimping, though soldering is also possible.

The MC4 connector is rated at 20 A and 600 V maximum, depending on the conductor size used. Standards allow 1000 V versions.

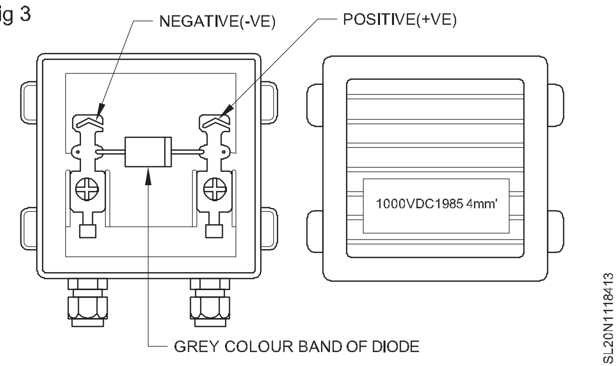
A general MC4 Connector Specification includes Manufacturer name, Rated for say, 30 amps max (the connector itself, not the wire), Rated for say, 1,000 volts max and Rated temperature range, say, -40 degrees C to +90 degrees C (-40 F to 194 F).

It is noted that, not to cut the MC4 connectors off of the solar modules, that voids the warranty of most manufacturers.

Constant spring pressure provides reliable low contact resistance. However, it is very important to never connect or disconnect them under load, even on low-voltage (12–48 V) systems. An electric arc may form which can melt and seriously damage contact materials, resulting in high resistance and subsequent overheating. This is partly because direct current (DC) continues to arc, whereas commonly used alternating current (AC) more readily self-extinguishes at the zero-crossing voltage point. Large arrays of panels are commonly interconnected in series, made of strings of panels generating 17 to 34 V each, with overall voltages up to 600 V per string.

Junction box on Backside of Solar panel (Fig 3)

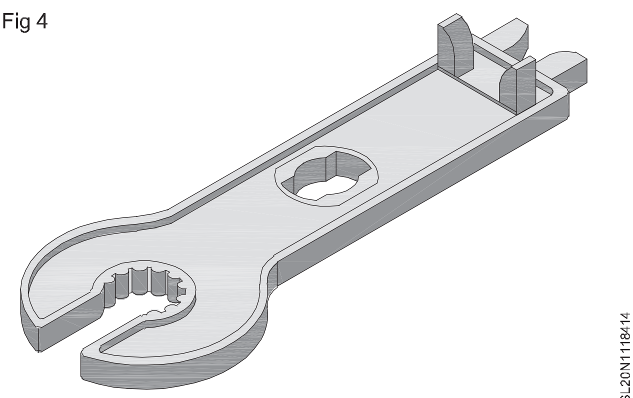
Fig 3



Due to the locking mechanism of the MC4 connectors, they will not come unplugged and are well suited for outdoor environments. The connectors can be separated but it requires a special MC4 unlocking tool.

Unlocking tool for MC4

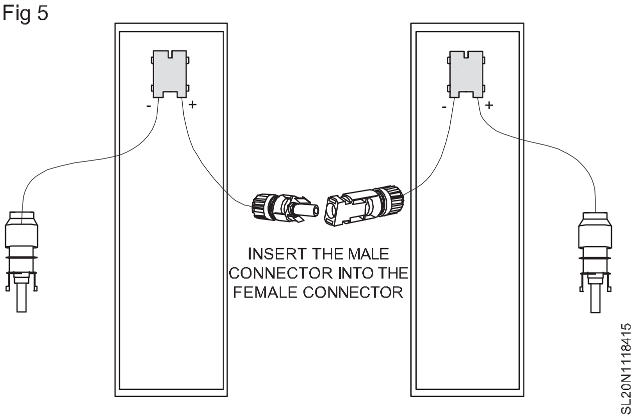
Fig 4



Series connection using MC 4

In a series connection the modules are wired together by connecting the positive lead on one module to the negative lead on another module. The male connector will snap directly into the female connector. This increases the voltage of the circuit.

