INSTITUTE OF AERONAUTICAL ENGINEERING
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Lab Manual:

High Voltage Engineering and Solar Laboratory (AEE111)

Prepared by

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Contents

INTRODUCTION

Introduction

This course is intended for practical experience by conduction experiments on different mediums of insulation break down and deal with solar power generation and measurement technology. It provides hands-on experience by examining the breakdown strength. The solar power applications have been analyzed with simulation tools.

Student Responsibilities

The student is expected to be prepared for each lab. Lab preparation includes reading the lab experiment from the lab manual. If you have questions or problems with the preparation, contact your Lab Assistant and faculty incharge but inatimely manner. Do not wait until an hour or two before the lab and then expect the lab Assistant and faculty incharge to be immediately available.

Active participation by each student in lab activities is expected. The student is expected to ask the Lab Assistant and faculty incharge any questions they may have.

A large portion of the student's grade is determined in the comprehensive final exam, resulting in a requirement of understanding the concepts and procedure of each lab experiment for the successful completion of the lab session. The student should remain alert and use common sense while performing a lab experiment. They are also responsible for keeping a professional and accurate record of the lab experiments in the lab manual wherever tables are provided. Students should report any errors in the lab manual to the faculty incharge or course coordinator.

Responsibilities of Faculty Teaching the Lab Course

The Faculty shall be completely familiar with each labprior to the laboratory. He/She shall provide the students with details regarding the syllabus and safety review during the first week.Lab experiments should be checked in advance to make sure that everything is in working order.The Faculty should demonstrate and explain the experiment and answer any questions posed by the students.Faculty have to supervise the students while they perform the lab experiments. The Faculty is expected to evaluate the lab worksheets and grade them based on their practical skills and understanding of the experiment by taking Viva Voce. Evaluation of work sheets has to be done in a fair and timely manner to enable the students, for uploading them online through their CMS login within the stipulated time.

Laboratory In-charge Responsibilities

The Lab Assistant shall be completely familiar with each lab prior to class. The Lab Assistant shall provide the students with a syllabus and safety review during the first class. The syllabus shall include the Lab Assistant office hours, telephone number, and the name of the faculty coordinator. The Lab Assistant is responsible for ensuring that all the necessary equipment and/or preparations for the lab are available and in working condition. Lab experiments should be checked in advance to make sure everything is in working order. The Lab Assistant should fully answer any questions posed by the students and supervise the students performing the lab experiments. The Lab Assistant is expected to grade the lab notebooks and reports in a fair and timely manner. The reports should be returned to the students in the next lab period following submission. The Lab Assistant should report any errors in the lab manual to the faculty coordinator.

Course Coordinator Responsibilities

The faculty coordinator should ensure that the laboratory is properly equipped, i.e., that the teaching assistants receive any equipment necessary to perform the experiments. The coordinator is responsible for supervising the Lab Assistant and resolving any questions or problems that are identified by the Lab Assistant or the students. The coordinator may supervise the format of the final exam for the lab. They are also responsible for making any necessary corrections to this manual and ensuring that it is continually up dated and available.

Lab Policy and Grading

The student should understand the following policy:
ATTENDANCE: Attendance is mandatory and any absence must be for a valid excuse and must be documented.
LAB RECORD's: The student must:

1. Perform the Pre lab assignment before the beginning of each lab,
2. Keep all work in preparation of and obtained during lab; and
3. Prepare a lab report on experiments which is done by student on a particular session.

Grading Policy:

The final grade of this course is determined using the criterion detailed in the syllabus.

Pre-Requistes and Co-Requisties:

General semiconductor devices exposure, power electronic converters and electrical instruments.

Note that the instructor reserves the right to alter any part of this information at their discretion. Any changes will be announced in class and distributed in writing to the students prior to the change staking effect.

Course Goals and Objectives

The objective of this course is to conduct experiments with different breakdown medium of insulation, measurement of high AC and DC voltages, testing of insulation under all types of conditions using generated high DC and AC voltages and this course includes experiments deal with solar power measurement technology.:

1. The different dielectric materials and their break down strength.
2. The measurement of high voltages and currents and testing of electrical apparatus
3. The Characteristics of PV System and measure the PV module specifications.

