

# **SURYAMITRA SKILL DEVELOPMENT PROGRAM**

## **GUIDELINES**



**NATIONAL INSTITUTE OF SOLAR ENERGY**

(AN AUTONOMOUS INSTITUTION UNDER THE MINISTRY OF NEW AND RENEWABLE ENERGY GOVERNMENT OF INDIA)

Faridabad-Gurgaon Road, GwalPahari, Gurgaon 122003, Haryana.

These Guidelines shall be effective from the July 01, 2015 for Suryamitra Skill Development Program of the National Institute of Solar Energy, Gurgaon. The Suryamitra Skill Development Program is oriented to provide skill development to Solar Photovoltaic Technicians for Solar PV Installer and Service Provider.

### **1.DURATION OF THE PROGRAM:**

The duration of the Suryamitra Skill Development Program will be three months consisting of six hundred hours including hundred hours of soft and entrepreneurship skills.

### **2. SELECTION OF PARTICIPANTS:**

For selection of participants to Suryamitra Skill Development Program, following essential and preferable qualifications are required:

**Essential Qualification:** The candidate should be 10 pass ITI in electrician/Wireman/Electronics and not below 18 years. The trainee should have certificate of ITI or diploma in any branches of Electrical/Mechanical/Electronics, Experience in certified electrician will also be preferred.

B. Tech or any other higher qualification is **not** allowed.

### **3. NUMBER OF SEATS:**

Presently, there shall be 30 seats for each batch of training program.

### **4. ADMISSION:**

- a) The State Nodal Agencies of the Ministry of New and Renewable Energy and the host institute will advertise about the batches of the program including dates and the venue of the training in the print and/or electronic media.
- b) The final selection of the trainees for the program shall be made by host institute and the details of the proposed participants must be communicated to NISE/concerned SNA before the commencement of the program.
- c) During the selection of trainees, special emphasis to be given to the trainees coming from rural background, unemployed, women candidates, SC/ST candidates.

### **5.TEACHING AND PRACTICAL WORK:**

1. The main curriculum of teaching would be as per the National Council of Vocational Training (NCVT) approved Module-5 which is attached with the Guidelines.
2. The training program is residential with a clear daily time table which would preferable include early morning physical exercise such as Yoga/PT etc.
3. The first hour of the day may be utilized for class-room lectures.

4. The practical hours may be utilized for hands on exercise in the lab sites, Experiments, class room exercises, software simulations if any, and to conduct the regular quizzes/class test and industrial visits.
5. For experiments/field visit, the batch may be divided into multiple groups depending on the availability of facility.
6. Motivational sessions (1 hr. duration each) shall be conducted once every two weeks.
7. The host institute shall provide one set of uniform to all the Suryamitra participants. Participants must attend the session in proper uniforms only. A T-shirt (Grey color) with NISE logo and a pant (Yellow Color) for both male/female. The jacket, safety helmets and boots must be provided to all participants, and may be retained by the host institute after the training.
8. Each participant/group shall be given an access to proper toolkits for working in the lab/site.
9. Each modules of a session guides the trainer to prepare the materials for that particular session. The trainer is free to opt for any references and, training methodology/slides, provided the objectives in the sessions are covered in full length.
10. The preferred medium of instruction would be the respective local language, but though Hindi and English may also be preferred depending on the demand from the class.
11. The trainer/institute may also conduct a class test/quiz at the end of each session as a part of continuous assessment. The criteria/pattern of conducting these quizzes and tests can be decided by the trainer. Also, each day may preferably start with the recap of the previous day's sessions.
12. Trainers are requested to give sufficient home works to the participants during the weekend.

#### **6.ATTENDANCE:**

- a) Every teaching/practical staff member handling a class will take attendance till the last instruction day of the training program and the records will be kept with the organizing institution.
- b) The trainees are normally expected to attend 100% theory and practical classes/workshop practices. However, no participants shall be allowed to be awarded certificate at the end of training unless he/she has 90% attendance in total.