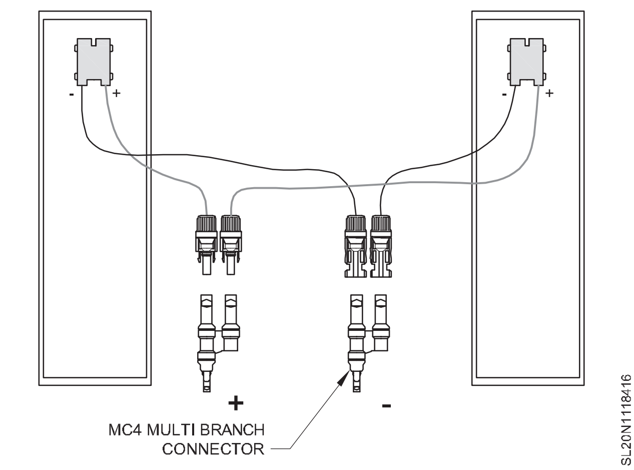
Fig 5



If the modules are rated for 18 volts at maximum power (Vmp), then two of them connected in series will measure 36 Vmp. If three modules are in series, the total Vmp would be 54 volts. The current at max power (Imp) will be constant when wiring a series circuit.

Parallel connection using MC4 multi branch connectors (Fig 6)

Fig 6



A device called a PV combiner box is used for paralleling more than two modules or paralleling strings of modules. The combiner box will be performing the same function of the multi-branch connectors but for more than two panels.

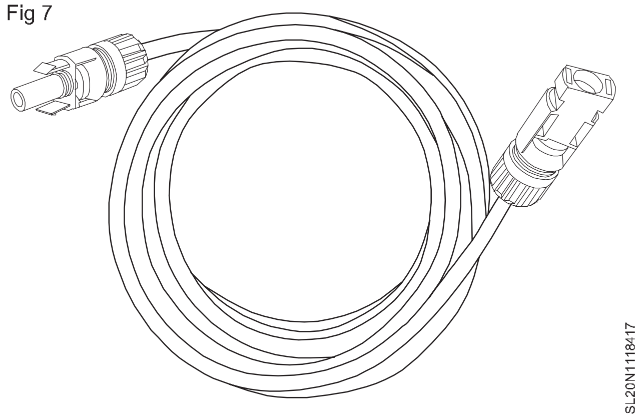
The total number of modules that can be combined will depend upon the electrical rating and physical size of the combiner box and also on the PV design. Further the technician should know how to select and use MC4 extension cables.

PV array wiring cables (Fig 7)

Solar cables are of 4mm or 6mm cables in general.The differences between cables/wires, sizing methods, and 4mm solar cable installation are discussed here.

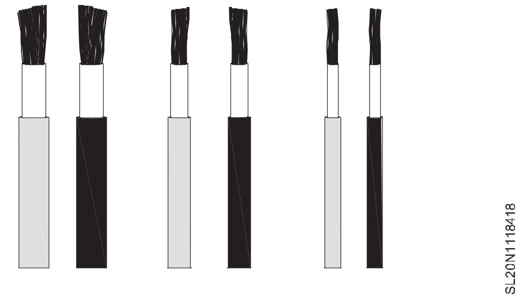
The terms "wire" and "cable" are assumed to be the same by the public, but there is actually a major difference between the two. A solar cable is a group of multiple conductors while a wire is only a single conductor. Hence wires are essentially the small components that make up the larger cable. A 4mm solar cable has multiple small wires inside the cable which are used to transfer electricity between different endpoints in the solar setup.

Fig 7



Different Solar DC cables (Fig 8)

Fig 8



Each wire located inside a 4mm cable works as a conductor and the cable is comprised of multiple such conductors. Solar wires are made from a study material such as copper or aluminum. These materials provide reliable connectivity and the ability to transfer electricity from the solar panels to the home.

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

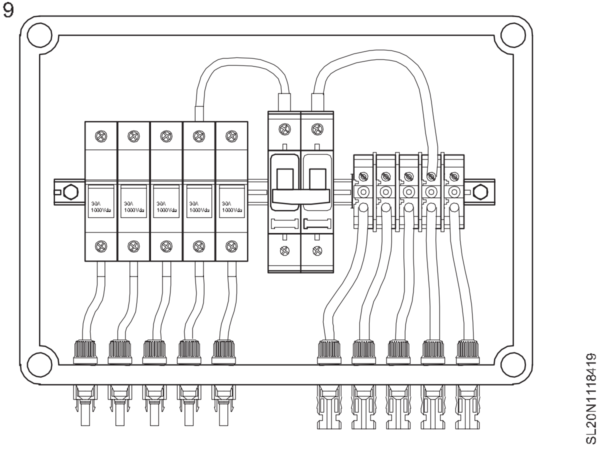
At this stage, you only have to insert the cable. Pass the screw nut over the cable and check the rubber washer again. Then you need to push the crimped cable into the female housing. You should hear a “Click” sound here as well to know it is locked it in place.