Use of Laboratory Instruments

One of the major goals of this lab is to familiarize the student with the proper equipment and converter concepts. Some understanding of the lab instruments is necessary to avoid personal or equipment damage. By understanding the device's purpose and following a few simple rules, costly mistakes can be avoided. In general, all devices have physical limits. The following rules provide a guide line for instrument protection.

Instrument Protection Rules

1. Set instrument scales to the highest range before its usage.
2. Be sure instruments are handled properly to avoid accidental touching of" hot" work pieces.
3. Check polarity markings and connections of instruments carefully before connecting power.
4. Never keep sharp tools such screw driver, tester and cutter in apron pockets.

Data Recording and Reports

The Laboratory worksheet or Observation

Students must record their experimental values in the provided tables in this laboratory manual and reproduce them in the lab reports. Reports are integral to recording the methodology and results of an experiment. In engineering practice, the laboratory work sheet serves as an invaluable reference to the technique used in the lab and is essential when trying to duplicate a result or write a report. Note that the data collected will be an accurate and permanent record of the data obtained during the experiment and the analysis of the results. You will need this record when you are ready to prepare a lab report.

The Lab Record

Records are the primary means of communicating your experience and conclusions to other professionals. In this course you will use the lab report to inform your faculty incharge about what you did and what you have learned from the experience. Engineering results are meaningless unless they can be communicated to others. You will be directed by your faculty incharge to prepare a lab report on a few lab experiments during the semester.

Your laboratory record should be clear and concise. The lab record shall be typed on a word processor. As a guide, use the format on the next page. Use tables, diagrams, as necessary to show what you did, what was observed, and what conclusions you can draw from this.

Order of Lab Report Components

COVERPAGE- Cover page must include lab name and number, your name, your lab partner's name, and the date the lab was performed. OBJECTIVE - Clearly state the experiment objective in your own words. EQUIPMENTUSED- Indicate which equipment was used in performing the experiment. FOREACHPARTOFTHELAB: Write the lab's part number and title in bold font. • Firstly, describe the problem that you studied in this part, give an introduction of the theory, and explain why you did this experiment. Do not lift the text from the lab manual; use your own words. • Secondly, describe the experimental setup and procedures. Do not follow the lab manual in listing out individual pieces of equipment and assembly instructions. That is not relevant information in a lab report! Instead, describe the circuit as a whole and explain how it works. Your description should take the form of a narrative, and include information not present in the manual, such as descriptions of what happened during intermediate steps of the experiment. • Thirdly, explain your findings. This is the most important part of your report, because here, you show that you understand the experiment beyond the simple level of completing it. Explain (compare expected results with those obtained). Analyze (analyze experimental error). • Finally, provide a summary of what was learned from this part of the laboratory experiment.Iftheresultsseemunexpectedorunreliable,discussthemandgivepossibleexplanation CONCLUSIONS-The conclusion section should provide a take-home message summing up what has been learned from the experiment: • Briefly re state the purpose of the experiment(the question it was seeking to answer) • Identify the main findings(answer to the research question) • Note the main limitations that are relevant to the interpretation of the results • Summarize what the experiment has contributed to your understanding of the problem PROBING FURTHER QUESTIONS-Questions pertaining to this lab must be answered at the end of laboratory report.

LAB-1 ORIENTATION

1.1 Introduction

In the first lab period, the students should become familiar with the location of equipment and components in the lab, the course requirements, and the teaching instructor.

1.2 Objective

To familiarize the students with the lab facilities, equipment, standard operating procedures, lab safety, and the course requirements

1.3 Prelab Preparation:

Read the Introduction and procedure of the experiment of respective experiments which are given this manual.

1.4 Equipment needed

Lab manual

1.5 Procedure

1. During the first laboratory period, the instructor will provide the students with a general idea of what is expected from them in this course. Each student will receive a copy of the syllabus, stating the instructor's contact information. In addition, the instructor will review the safety concepts of the course.

2. During this period, the instructor will briefly review the equipment which will be used throughout the semester. The location of instruments, equipment, and components will be indicated. The guide lines for instrument use will be reviewed.

1.6 PROBINGFURTHERQUESTIONS

Questions pertaining to this lab must be answered at the end of laboratory report.