#### **7.FEE STRUCTURE:**

- a) No fee will be charged from the trainees. However, the trainees will make their own arrangement for joining the training and going back. Any amount collected as security deposit must be refunded at the end of the course and need to be in the proper records.
- b) The boarding and lodging of the trainees will be provided by the organizing institution. The Ministry of New and Renewable Energy through State Nodal Agency will provide Rs 300 per trainee for 30 trainees for 90 days which amounts to Rs 8.10 Lakhs.

- c) The Ministry of New and Renewable Energy through State Nodal Agency will provide course fee to the institute at the rate of Rs 25/- per hour x 30 participants x 600 hours which amounts to Rs 4.50 Lakhs.
- d) The Ministry of New and Renewable Energy through State Nodal Agency will provide assessment charges for 30 trainees @ Rs 800/- which amounts to Rs 0.24 Lakhs.

#### **8.ASSESSMENT OF TRAINEES:**

The final examination consisting of written test, practical examination shall be conducted at the end of the three months by the Skill Council for Green Jobs or NCVT strictly as per the module 5.

#### **9. INDUSTRIAL VISIT**

During first two months of suryamitra program, at least 3 visits to medium or large industry to know power transmission, distribution, loads, cabling etc. and one visit to 33 kV substations must be planned.

#### **10. EMPLOYMENT ASPECTS**

At the end of the suryamitra program, the host institute may arrange for placement of the “Suryamitra” by inviting, solar industries, EPC companies, marketing companies, large contractors working with Transco, Discoms etc. Maximum number of the participants must be provided employment at the end of the program. Host institute may coordinate with SNA’s to invite companies for the placement.

## Curriculum for Suryamitra Skill Development Program

- This content is planned into sessions according to the course curriculum structure based on the module 5 of the national skill development council of India.
- ‘T’ represents theory hours and ‘P’ represents practical hours. For example : a session “1T and 7P” refers to total 8 hours of session with 1 hour of theory and 7 hours of practical.
- The sessions from 1 to 16 must be covered in the same sequence as given to maintain the chronology of the knowledge transfer. However the session 17 can be incorporated in between as and when required.

### SESSIONS 1 to 19

#### Session 0: Introduction to Suryamitra, Overview of Course (0.5 Day : 4T)

#### Session 1 - 3: Course on Basic Electricals(7 Days : 7T + 49P)

**What is Electricity** -Lecture: *Briefing*: Electron theory, (Molecules, Atom, Protons, Neutrons), Structure of atom, Electric Current. Voltage, Current, Resistance, Example (Example: water flow from outlet of a water tank) Measurement Units - Volts, Amp, Ohm.

#### **Electrical Lab work / Demo**

Demo-1: Voltage, Current, Resistance (water flow through outlet of water tank)

Demo-2: Voltmeter, Ampere meter & Resistance (Rheostat)

Demo: Safety and its importance, PPEs, Safety Signs, Safety Slogans, Safety Rules, Fire Extinguishers

Demo: PPEs, All types of fire extinguishers,

Mock drill: Practice on usage of fire extinguishers (any two types)

#### **Tools / tackles**

**Lecture** :*Briefing* : Screw Drivers, Spanners, Pliers, Nippers, Hammers, Hacksaw, Cutters, Chisels, Allen Keys, Hand Drill, Drill bit, Try Square, Gimlet, Ratchet, Pipe vice, Bench vice, Pin vice, Plumb bob, Centre punch, Wrench, Blow lamp, Pipe cutter, Reamer, Box spanner, Crimping tool, Measuring tape, Pulley puller, Neon tester, Mallet, Wire stripper.

#### **Electrical Lab visit / Demo**

Demo: All types of tools & tackles (*applications / safety precautions*).

#### **Group Exercise**

Exe.-1: Recognize the right tools - Practice Screw Drivers, Spanners, Pliers, Nippers, Hammers, Hacksaw, Cutters, Chisels, Allen Keys,

Exe.-2: Practice hand drill, try square, gimlet, ratchet, pipe vice, bench vice.