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.

Array Junction Box or Combiner Box (Fig 9)

Fig 9



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.

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:

Demonstrate testing & Commissioning of rooftop solar panel

Objectives: At the end of this lesson you shall be able to
- **carry out first switch ON and no load test.**

Requirements
Trainer has to arrange the required tools, equipments and materials for this exercise.

PROCEDURE

TASK 1: **Conduct the 'No load test' after ' Switch ON'**

Observation of parameters pre operation and Operational test before connecting to Load:

1 Switch on disconnect of charge controller (if available external to PCU) to battery.

2 Switch on the disconnect of battery to inverter.

3 Switch on disconnect of solar PV panel to charge controller

4 Switch on the inverter.

5 Observe correct working condition of above before connecting load.

6 Test and measure voltage and current on.

- Battery voltage
- Charge controller
- Solar panel
- Inverter output

7 Record the observations.

Observations

S.No.	List the observation

— — — — — — — —

SOP (Standard Operation Procedures) of rooftop solar 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 practice 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

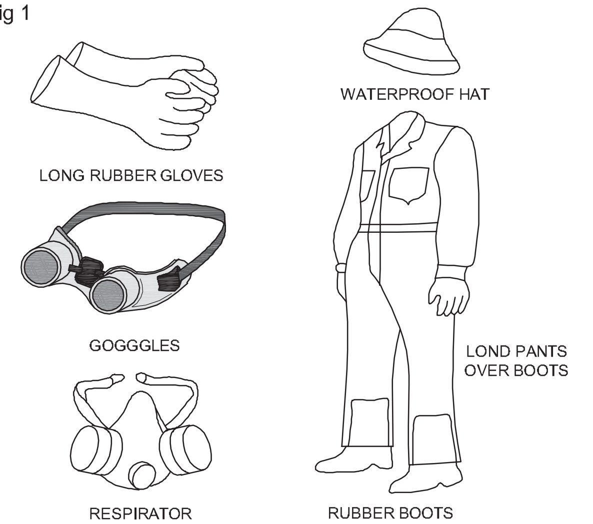
- The skin, example from contact with corrosive materials
- The body, example from extremes of heat or cold

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.

Safety at heights

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

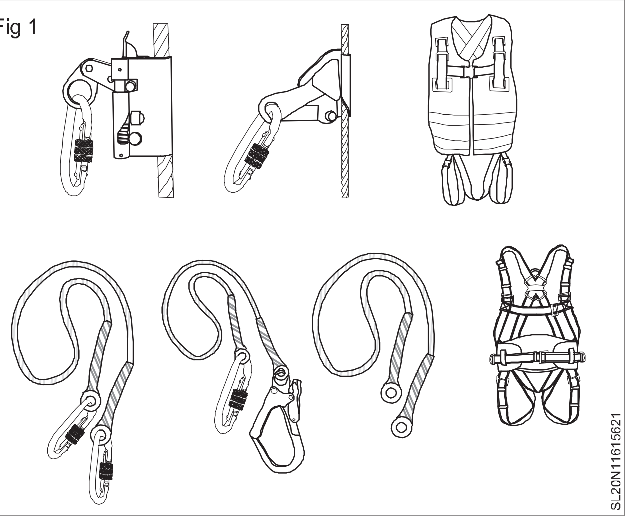


Fig 2 Fall protection hazards

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 fibre glass 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, toe boards, and man lifts 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.

Demonstrate standard operating procedures of 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.**

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.

— — — — — — — —

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.

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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Types of Maintenance (Preventive/Corrective/Condition Based)

Objective: At the end of this lesson you shall be able to
- **practice maintenance activities in Solar PV plant.**

Solar Technician has to practice various maintenance activities at the solar power plant.

Maintenance basics are to understand importance of maintenance and to plan and perform various activities in maintenance of the plant

Maintenance is a combination of activities done in the Solar PV power plant to retain the healthy working condition accepted at the time of commissioning, for all the times.

Also the repair and rectification works carried out at any point of time whenever failure is noticed during inspection and reported by customer.

Further training and information on in fault diagnosis and testing, the overall design, the location relative to service facilities, availability of spare parts, availability of diagnostic instruments & test gear and the maintenance policy are required for effective functioning of maintenance team.