LAB-2 Generation of Ac High Voltages

2.1 Introduction

Generation of high voltages at power frequency is essential for testing the efficacy of insulation of High Voltage Apparatus used in Power Systems. The generation and testing is carried out in a laboratory, using High Voltage testing transformers. These testing transformers can either be located indoor or outdoor. Testing transformers are different from power transformers in a sense that they are not rated for high power handling. They are designed to withstand frequent short circuits when the test object fails or experiences flashover. Therefore, special methods are used, which are not applicable when generating high voltage in high power applications.

2.2 Objective

By the end of this lab, the student should learn the how to generate the high AC Voltages.

2.2.1 Prelab Preparation:

Read the material in the text book that describes operation of cascaded transformer. Prior to coming to lab class, have glance of the Procedure.

2.3 Equipment

1. Cascaded transformer.
2. Control Pannel.
3. Rectifier.
4. Resistance Divider.

2.4 Background

The optimum rating of a single testing transformer unit is 300 kV. Beyond this level, the cost of insulation rises rapidly and transportation becomes difficult. Cost of insulation for a single unit is proportional to square of operating voltage. At higher test voltages a cascade arrangement of several single unit transformers is used to generate high voltages for testing. Each of the units are enclosed by large size metal rings to prevent corona. For voltages higher than 400 KV, it is desired to cascade two or more transformers depending upon the voltage requirements. The transformers are usually identical, but transformers different designs can also be used. With this, the weight of the whole unit is subdivided into single units and, therefore, transport and erection becomes easier.

2.5 Procedure

1. Connect 1 phase 230V AC supply to the control panel.
2. Connect variable output to the input of the transformer. [P1 – Red, P2 – Black, A – Green]
3. Connect HT lead of the transformer to test specimen and the specimen should be grounded with the control panel ground and mother ground.
4. Switch on the mains and control MCB.
5. Insert key and put the control circuit to ON.
6. If emergency button is pressed release it. (Turn clockwise to release)
7. Press MAINS ON; the MAINS ON, HT OFF indicators starts glowing.
8. If the SAMPLE FAIL/RESET is glowing, reset the equipment.
9. If dimmer is not in zero position after pressing the reset button, it will auto return. In this process the HT DECREASE indicator will glow. Once it reaches zero, the UNIT READY indicator glows.
10. Select the tripping current with the help of leakage current selector switch
11. Press the HT ON then HT ON indicator starts glowing while HT OFF indicator goes off.
12. Increase the voltage at required level with the help of HT INCREASE push button.
13. If breakdown occurs in-between then SAMPLE FAIL/RESET indicator glows and dimmer is stopped.
14. For withstand test put the TIMER switch to ON position. If the equipment trips within the set time then we conclude that the specimen has failed and the SAMPLE FAIL/RESET glows.
15. If specimen withstands the voltage in set time, we conclude that the specimen has passed the test and SAMPLE PASS indicator glows.

2.6 Circuit Diagram

2.7 ProbingFurtherQuestions

1. How do you increase the voltage of an AC circuit?
2. How do you convert low voltage to high?
3. what are the disadvantages of using cascaded transformer?
4. What is the continuous rating of Cascade transformer?
5. Why is Cascade necessary?