Exe.-3: Drilling Practices, usage of drill bits, filing practices, Try Square, Gilmet, ratchet, pipe vice, bench vice, pin vice

Exe.-4: Practice Filing, Chisel, Marking, level, Pipe cutter, Reamer

Exe.-5: Practice Box spanner, Crimping tool, Measuring tape, Pulley puller, Neon tester, Mallet, Wire stripper

**Lecture - Soldering:** *Briefing:* Soldering (What? Why? & How?), Solder, Flux, Soldering Iron, blow lamp.

**Fuse:** *Briefing:* Fuse (what & why?), Fuse Wires, Rewirable / HRC fuses, Cartridge Fuse, MCB, MCCC and ELCB

**Electrical Lab visit / Demo**

Demo-1: Solder, Flux, Soldering Iron, Blow Lamp

Demo-2: Various types of fuses, Fuse wires, MCBs, ELCB

**Group Exercise**

Exe.-1: Soldering applications

Exe.-2: Rewiring / replacement of fuse

**Wires & Cables Lecture:***Briefing:* Types of wires and cables, Insulating Materials, Standard wire gauge, Specifications of wires and cables, Colour coding, Low and high voltage, Precautions in using cables, Wire ferrules, Continuity / Continuity tester, Meggar

**Electrical Lab & Yard visit / Demo**

Demo: various types of wires and cables,

**Group Exercise:**

Exe.-1: unreeling wires and cables, inserting number ferrules in wires.

Exe.-2: Continuity testing (Wires and cables)

Exe.-3 : Meggar Value Measurement (HT Cables)

**Cabling / wiring accessories - Lecture - Briefings:** Cable/Wire lugs, Cable drums, Cable trays, Wire stripper, Cable cutter, Crimping tool, Voltmeter, Ampere meter, Watt meter.

**Electrical Lab & Yard visit**

Demo-1: All types of wires & cable lugs and tools.

**Group Exercise**

Exe.-1: Cable cutting, Insulation removing, Cable laying in cable trays,

Exe.-2: Practice on underground cable laying

Exe.-3: Practice on cable laying in cable trays.

**Laws of resistance and Ohms Law -Lecture :** *Briefing :* Simple Electric Circuit, Open circuit, short circuit, sources of electricity, Effects of electric current, Volts, Ampere, Resistance, Ohm's law, series / parallel / Mixed (compound) resistance circuits, Rheostat.

**Group Exercise:**

Exe.-1: Practice on measurement of resistance with series, parallel and mixed circuits.

Exe.-2: Practice on measurement of voltages in parallel and mixed circuits.

**Common Electrical Accessories :** *Lecture: Briefing:* Switches, lamps, plug, sockets, tube light circuit, MCB, ELCB, MCCB, house wiring accessories, safety alarms.

**Visit to Electrical Lab**

Demo: Electrical accessories,

**Group Exercise:**

Exe.-1: Tube light circuit making

Exe.-2: Fault Finding (Tube light Circuit).

Exe.-3 : Simple house wiring circuit (applications of electrical accessories)

**Work, Power & Energy**

**Lecture: Briefing :** Work, Mechanical Power, Energy, Units of Energy, Pump & its efficiency, Heating Effects of electric circuits, Wattage of household items, Horse Power.

**Magnetism – Lecture - Briefing:** Magnetism, Types of Magnets, Terms of Magnetism, Magnetic Needle, Current & Magnetic field, Law of ampere, Solenoid, Self & Mutual Inductance, Hysteresis Loss

**Alternating Current - Lecture: Briefing:** Alternating Current, Frequency, voltage, RMS value, Average Value, Sine wave, Single Phase, 3 Phase, Line Voltage, TPM Switch, Change Over switch. Clip On meter, Contactor, ON/Off Switch, Reversing Switch, Electrical Measuring Instruments (Description and applications): Multimeter, wattmeter, energy meter, P.F. Meter, Frequency meter (Digital and Analog). Simple AC Circuit

**Group Exercise:**

Exe.-1: Measurements of AC voltage & Current (Application of digital and analog meters)

Exe.-2 : Practice Oscilloscope (Measurement of voltage, current, frequency, Wave shape)

Exe.-3 : Electrical Wiring for ON / Off Switch with Power Contactor.

Exe.-4: Practice Electrical wiring for reversing switch

Exe.-5: Practice usage of Multimeter.