Preventive maintenance

- It is a policy of replacing components or parts of a system that are nearing the end of their life and therefore wearing out and is carried out before the components actually fail.
- Failure of components entering the wear – out period or subjected to continuous wear can be easily predicted to make the replacement possible improving the reliability of the system to a great extent
- Preventive maintenance may not be possible while it becomes difficult to accurately predict the point at which components enter the wear out period or it is uneconomic to carry out P.M.
- Disadvantage: the disturbance created during P.M. activity may itself cause failure(s)
- Components covered under the P.M. category are those with moving parts which are continuously in use. Example:
- Contacts on relays
- Switches
- Switches subjected to arcing when switching inductive or capacitive loads
- Filament lamps

Factors influencing the failures and against which PM activity is carried out are:

- Vibration and noise
- Shock
- Dust
- Damage of cover
- Stains and smudges
- Temperature
- Humidity
- Corrosion
- Continuous monitoring, cleaning and inspection helps in getting alert about the problems leading to failure. A minor failure ignored or not noticed at the beginning leads to permanent breakdown later; hence, perfect monitoring of failure chances and preventive measures taken in time avoids all breakdowns.

A typical preventive maintenance chart

PREVENTIVE MAINTENANCE CHART
MACHINE No.: 1
ITEM
INSPECTED: ELECTRICAL CONTROL PANEL

MONTHS ⇒ CHECKED POINTS ⇓	1	2	3	4	5	6	7	8	9	10	11	12
General inspection												
Terminals												
Fan operation												
Air flow												
Loose contacts												
Relays												
Contactors												
Capacitors												
Switches												
Indicating lamps												
Voltmeters and ammeters												
Cleanliness: dust, oil, insects, webs etc												
Potentiometers												
LED/LCD displays												
Electronic cards												
Test point voltages/currents												
Checked by:												
Remarks:												

SPECIAL INSTRUCTIONS:		**MANDATORY REPLACEMENTS:**
1.	3.	
2.	4.	

The main activities under PM of SPV systems include:

- Mounting structure integrity
- Module cleaning
- Hotspots detection
- Junction box servicing
- Inverter servicing
- Cabling connections
- Balance of plant
- Inverter Servicing
- Earthing protection
- Vegetation control

Solar PV Panel Analysis is done to identify the defects and find remedies. They should be detected visually for

- Defective frames
- Yellowing (The panel becomes yellow)
- Defective connection boxes
- Broken glass
- De-lamination
- Any others........(to specify observation)

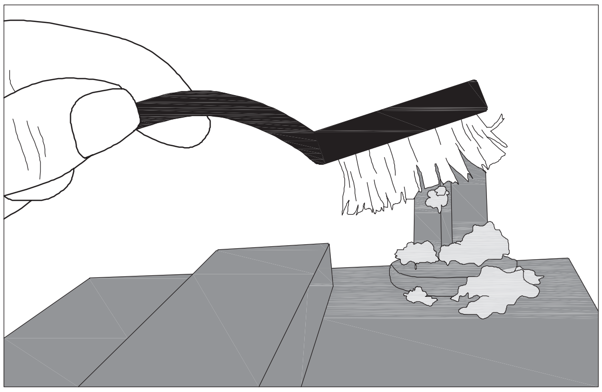
A periodic schedule for maintenance activities should be ready with the maintenance team.

- As a daily schedule it can be to Ensure security of the power plant and Monitor power generation and export. Find out similar duties for daily performance.
- To Inspect and clean the PV modules from dust and other dirt like bird's dropping etc. as and when required can be a weekly monitored activity.
- Check quarterly keeping the inverters clean to minimize the possibility of dust ingress.
- Ensure half yearly all electrical connections are kept clean and tight.

- In annual check category include points like Check mechanical integrity of the array structure, Check all cabling for mechanical damage, Check output voltage and current of each string of the array and compare to the expected output under the existing conditions, Check the operation of the PV array DC isolator etc.

