SOLAR PHOTOVOLTAIC SYSTEM DESIGN AND INSTALLATION

(UGC approved certificate course)

Post Graduate Department of Physics

G.S.S.D.G.S Khalsa College (Autonomous), Patiala –147002

Certificate course	*Solar photovoltaic system design and installation*
Course Coordinator	Dr. Arvind Sabharwal
Department	Physics
Mail ID	arvindsabharwal1976@gmail.com
Duration	120 hours
Credits	4
Timings	Saturdays, Sundays and Punjab Government Holidays/working days as per feasibility
Eligibility	10+2 with Physics, Students pursuing Diploma in Electrical, Mechanical and Electronics, B.Sc (N.M), B.Sc (Comp) and all others related to Physics stream after 10+2.
Course fee	Rs. 8000/- (Rupees Eight thousand only)
Examination Fee	Rs 1620/- (Rupees one thousand and twenty only)

Objectives:

The programme aims to develop the skills of youth, considering the opportunities for employment in the growing Solar Energy Power project's installation, operation & maintenance in India and abroad. The Programme is designed to prepare the candidates to become new entrepreneurs in Solar Energy sector.

Learning outcomes:

The course teaches the basics of electrical, SPV applications and solar power plant including standards, preventive maintenance, trouble-shooting etc. This programme is also designed to prepare the candidates to become new entrepreneurs in Solar Energy sector. It will cover the following learning outcomes:

- Understand the basics solar energy and concept of solar PV (photovoltaic) system
- Survey a solar PV installation site
- Understand all equipment related to solar PV system
- Design an y solar PV system as per Customer's requirements as well as appropriate codes and standards
- Prepare the necessary technical documents related to the design, installation and operation of the PV system
- Installation of solar PV system based on the relevant designs and drawings.

- Operation and Maintenance of solar PV system including identification and troubleshooting of faults along with ensuring of safety while installation and operation
- Undertake project management for installation of solar PV system
- Understand necessary formalities with authorities for applications, submissions, approvals, interconnections, inspections, certifications, commissioning, etc. for PV system
- National and State Policies for SPV Power Plants
- Different Metering mechanisms and Key Implementation Requirements, Standards, Regulations
- Pre-commissioning inspection of the Solar PV Power Plant
- Work safety at a SPV site including knowledge of Personal Protective Equipment, First-aid kit, Fire-extinguishers and Safe job practice at height.
- Understand the basics concept of various solar thermal technologies
- Site survey of a solar thermal system
- Understand all equipment related to the solar thermal system
- Design of solar water thermal system as per Customer's requirements as well as appropriate codes and standards
- Prepare the necessary technical documents related to the design, installation and operation of the solar thermal system
- Installation of a solar thermal system based on the relevant designs and drawings
- Operation and Maintenance a solar thermal system and ensuring safety while installation and operation of the solar thermal system
- Undertake project management for installation of a solar thermal system
- Understand the various necessary formalities with authorities for applications, submissions, approvals, interconnections, inspections, certifications, commissioning, etc. for solar thermal system
- National and State Policies for solar thermal system
- Pre-commissioning inspection of the Solar thermal Power Plant
- Work safety at a solar thermal installation site including knowledge of Personal Protective Equipment, First-aid kit, Fire-extinguishers and safe job practice at height.
- General aspects of Entrepreneurship and start-up of business
- Development of solar business in the field of Manufacturing, Installation, Operation & Maintenance, Testing & Commissioning
- Development of business-specific project profile including Market Research, Land & Cost analysis, Vendor availability, Transport feasibility, Manpower, Loans, Policies & Subsidies

Scope:

India has tremendous scope of generating solar energy. The geographical location of the country stands to its benefit for generating solar energy. The reason being India is a tropical country and it receives solar radiation almost throughout the year, which amounts to 3,000 hours of sunshine. This is equal to more than 5,000 trillion kWh. Almost all parts of India receive 4-7 kWh of solar radiation per sq metres. This is equivalent to 2,300–3,200 sunshine hours per year. States like Punjab, Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, and West Bengal have great potential for tapping solar energy due to their location. Since majority of the population lives in rural areas, there is much scope for solar energy being promoted in these areas. Use of solar energy can reduce the use of firewood and dung cakes by rural household. The electricity bill of a household can be reduced to only Rs 3000 a year by installation of a solar power roof top plant.

Solar Energy Power in India: Future

Initiatives by Punjab Energy Development Agency (PEDA) in our state Punjab

I. Solar Photovoltaic projects of capacity 9.5 MW has been commissioned in the State under Jawaharlal Solar Mission, Govt. of India Programme.
II. Another 1 no. plant of capacity 1 MW has also been commissioned at Village Phullokhari, District Bathinda.
III. 27 plants of Capacity 219 MW Solar Power Plants under Phase I have been commissioned.
IV. 21 plants of Capacity 194 MW solar Power Plants have been commissioned.
V. 19 no plants of 500 MW Solar Power Plants which were allocated and out of which 12 plants of 325 MW capacity plant have been commissioned and 175 MW are under construction.
VI. A major rooftop programme for Solar Photovoltaic Power Project has been launched in the State under which the rooftop SPV Power Projects has been setup at various important Govt., Institutional and Religious buildings namely Punjab Raj Bhawan, Punjab Civil Secretariat, Golden Temple, Wagah Border, Punjab Agricultural University, Ludhiana and Pushpa Gujral Science City, Kapurthala. Rooftop projects shall be continued to be promoted in all sectors in order to enhance the share of solar power in the State.