Exe.-6: Practice connection and usage of watt meter

Exe.-7: Practice Usage of PF Meter and Energy Meter

**Generation, Transmission and Distribution Of Electricity - Lecture : Briefing :** Generation (Steam, Hydro, Solar, Nuclear) Distribution Methods, Sub Station, Circuit Breakers, DC Transmission, Underground Cable systems, Cable Construction, Cable Trench

**Lightning arrester : Lecture- Briefing :** principle and types, HV transmission, surge voltage, lightning arrestors.

**Visit to substation.**

**Session 4: Introduction to Renewable and Solar Energy( 1 Day: 3T+5P)**

Module 4.1: Renewable Energy and its prospects various RE sources.

Module 4.2: Introduction to Solar Energy and Solar Radiation, its importance, Differentiate solar PV and solar thermal energy.

Module 4.3: Solar Resource Measurement, Instrumentation and its applications.

**Session 5: Introduction of Photovoltaic Technology and its applications (5 Days: 5T + 35P)**

Module 5.1: Basics of Light to Energy Conversion

Module 5.2: Brief History of Solar/PV cells

Module 5.3: Physics of Energy Conversion in Solar Cell (Current and Voltage)

Module 5.4: Understanding basic terminologies of a PV cell (I-V Curve, efficiency, FF)

Module 5.5: Solar Cells to Module, Module name plate specifications, Module to Array and Basic Structure of PV module

Module 5.6: Classification of PV Modules based upon technology

Module 5.7: Brief on PV Cell/Module manufacturing process

Module 5.8: STC and NOCT test conditions and Characterization of PV Modules

Module 5.9: Factors affecting output of a PV module (Temperature, Irradiance, Tilt angle, cell area, shadowing, dust, mismatch, PV module configurations, MPPT operation etc.)

Module 5.10: PV module defects and degradation in the field (Techniques for identification of defects)

Module 5.11: PV module Testing and Certification Standards

Module 5.12: Applications of PV, different configurations of PV power system: Stand alone, Grid, hybrid system etc.

## **Session 6: Components of a PV System: Battery, inverter and Charge controllers (5 days: 5T+35P)**

- Module 6.1: Basics of standalone PV system, Balance of System (BOS)
- Module 6.2: Introduction: Batteries, type of batteries, operation and structure
- Module 6.3: Basic Terminologies of a Battery, Charging & Discharging Characteristics
- Module 6.4: Factors affecting Battery operation and Selection Criteria
- Module 6.5: Testing standards for batteries
- Module 6.6: Introduction: Inverter, type of Inverters, operation, make and specifications
- Module 6.7: Basic Terminologies of a Inverter and Characteristics
- Module 6.8: Factors affecting inverter operation and Selection Criteria
- Module 6.9: Testing standards for inverters
- Module 6.10: Basics of Charge controllers, operation and specifications, DC-DC converters
- Module 6.11: Types of charge controllers and selection criteria
- Module 6.12: Components of a grid connected SPV system (ACB, DB and cabling)
- Module 6.13: Types of wires and selection criteria, wire sizing.
- Module 6.14: Other components like: Junction Box, Lighting arresters, grounding etc.

## **Session 7: Fundamentals of PV system sizing (5 Days : 5T and 35P)**

- Module 7.1: What is Sizing, significance and steps involved in sizing?
- Module 7.2: Load Estimation, analysis and basics on energy efficiency.
- Module 7.3: Site survey and assessment. Shading analysis, Customer profiling and Role play.
- Module 7.4: Inverter, Battery sizing and its aspects.
- Module 7.5: Module sizing and its aspects. Lay out diagrams. Spacing of PV strings and placing of each component. Selection of modules, batteries and inverters from the market specifications.
- Module 7.6: Various steps involved in sizing of grid connected PV systems.
- Module 7.7: Introduction to single line diagram and its significance.
- Module 7.8: Listing of various components required for a grid connected and stand alone Solar power plant. (A check list of Each and every component).
- Module 7.9: Understanding of various costs (Project heads) involved in the solar projects.