Fig 1 Cleaning of Battery terminal

Fig 1



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Corrective maintenance

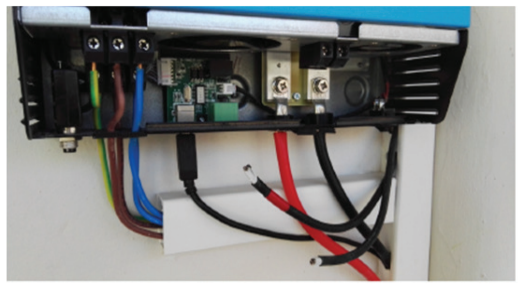
- Replace as and when failed
- Most preferred for Electronic control systems because failures of components are random
- and cannot be predicted
- Carrying out preventive maintenance action itself may be real cause of the fault
- Corrective Maintenance is concerned with the detection, location and repair of the faults as they occur
- Developing skill in this area requires good understanding of overall system, its circuit operation and its fault location methods

Some of the corrective maintenance activities pertaining to Solar PV systems are:

- Tightening loose connections
- Replacing damaged modules
- Replacing blown fuses
- Repairing blown fuses
- Rectifying inverter faults
- Repairing equipment damaged by intruders
- Replacing blown connectors
- Rectifying SCADA faults
- Rectifying mounting structure faults

Fig 2 Loose and disconnected wires

Fig 2



Demonstrate electrical maintenance of inverters

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
Trainer has to arrange the required tools, equipments and materials for this exercise

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.

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
- Battery low
- Over load

5 If the LED are lighting it corresponds to the good status as mentioned in the manual.

6 If the LED is not lighting the corresponding function may or may not be correct.

7 If system doesn't give any other mal function but LED indication not there it may require change of LED. Refer manual for method changing and verify spares provided. If not mentioned call service personnel. Do not leave the faulty LED not changed. Because the purpose of intimating the fault is not served.

8 If LED doesn't light and corresponding function not available then PCU needs servicing.

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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.

4 Regularly clean the junction boxes.

5 Look for MCB trip, fuse blown and blackening of SPDs etc.

6 Report faults immediately and take suitable remedies.

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			

Demonstrate of solar panel maintenance, cleaning, DC array inspection precautions while cleaning

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

Requirements
Trainer has to arrange the required tools, equipments and materials for this exercise

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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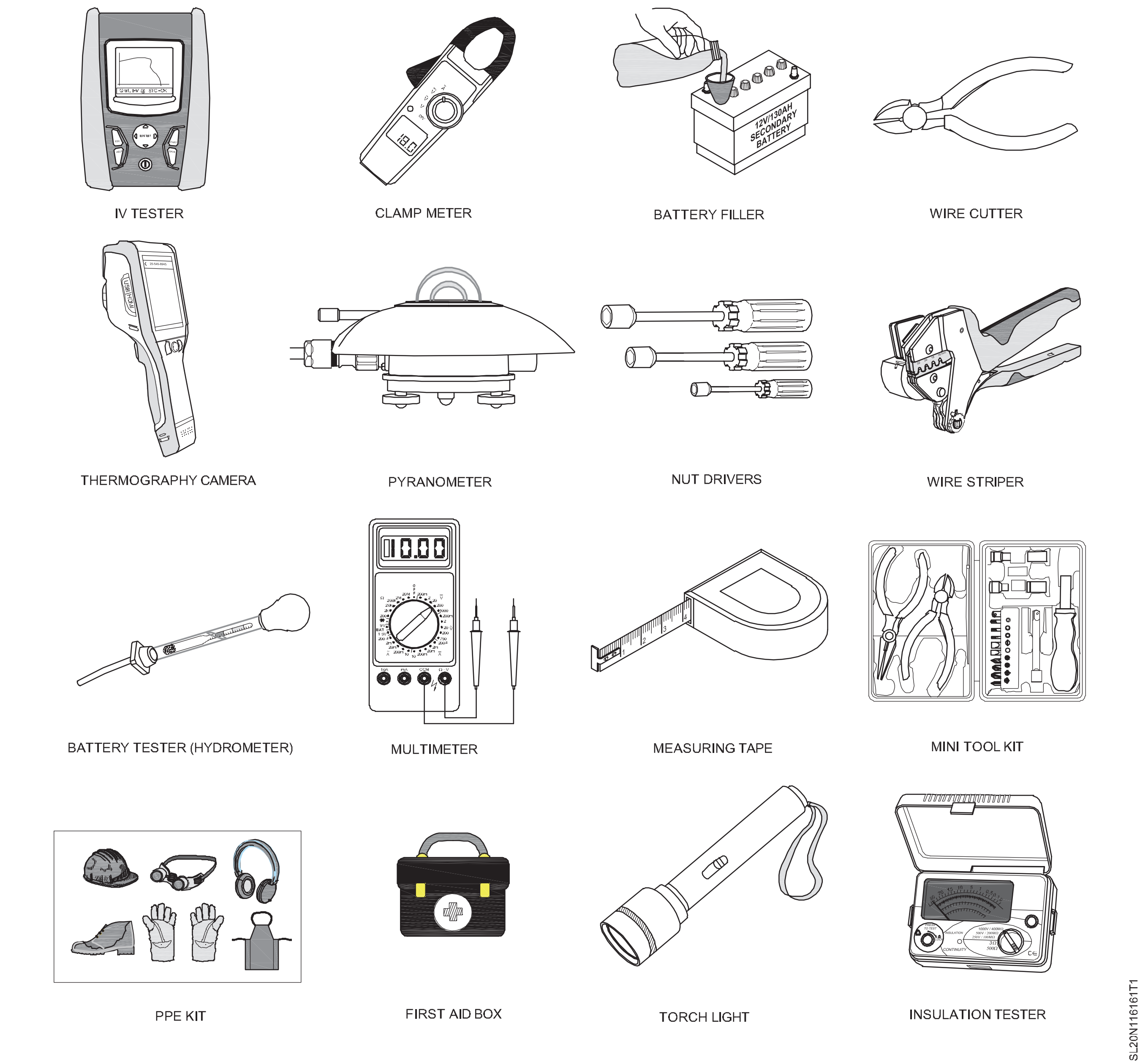
Tool & Equipment for Maintenance Team