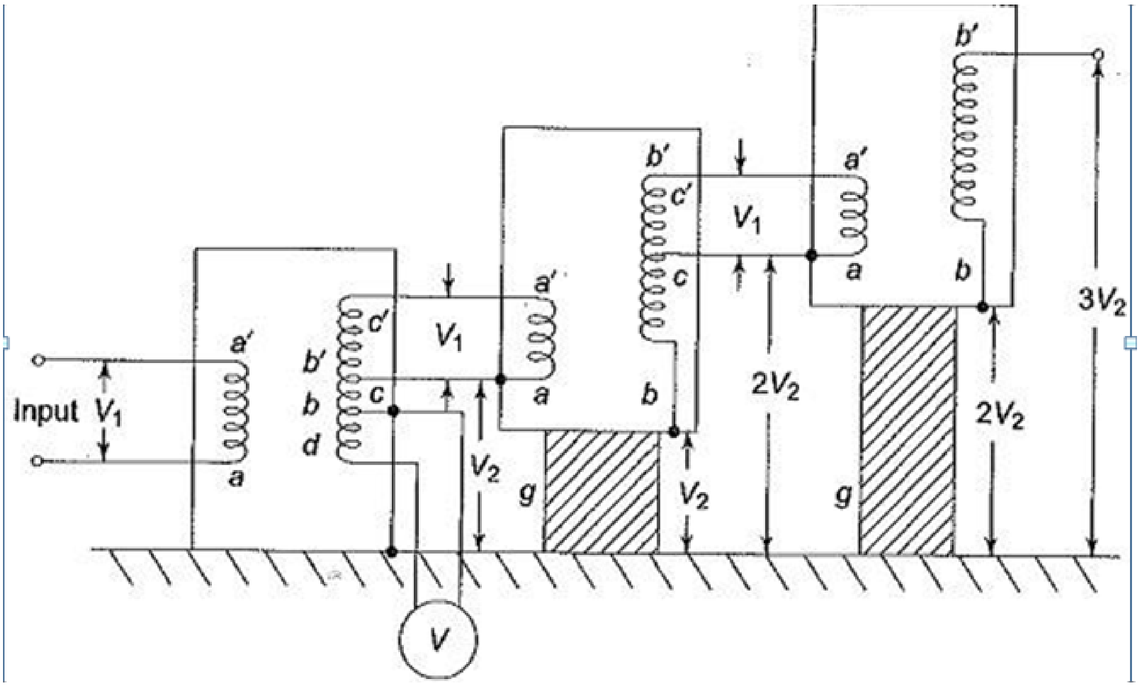


Figure 2.1: Generation of Ac High Voltages .

LAB-3 Verification of Breakdown Potential of Air at Specified Gap

3.1 Introduction

A gas in its normal state is almost a perfect insulator, however, when a high voltage is applied between the two electrode immersed in a gaseous medium. The gas becomes a conductor and an electrical breakdown occurs. The processes that are primarily responsible for the breakdown of gas are ionized by collision, photo ionization and the secondary ionization processes.

3.2 Objective

By the end of this lab, the student should learn the spark over characteristics of following electrode configurations in air subjected to HVAC. The set of electrodes are as below. i) Point to Point electrodes.

3.3 Prelab Preparation:

Read the material in the textbook that describes the spark over characteristics of pin elelectrodes. Prior to coming to lab class, have glance of the Procedure.

3.4 Equipment needed

1. Cascaded transformer.
2. Control Pannel
3. Rectifier.
4. Resistance Divider
5. Rod gap apparatus

3.5 Background

The process of liberating an electron from a gas molecule with the simultaneous production of a positive ion is called ionization. If the electric field is uniform, a gradual increase in voltage across a gap produces a breakdown in voltage across the gap on the other hand, if the field is non-uniform an increase in voltage will first cause a discharge in the gas to appear at points with highest electric field intensity, namely at sharp points or where the electrodes are curved or on transmission lines. This form of discharge is called a corona discharge and can be observed as bluish luminance. This phenomenon is always accomplished by hissing noise and the air surrounding the corona region becomes converted into Ozone.