## **Session 8: Trouble Shooting of PV Modules (3 Days: 3T and 21P)**

- Module 8.1: Introduction to instruments used for monitoring performance of PV module.
- Module 8.2: Quality assessment of the PV modules delivered at the site.
- Module 8.3: Methods/Techniques in identifying various defects in a PV module.
- Module 8.4: Measurement of various parameters in a PV module/PV string.
- Module 8.5: Interpretation of performance data, and troubleshooting of possible defects in PV module.

## **Session 9: Troubleshooting of Batteries, Inverters and Charge controllers (4 Days: 4T and 28P)**

- Module 9.1: Quality assessment of the batteries inverters and charge controllers delivered at the site.
- Module 9.2: Introduction to tools required for battery and inverter maintenance.
- Module 9.3: Trouble shooting of Batteries, all types of batteries, Complaints and servicing.
- Module 9.4: Trouble shooting of inverters, Complaints and servicing.
- Module 9.5: Trouble shooting of Charge controllers: Complaints and servicing.



Module 9.6: Trouble shooting of other balance of systems: wires, connections, casings, Fuses and relays.

**Session 10: Importance of Tools and its applications (1 Day: 1T and 7P)**

Module 10.1: Introduction to various tools used in the power plant installation, its usage.

Module 10.2: Safe handling of tools.

**Session 11: Check list preparations and Pre-requirements of installation. (2 Days : 2T and 14P)**

Module 11.1: Solar PV plant installation check list.

Module 11.2: Qualitative and Quantitative assessment of various components in the system.

Module 11.3: Safe handling of each component, in the site, during transportation and stocking.

Module 11.4: Essential documentation required for site installations.

**Session 12: Structure Erection and Civil Works ( 3 Days : 3T and 21P)**

Module 12.1: Brief on civil foundation and, erection of supporting structures.

Module 12.2: Fixing the foundation of the structure and, the grounding considerations.

Module 12.3: Installation of mechanical structure

Module 12.4: Foundation: Reinforcement and Shutting other balance of systems

Module 12.5: Mechanical safety aspects.

**Session 13: Installation of Solar Power plant (5 Days : 5T and 35P)**

Module 13.1: Preparation and general considerations for installation (DC and AC components).

Module 13.2: Installation of Array support structure and mounting of PV modules.

Module 13.3: Interconnection of modules, strings and Combiner boxes.

Module 13.4: Installation of other System components, i.e. Inverter, battery etc.

Module 13.5: Installation of AC and DC power distribution boxes.

Module 13.6: General safety consideration in the installation phase of solar power plant.

**Session 14: Cable Tray and Cable Laying: SCADA and Control System (1 Day: 1T and 7P)**

Module 14.1: Details of various cable tray and materials used for the same. Precautions on the cable laying procedures.

Module 14.2: Guidelines for DC and AC cable layout and connections.

Module 14.3: Introduction to SCADA control system, and their relevance.

Module 14.4: The basic understanding of fault identification scenario on SCADA systems.

**Session 15 : Commissioning and Testing (4 Days: 4T and 28P)**

Module 15.1: The procedures involved in the commissioning of the power plants.

Module 15.2: Preparation and verification of various check list for commissioning and testing.

Module 15.3: Electrical testing of PV arrays, inverters and other system components.

Module 15.4: Complete System Testing, functional testing and trouble shooting.

Module 15.5: Testing for islanding protection.

### **Session 16: Operation and Maintenance( 14 days : Theory and Practical)**

Module 16.1: Various protocols for operation and maintenance of PV power plant. Brief on various check points for daily maintenance. Allocation of work priorities.

Module 16.2: Procedures for trouble shooting and repairs during the maintenance. Guidelines to handle emergency situations. Safety practices in work sites. Documentation of events.

During this period the Suryamitra participants are expected to be associated with any of the solar power plants sites and earn hands on experiences on the operation and maintenance of the plant as an internship project.