Objectives: At the end of this exercise you shall be able to
- **brief about general maintenance kit**
- **explain the maintenance of battery.**

- Documentation such as O&M Manual and Datasheets are essentials for beginning the activity. Safety first is to be strictly followed for technician as well as the equipment. First aid kit and PPE are understood thoroughly and their availability to be ensured. Their usable condition is to be checked.
- System Service logbook and writing utensils are a must.
- Equipment such as Digital Multimeter, Clamp Meter, Hydrometer, Sun pathfinder, Thermography Camera, IV- Tester, Pyranometer etc are carried for the maintenance work.
- Other essentials include Battery maintenance kit, Battery water filler, Tool kit having Screw drivers, Nut drivers 1/4in & 5/16in, Crimping tool set, Angle Finder, Measuring Tape, Compass, Flashlight and Cleaning Brush Hammer, Wire Cutter Wire Stripper Cutting Pliers

Fig 1



- The using methods of various tools and equipment have been discussed at different sections of this course content and to be recalled as and when required.
- The safety and PPE kits are discussed later in a elaborate way since more attention exclusively to be given.
- Standard Operating Procedures (SOP) are also dealt in detail to educate the solar technician completely.

General Maintenance Kit

Maintenance Checklist may initially include for every component about their manufacturer's details such as, Basic Information of Company that includes Company Name, Name of the Contact Person Designation of Contact Person, Mobile number of Contact Person, Landline number of Contact Person, E-mail Address of the contact Person, Company Website, Company Local Address etc.

Basic Information of Plant may include Date of Inspection &Maintenance, Plant Capacity etc.

Carry out the following inspections:

- Module & Array Inspection shall give details on Module Condition, Module Cleaning, Damage of Module, Dirt Accumulation etc.
- Check Shading observed on Modules.
- Inspect a subset of array top glass inspection - look for Blemishes, spots, bonding of frame to glass and discoloration.
- Back sheet inspection - look for spots, Blisters burn through, Discoloration. Check for Insulation on module wiring.
- Proper wire condition and sizing.
- Check for connectors on array wiring extensions.
- Inspect module Junction boxes - look for sealants, proper wire management.
- Check for proper grounding of array and array mount.
- Inspect module clamping methodology - check for loose fasteners, secured and sealed properly.
- Perform thermal scan of modules and note any discrepancies
- Check for Proper Labelling
- Visually check array - if broken, damaged or loose module, loose racking hardware, wiring and MC4 connectors. Visually inspect all supporting parts-corrosion/evidence of rust, when encountered apply the cold galvanization spray.
- Verify proper operation of dc disconnections. Measure output circuit conductor to see if any combiner box is reading low.
- Measure output current of each combiner box on single string, if low check for all strings
- Visually check all D.C disconnections and combiners - corrosion, blown fuses, moisture entry, heat distortion, insect or rodent issues.
- Check all duct seals, gaskets and other sealing methodologies are fully intact and functional. Repair or replace if necessary.
- Inspect wire, conduits, piping, tighten all electrical connections and correct if any issue is identified.
- Check for ground continuity between the frames and racking structure.
- Check for continuity of cable to electrical earth.
- Check for corrosion - copper wires, PV frames and galvanized steel racking structure
- For Ballasted system, verify ballasted material is not degraded.
- For folded rack sites, verify wind deflectors are firmly attached to racking structure.
- Inspect array for build-up of debris underneath, clean whenever necessary. Check for labelling.