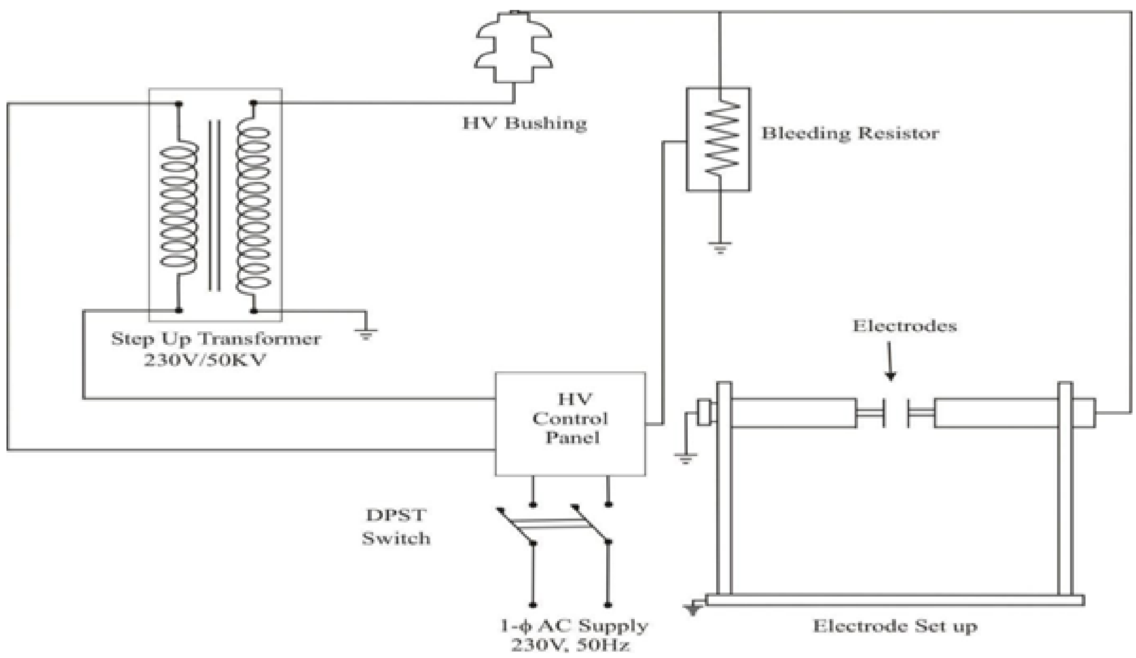
3.6 Procedure

1. Connections are made as per the circuit diagram.
2. Ensure all earth potentials are properly connected to the main earth point.
3. Keep the dimmer at zero position.
4. Place the electrode set, make zero adjustment and keep certain space between the electrodes configuration.
5. Switch ON the power supply to the control panel.
6. Slowly and gradually increase the voltage with the help of dimmer until the flash over occurs between the two electrodes used in the set.
7. Note down the gap length and flash over voltage with the help of meter provided in the control panel.
8. Repeat the above procedure for different gap length between the electrodes and also for the different electrode configuration with both positive and negative polarity.
9. Then plot the graph between flash over Voltage V/s the gap length.

3.7 Point to Point Electrodes.

1. Cascaded transformer.

3.8 Circuit Diagram



S. No	Gap Length (mm)	Breakdown Voltage in KV

3.9 Point to Point Electrodes.

3.10 ProbingFurtherQuestions

1. What is the breakdown voltage of air?
2. What is meant by breakdown voltage?
3. What is the relation between breakdown voltage V and GAP distance d is?
4. Why does breakdown voltage increase with pressure?

LAB-4 Determination of Breakdown Voltage of Air by Rod Gap Apparatus

4.1 Introduction

Atmospheric air has been widely used as an insulation medium for high voltage electrical apparatuses. However, compared with apparatuses that use SF6 gas, those that use air are far larger because of the lower insulation performance of air. To combat this problem, the breakdown voltage of the gas-insulated gap under a non-uniform electric field can be increased by inserting a barrier in the inter-electrode gap. This can not only reduce the size of the apparatus by reducing the volume of air required, but also improve the reliability of the insulation

4.2 Objective

By the end of this lab, the student should learn the spark over characteristics of following electrode configurations in air subjected to HVAC. The set of electrodes are as below. i) Point to Plane electrodes. ii) Plane to Plane electrodes.

4.3 Prelab

Read the material in the textbook that describes characteristics of electrodes using breakdown of insulation under specimen. Prior to coming to lab class, have glance of the Procedure.