### **Session 17 : Soft and Entrepreneur Skills ( 12 Days: 25 T and 71P)**

Module 17.1: Development Competency / Proficiency in English/Vernacular

Module 17.2: Effective Communication, Self & Time Management, Motivation Techniques, Interpersonal Skill Development, Computer Literacy, Life Skills

Module 17.3: Entrepreneurship

Module 17.4: Occupational safety, Health and Environment Education

(For more details of the syllabus refer document for “Soft and Entrepreneur Skills” published by [www.sdi.gov.in](http://www.sdi.gov.in))

### **Session 18 : Assessment (2 days: Theory and Practical)**

### **Session 19 : Valedictory function, Feedback collection and Certification distribution (0.5 day)**

# Guide for Suryamitra Skill Development Practical Sessions

## Experiment No. 1

### Objective

To demonstrate the I-V and P-V Characteristics of PV module with varying radiation and temperature level.

### Observations

Table for I-V and P-V characteristics of PV module. Take 4 set of readings at different radiation and temperature levels.

### Results

1. Draw the I-V curves of all the sets on a single graph and show the characteristics at different radiation and temperatures levels.
2. Draw the P-V curves of all sets on a single graph and show the characteristics at different radiation and temperatures levels.
3. Calculate the fill factor for the given module.

## Experiment No. 2

### Objective

To demonstrate the I-V and P-V characteristics of series and parallel combination of PV modules.

### Observations

Table for I-V and P-V characteristics of PV modules in series and parallel. Take 3 sets of readings for different radiation and temperature levels.

### Results

1. Draw the I-V curves of all the 3 sets on a single graph for series and parallel connected modules and show the characteristics at different radiation and temperatures level.
2. Draw the P-V curves of all the 3 sets on a single graph for series and parallel connected modules and show the characteristics at different radiation and temperatures level.

## Experiment No. 3

### Objective

To show the effect of variation in tilt angle on PV module power.

### Observations

Tables for evaluating effect of tilt. Take each set of readings for different positions but during one set its position will be fixed. Radiation on module will be calculated by taking an average of the radiations recorded at three different locations on the module (viz. upper end, middle and lower end).

### Results

1. Draw the graph between tilt (as x-axis) and Radiation and Power (on left and right y-axis). Relation between radiation and power o/p will be linear.
2. Get the I-V and P-V curve, at each tilt angle, with the help of Real time plotter.

## Experiment No. 4

**Objective**

To demonstrate the effect of shading on module output power.

**Observations**

Table for evaluating the effect of shading on cells.

**Results**

1. Demonstrate the power level for different sizes of shading elements (by using digital meters and data logger separately)
2. Get the I-V and P-V curves of module for different shading types with the help of plotter

**Experiment No. 5****Objective**

To demonstrate the working of diode as Bypass diode and blocking diode.

**Observations**

1. Power output of series connected modules before using bypass diode with shaded module will be close to zero. After using bypass diode with shaded module, power output of series connected modules gets increased from nearly zero to higher value.
2. Connections with two configurations of blocking mode without using diode, observe the reverse flow of current through a LED glow in these two cases.
3. Connections with two configurations of blocking mode using diode, LED will not glow in these two cases.

**Results**

Observe the working of blocking diode and Bypass diode

**Experiment No. 6****Objective**

To draw the charging and discharging characteristics of battery.

**Observations**

Discharging experiment can be done at different current values. This can be achieved by changing the load. Table for discharging/charging of battery:

Time	Voltage	Current

**Results**

1. Draw charging and discharging curves by taking time (in hrs) on x-axis and voltage and current on y-axis.

**Experiment No. 7**

## Objective

Observe the output waveform of the inverter in auto mode.

## Experimental set-up

Output of the charge controller will be given to the inverter input and load will be connected to the output of the inverter (as shown in fig). Inverter has an option to get fired with default signal or generated PWM signal. In this experiment inverter will be in automatic mode in which gate will be fired with the default signal.

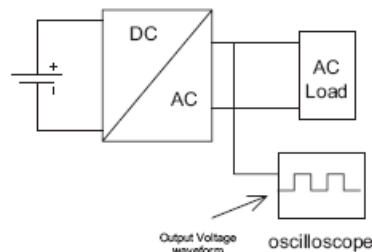


Fig.1. Experimental set-up for waveform observation

## Results

Observe the waveform of the output AC of inverter. Note the frequency and RMS value of the output of the inverter.