For combiner box (AJB) perform the following:

- Measure the current in each string, if found zero then check the fuse (replace if necessary)
- Check for any damages of cabinet or enclosures.
- Check for deposition of any dirt or dust.
- Check out for wear out screws or handle of enclosure and support structure. Check for any loose connections or tightness of the terminations.
- Check for heating, hardening of cables and change in colour of the components of the combiner box.
- Proper wire condition, sizing and insulation.
- Check for proper labelling.
- Check for proper functioning of the MCB, MCCB, Disconnect or switch and diodes.

In case of OFF grid battery backup systems carry out the following inspections:

For charge controllers:

- Check for any damages of cabinet or enclosures.
- Check for proper wire condition, sizing and insulation.
- Check for deposition of any dirt or dust.
- Check for proper labelling.
- Input and output disconnects labelled.
- Check for proper grounding.

For Battery banks:

- Proper ventilation for cooling.
- Check the terminals protected from shorting.
- Check for proper wire condition, sizing and insulation and burnt marks if any. Check for deposition of any dirt or dust.
- Check for electrolyte leaks and cracks in cells.

- Check for corrosion at terminals, connectors, racks and cabinets.
- Check for ambient temperature (all cells must be at same ambient temperature). Flooded vented to outside.
- Check for proper labelling.
- Check for proper wire condition, sizing and insulation

For inverters perform the following inspections:

- Visually inspect inverter for external damage
- Check the functionality of inverter
- Check that the installation is neat and permanent
- Check inverter display and record all input and output voltages
- Clean area around inverter and verify base is sealed
- Shut down A.C/D.C breakers to inverter, power down the inverter
- Wait for inverter to discharge (approx. 5 min)
- Install safety lock outs
- Check for conduits and wire sizes installed properly. Check area around
- inverter is cleaned and verify base is sealed
- Vacuum all debris from inverter
- Visually inspect for moisture intrusions
- Clean or replace air filters and clean air returns
- Check the tightness of cable termination
- Check for proper wire condition, sizing and insulation
- Check for proper labelling of cables
- Inspect Air filters
- Visually inspect inverter for external damage
- Check the functionality of inverter
- Check that the installation is neat and permanent
- Check inverter display and record all input and output voltages
- Clean area around inverter and verify base is sealed
- Shut down A.C/D.C breakers to inverter, power down the inverter.
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- Visually inspect for moisture intrusions
- Clean or replace air filters and clean air returns
- Check the tightness of cable termination
- Check for proper wire condition, sizing and insulation
- Check for proper labelling of cables
- Inspect Air filters
- Check for abnormal operating temperature
- Check for faulty fuses
- Power up the inverter
- Check the system is properly operational
- Check for ventilation condition (exhaust fan is working properly or not)
- Record Inverter and Meter power reading
- Check if Inverter inlet and outlet fan is working properly or not
- Check for Noise levels of inverter
- Torquing of terminals and fasteners
- Check for proper grounding levels
- The inverter mounted on ground or wall should be at a height convenient for reading its display
- Check for Inverter ground fault interruptions

Perform the following inspections for Trackers:

- Inspect flexible conduit and wires between moving modules for wear and cyclic motion
- Examine gear box for leakage of oil or grease
- Check for ground braids between movable torque tube and wear due to cyclic motion, replace if necessary
- For multiple tracker motors, examine array controlled by each tracker, and confirm they are in same positional orientation for all groupings
- Check there is no cracking at tube ends
- Inspect the wind sensor is positioned properly and functional
- Wherever available confirm date and time in tracker PLC's
- Check U-joint is greased properly
- Check for proper wire condition, sizing and insulation
- Check seal tight on trackers
- Check torque tubes and drive shafts to ensure that they haven't got loose by themselves
- Check array for backtrack shading
- Check for deposition of any dirt or dust
- Check for proper labelling
- Check sensors or mini controllers for its proper functioning
- Check for all fuses in the main controller

In case of SCADA systems the following inspections need to be carried out:

- Check for proper wire condition, sizing and insulation
- Wire management must be proper and secured to weather station instrumentation (module temp sensor, ambient air temperature sensor, pyranometers etc.)