4.4 Equipment needed

1. Cascaded transformer
2. Control Pannel
3. Rectifier.
4. Resistance Divider
5. Rod gap apparatus

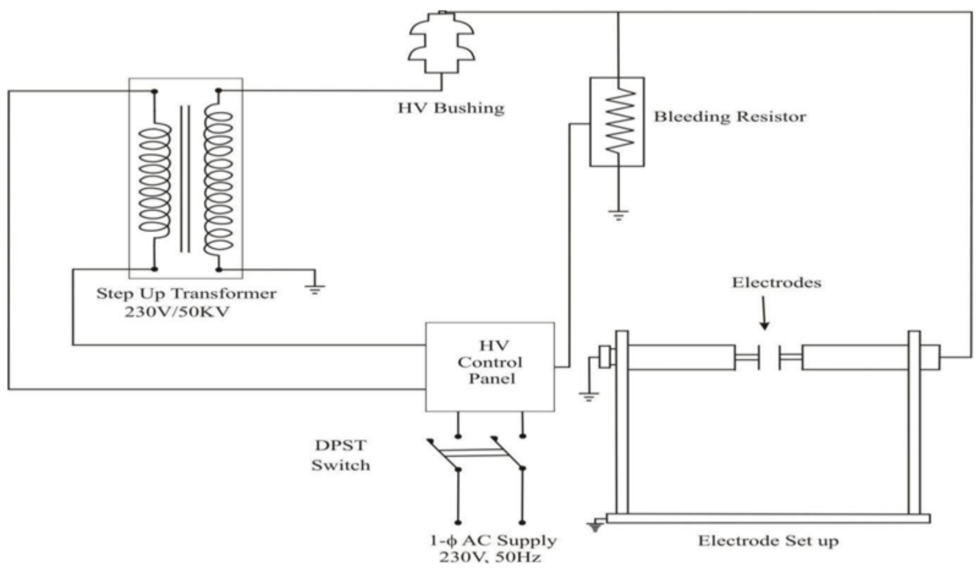
4.5 Background

The most efficient method of generating high DC voltages is through the process of rectification employing voltage multiplier circuits. However, more recent investigations have shown that these rods can be used for dc measurement provided; certain regulations regarding the electrode configurations are observed. The breakdown voltage of a rod gap increases more or less linearly with increasing relative air density over the normal variation in atmospheric pressure, also the breakdown voltage increases with increasing relative humidity. The earthed electrode must be long enough to initiate positive breakdown streamers. If the high voltage rod is the cathode with this arrangement, the breakdown voltage will always be initiated by positive streamer for both the polarities, thus giving a very small variation and being humidity dependent. High voltage rectifier is used in this experiment, which is fabricated using high quality and high stability diodes. These diodes are connected in series to withstand the required voltage. The entire assembly is put inside the epoxy fiber glass tubes filled with oil, for cooling. The epoxy fiber glass tubes are painted with anti tracking paints

4.6 Procedure

1. Connections are made as per the circuit diagram.
2. Ensure all earth potentials are properly connected to the main earth point.
3. Keep the dimmer at zero position.
4. Place the electrode set, make zero adjustment and keep certain space between the electrodes configuration.
5. Switch ON the power supply to the control panel.
6. Slowly and gradually increase the voltage with the help of dimmer until the flash over occurs between the two electrodes used in the set.
7. Note down the gap length and flash over voltage with the help of meter provided in the control panel.
8. Repeat the above procedure for different gap length between the electrodes and also for the different electrode configuration with both positive and negative polarity.
9. Then plot the graph between flash over Voltage V/s the gap length

4.7 Circuit Diagram



S. No	Gap Length (mm)	Breakdown Voltage in KV

4.7.1 Point to Plane Electrodes.

4.7.2 Plane to Plane electrodes

S. No	Gap Length (mm)	Breakdown Voltage in KV

4.8 ProbingFurtherQuestions

1. Why do we use sphere gap for High Voltage?
2. What is breakdown voltage of capacitor?
3. What is the formula for breakdown voltage?
4. How do you calculate breakdown voltage?

LAB-5 Determination of Breakdown Voltage of Air Using Sphere Gap Apparatus

5.1 Introduction

Sphere gap is an absolute method of measurement of the peak value of high voltage for alternate, direct and 1150sec impulse voltage for spacing up to 0.5D (Where D= Sphere diameter). It can be measured accurately within ±3

5.2 Objective

By the end of this lab, the student should learn the Measurement of HVAC and using spheres gap with spark over voltage corrected to Standard Spheres.

5.3 Prelab Preparation:

Read the material in the textbook that describes operation of sphere gap measurement. Prior to coming to labclass, have glance of the Procedure.