Rooftop Solar Power Plants:

VII. World's Largest rooftop plant of 19.50 MW was set up at Beas, Amritsar and power being sold to PSPCL under 25 Years PPA.
VIII. India's second largest Single rooftop solar power plant capacity 2 MW was facilitated and has been installed at The New Fruit and Vegetable Market, SAS Nagar (Mohali) under the Rooftop Projects category.

IX. Second highest capacity 12.9 MW was achieved under Net Metering scheme rooftop solar projects by covering 399 homes/schools/industry / commercial establishments etc.

ORDINANCE FOR

CERTIFICATE COURSE

ON

"SOLAR PHOTOVOLTAIC SYSTEM DESIGN AND INSTALLATION"

UNDER

DEPARTMENT OF PHYSICS

GENERAL SHIVDEV SINGH DIWAN GURBACHAN SINGH KHALSA COLLEGE,
PATIALA

(AN AUTONOMOUS COLLEGE)

(NAAC ACCREDITED 'A' GRADE)

COLLEGE WITH POTENTIAL FOR EXCELLENCE STATUS BY UGC
E-MAIL: KHALSACOLLEGEPATIALA@GMAIL.COM
WEBSITE: WWW.KHALSACOLLEGEPATIALA.ORG

GUIDELINES

These Guidelines shall be effective from the July 01, 2019. This program initially was developed by NISE and 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 *SOLAR PHOTOVOLTAIC SYSTEM DESIGN AND INSTALLATION* Program will be consisting of 120 hrs including developing soft and entrepreneurship skills.

2. SELECTION OF PARTICIPANTS:

For selection of participants to this certificate course, following essential and preferable qualifications are required:

Essential Qualification: The candidate should be 10+2 (Science Stream, Diploma in Electrical, Mechanical and Electronics) not below 18 years. 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 college 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 college and the details of the proposed participants would be put on website 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 training program would be designed to run on Saturday/Sunday and other Government Holidays.

2. 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. Each participant/group shall be given an access to proper toolkits for working in the lab/site.

8. 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.

9. 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.

10. 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.

11. 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) A nominal fee would be charged from the trainees.
b) No boarding and lodging of the trainees will be provided by the college.

8. ASSESSMENT OF TRAINEES:

The final examination consisting of written test, practical examination shall be conducted at the end of 120 hrs by Controller, Examinations, Khalsa College, Patiala.

9. INDUSTRIAL VISIT

During first month of 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 certificate program, the host institute may arrange for placement of learners 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.

Curriculum

1. 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.
2. 'T' represents theory hours and 'P' represents practical hours. For example : a session "1T and 5P" refers to total 6 hours of session with 1 hour of theory and 6 hours of practical
3. 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.

SCHEME

SOLAR PHOTOVOLTAIC SYSTEM DESIGN AND INSTALLATION
CREDIT- 4
SESSION 2019-2020 & 2020-2021

Code	**Title of Paper**	**Credit**	**Max Marks**			**Examination Time (Hours)**
Papers						
CSPS 1.1.1	Solar Photovoltaic System Design And Installation (Theory, MCQ) Syllabus provided in Modules 4.1 – 16.2 under Sessions 9-15 (Page9-13)	1	30			1
Laboratory/Practical's			**Total**	**Ext.**	**Int.**	**Total**
CSPS 1.1.2	Solar Photovoltaic System Design And Installation (Practical) Syllabus provided in Practical Sessions (Page 16-25)	3	70			4

SESSIONS 1 to 16

Session 0 : Course on Basic Electricals (4 Days: 7T + 17P)

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, rachet, 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, MCCCB 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 ferules 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 & it's 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

Lightening arrestor : 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+3P)

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 (2 Days: 5T + 7P)

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 (2 days:5T+7P)

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 (2 Days : 4T and 8P)

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 standalone 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 (2 Days: 3T and 9P)

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 (2 Days: 4T and 8P)

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 10P)

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
(1 Days : 1T and 5P)

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
(2 Days : 2T and 10P)

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 5P)

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 (1 Days: 1T and 5P)

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 (1 days : 1 Theory and 5 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 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.

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 difference 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.

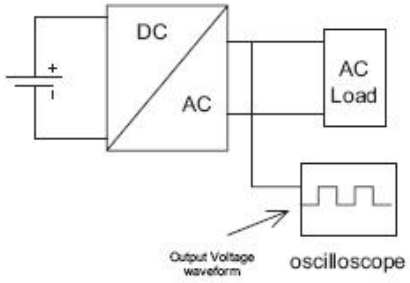

Fig.1. Experimental set-up for waveform observation

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 sets on a single graph and show the characteristics at different radiation and temperatures level.
2. Draw the P-V curves of all sets on a single graph and show the characteristics at different radiation and 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 equipment's.
Determine resolution and accuracy of measuring equipment's.

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 Charactertics 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 sets on a single graph and show the characteristics at different radiation and 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.

Equipment's 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 Charactertics

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:

_____

- 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 = *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 Vpv (V)	Current from PV panel I pv (A)	Voltage from the charge controller Vcc (V)	Current from the charge controller Icc (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 Vpv (V) :
- Current from PV panel Ipv (A) :

Voltage to/from battery Vbat (V) :

- Current to/from battery Ibat (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 electroscopy6+

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.