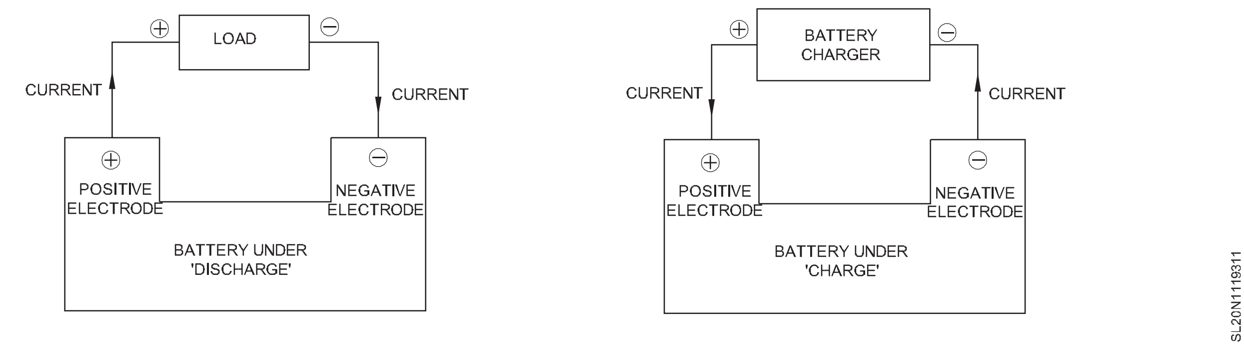
- Check that there is no moisture ingress in enclosures, seal as necessary
- Check for enclosures open and close hasps are functioning properly
- Check that wires are landed and secured properly within SCADA
- Cleaning inside of enclosures (dust, debris, insects etc.) vacuum with static-free vacuum
- Check for proper ventilation (fans must turn freely and functional) Check for deposition of any dirt or dust
- Verify all pyranometers are properly secured and mounted properly

The above inspection points are indicative and in actual case depending on plant design and modern features etc the reality would be exhaustive. At any point of time training and retraining of the solar technician by self or by the management of employed place will be essential to meet the market demands.

Documents & Records for maintenance activity:

- Detailed inspection sheet with all remarks incorporated in prescribed formats must be sighed at every stage by the inspecting team and the customer who may be an individual public or representative of firm or plant manager as the case may be.
- Defects investigation reports: indicate defects reported, date & time, testing method adopted, used tools &equipments, fault located block, relation with reported fault, action taken, replacement done, spare used, spare drawn from, suppliers of spare, number of occurrence etc
- Expert systems: Tabulation of symptom of defects, probable causes, probable problem area or block, suggested remedial measures
- Cause and effect diagrams: pictorial representation of each fault linked with associated blocks, possible defective components
- Periodical reports to management, design department etc to take action to prevent the failures in future

Fig 2



BATTERY MAINTENANCE

Battery 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.

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 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.

Demonstrate of battery maintenance, checking

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

Requirements
Trainer has to arrange the required tools, equipments and materials for this exercise

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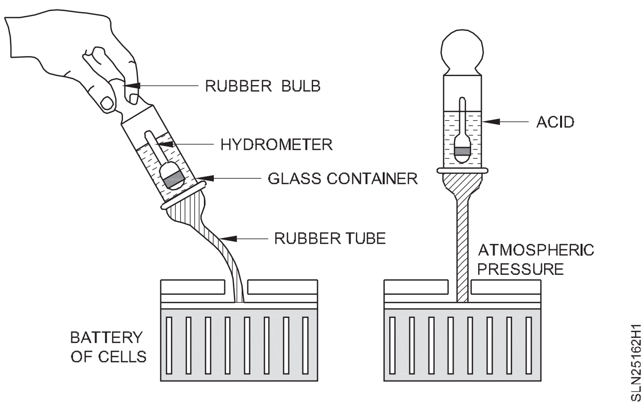
TASK 2: **Check for specific gravity of electrolyte in a battery**

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. (Fig 2)

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 (Fig 3)

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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Inspect of mounting structure of solar modules and procedure of replacement of defective fixtures

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
Trainer has to arrange the required tools, equipments and materials for this exercise

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

S.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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