## Experiment No. 8

### Objective

Workout power flow calculations of standalone PV system of AC load with battery.

### Observations

The quantities to be observed are AC load current, AC load voltage, inverter input voltage, current, battery current and battery voltage with different parallel combinations of modules.

### Results

Show the power balance in both the sets by following formulae:

1. Array power = Inverter i/p power + battery power + loss due to charge controller
2. Inverter efficiency = AC load power \* 100 / Inverter input power (DC).

## Experiment No. 9

### Objective

Workout power flow calculations of standalone PV system of DC load with battery.

### Observations

The quantities to be observed are DC load current, DC load voltage, battery current and battery voltage with different series parallel combinations of modules.

### Results

Show the power balance by following formula:

**Array power** = load power + battery power + Power loss by charge controller

## Experiment No. 10

**Objective**

Find the MPP manually by varying the resistive load across the PV panel.

**Observations**

For the fixed radiation and temperature note the following readings for different values of load resistance R.

S.No	V(volts)	I(amps)	R(ohms)	P(watts)
1				
2				
3				
4				

**Results**

1. Draw the I-V curves of all the setson a single graph and show the characteristics at different radiationand temperatures level.
2. Draw the P-V curves of all setson a single graph and show the characteristics at different radiationand temperatures level.
3. From the table find the value of maximum value of P. This will be corresponding to a particular value of R. Note down the value of Pmax and Corresponding R.

$V_m$	
$I_m$	
$P_m$	
$R_{opt}$	

**Experiment No. 11****Electrical Measuring Equipments****Objective**

To understand how to use various electrical measuring equipments.  
Determine resolution and accuracy of measuring equipments.

**Observations**

Tabulate the findings as shown in the table.

	Voltage set at constant voltage DC power supply	Multimeter Range	Resolution and accuracy	Expected range of measured values
Multimeter -1				
Multimeter -2				
Multimeter -3				

**Results**

Show the resolution and accuracy of the measuring equipments and conclude on the obtained observations.

**Experiment No. 12**

## I-V Characteristics of a PV Module

### Objective

To determine the different electrical parameters of a monocrystalline and polycrystalline silicon solar panel

### Observations

Tabulate the findings as shown in the table.

Voltage(V)	Current(A)	Power (voltage x current) W

Plot I- V graph and determine the fill factor and efficiency of different PV Module.

### Results

1. Draw the I-V curves of all the sets on a single graph and show the characteristics at different radiation and temperatures level.
2. Draw the P-V curves of all setson a single graph and show the characteristics at different radiationand temperatures level.

## Experiment No. 13

### Shading Effect of a PV Panel

#### Objective

To study the effect of shading on the output of solar panel.

#### Observations

Measure the voltage and current when the Solar panel is completely illuminated by the sun.

Tabulate the findings as shown.

Number of solar cells shaded	Voltage(V)	Current(A)	Power(W)
0			
1			
2			
..			
10			

### Results

Plot a graph with number of solar cells shaded along X-Axis and Output power along Y-Axis.

## Experiment No. 14

### Shading Analysis on Site

#### Objective

To do a shading analysis on the site where solar PV system needs to be setup.

#### Equipments required

Sun path diagram for the given location. Elevation and azimuth angle measuring protractors, magnetic compass.

#### Procedure

- Set the Azimuth angle measuring paper on a horizontal surface facing south.
- Understand the different terms used in a sun path diagram.
- Identify an obstacle and measure its azimuth angle as well as altitude angle.
- Mark that point on the sun path diagram.
- Repeat this process from east to west.
- From the sun path diagram, determine the total sun shine hours throughout the year.

#### Results

Plot a graph with solar elevation angle along X-Axis and solar azimuth angle along Y-Axis.

## Experiment No. 15

### Battery Characteristics

#### Objective

To understand Electrical parameters associated with batteries charging/discharging curves and of a battery management system

#### Observations

Determine the following parameters of the two different types of battery

- Terminal voltage
- Charge capacity of the battery
- C rating of the battery
- Safe charging/discharging current of the battery:  $\frac{\text{Charge capacity of the battery}}{\text{charging time of the battery}}$
- For Discharging curve: Disconnect PV and grid connection. Switch on the load and measure the battery voltage every 3 mins.
- Take 10 readings and tabulate the findings as shown

Time	Battery terminal voltage(V)

#### Results

Plot time vs. battery voltage. (To find charging curve of the battery, connect PV & grid and disconnect the load. Repeat the same procedure as discharging characteristics to obtain the charging characteristics curve.)



## Experiment No. 16

### MPPT and PWM charge controller characteristics.

#### Objective

To understand difference between MPPT and PWM charge controller, efficiency of MPPT and PWM charge controller and energy flow in a system involving MPPT and PWM charge controller

#### Observations

Observe the working of MPPT and PWM charge controller.

Efficiency of the charge controller is calculated =  $\frac{V_{cc} I_{cc}}{V_{pv} I_{pv}} * 100\%$

If the PV output is low due to cloudy conditions constant voltage and current source can be used instead of PV panel.

#### Tabulation

Type of charge controller	Voltage from PV panel V <sub>pv</sub> (V)	Current from PV panel I <sub>pv</sub> (A)	Voltage from the charge controller V <sub>cc</sub> (V)	Current from the charge controller I <sub>cc</sub> (A)	Efficiency of the charge controller
PWM					
MPPT					

#### Results

Draw the I-V and P-V curves for PWM and MPPT and mark the maximum power points under different radiation and temperatures level.

## Experiment No. 17

### Study of Solar DC System

#### Objective

To understand and determine the power flow in a solar DC system.

#### Observations

Circuit connections are made as for the solar DC System and the voltage and current readings at various points are determined using clamp meter and tabulated.

#### Tabulation

- Voltage from PV panel V<sub>pv</sub> (V) :
- Current from PV panel I<sub>pv</sub> (A) :
- Voltage to/from battery V<sub>bat</sub> (V) :
- Current to/from battery I<sub>bat</sub> (A) :
- Voltage to LED1 :
- Current to LED1 :
- Voltage to LED2 :
- Current to LED2 :
- Voltage to LED3 :
- Current to LED3 :
- Voltage to fan :
- Current to fan :

Various loading conditions	Power from PV panel P1(W)	Power to the battery P2(W) (If current is flowing into the battery represent the power as negative)	Power to the load P3 (W)	Efficiency of DC system = $P3/(P1 + P2)$
LED1				
LED1+LED2				
LED1 + LED2 +LED3				
Fan				
All loads are ON				

### Results

Conclude on the obtained observation and determine the power flow in the system.

## Experiment No. 18

### Solar PCU Study

#### Objective

To understand how a solar PV standalone system works

To determine the power flow in a solar PV system

#### Observations

Voltage and current values at various points of the system can be determined either by using the monitoring software or clamp meter. Load box consists of four tungsten bulbs; each one needs to be switched ON in succession and the voltage and current values needs to be determined.

#### Tabulation

Loading condition	Power from the PV panel P1 (W)	Power from battery P2 (W) (negative if current flows into the battery)	Power to the load P3 (W)	Efficiency of the PCU
Bulb 1				
Bulb1+2				
Bulb1 +2+3				
Bulb 1+2+3+4				

### Results

Conclude on the obtained observation with variations in load and determine the power flow in the system.

## Experiment No. 19

### Demo on Conversion of Normal Inverter to Solar Inverter

#### Objective

To convert a normal inverter system to a solar inverter system.

#### Observations

Efficiency of the solar conversion kit is determined by measuring the input and output power.

Power Input	Power Output	Efficiency

#### Results

Conclude on the power variations and efficiency determined with the inclusion of solar conversion kit.

## Experiment No. 20

### Comparison of Various Inverters Using Electroscopy

#### Objective

To compare the performance of two inverters using electroscopy

#### Observations

Electroscopy is equipment which can be used to measure the efficiency of an inverter.

Usage instructions for electroscopy is in the appendix section.

Efficiency of two inverters are determined and noted down.

Tabulate

	Efficiency
Inverter - 1	
Inverter - 2	

#### Results

Conclude on the efficiency of different Inverters.