5.4 Equipment needed

1. Cascaded transformer.
2. Control Pannel
3. Rectifier.
4. Resistance Divider
5. Sphere gap apparatus kit

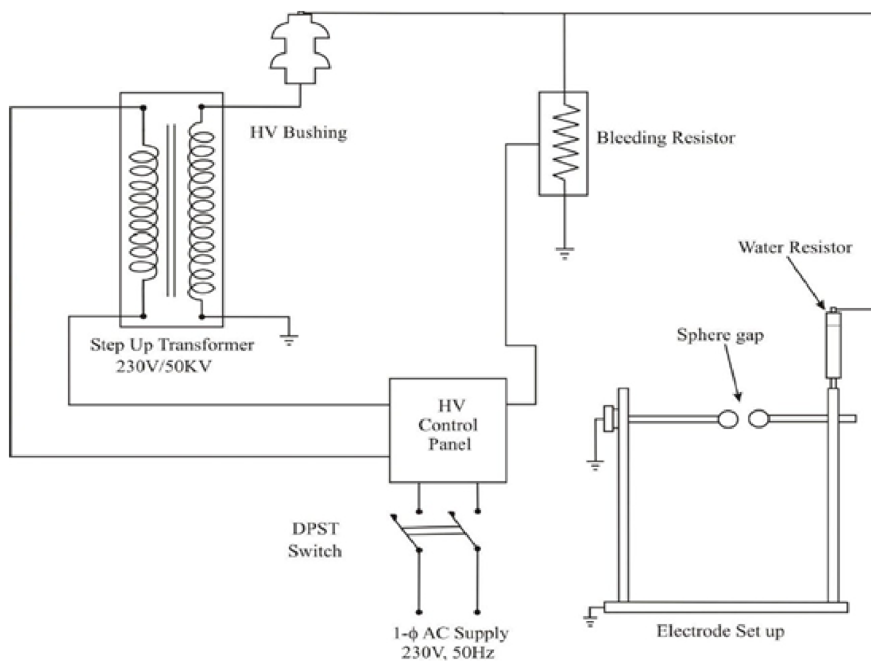
5.5 Background

There are two types of sphere gaps, namely, i) Vertical sphere gap ii) Horizontal sphere gap. In vertical sphere gap two identical spheres are arranged vertically such that lower sphere is grounded permanently. In horizontal sphere gap assembly both spheres are connected to the source. One of the sphere is grounded. In horizontal configuration it is generally arranged that both spheres are symmetrically charged at high voltage above the ground. The sphere may be made up of aluminium, brass, copper or light alloys and the surface should be free from burs. The radius of curvatures should be uniform. The radius of curvature measured with sphere meter at various points over and over by a circle 0.3D around. Sparking point should not differ by exceeding ±2

5.6 Procedure

1. Connections are made as per the circuit diagram.
2. Ensure all earth potentials are properly connected to the main earth point.
3. Keep the dimmer at zero position.
4. Place the electrode set, make zero adjustment and keep certain space between the electrodes configuration.
5. Switch ON the power supply to the control panel.
6. Slowly and gradually increase the voltage with the help of dimmer until the flash over occurs between the two electrodes used in the set.
7. Note down the gap length and flash over voltage with the help of meter provided in the control panel.
8. Repeat the above procedure for different gap length between the electrodes and also for the different electrode configuration with both positive and negative polarity
9. Then plot the graph between flash over Voltage V/s the gap length.

5.7 Circuit Diagram



5.8 Tabular Column

5.9 ProbingFurtherQuestions

1. Why do we use sphere gap for High Voltage?

S. No	Gap Length (mm)	Breakdown voltage measured from Sphere Gap V_0 in KV

2. How a sphere gap is used to measure the peak value of voltages?
3. Why is there no humidity correction factor for sphere gap?
4. What are the factors influencing the spark over voltage of a sphere gap?

LAB-6 Determination of Breakdown Voltage of Solid Insulator

6.1 Introduction

Pin type insulators are widely used in 11 kV overhead transmission and distribution systems to insulate the overhead conductors from the grounded transmission towers. These insulators are made of porcelain and have a high dielectric strength. The insulators are so designed that flashover along its surface takes place at a much lower voltage compared to the complete breakdown or puncture voltage of the insulating material

6.2 Objective

By the end of this lab, the student should learn the determination of breakdown of solid insulators such as paper, thermocol and glass

6.3 Prelab Preparation:

Read the material in the textbook that describes operation of Solid insulator. Prior to coming to lab class, have glance of the Procedure.

6.4 Equipment needed

1. Cascaded transformer.
2. Control Pannel
3. Rectifier.
4. Resistance Divider
5. Solid insulators.

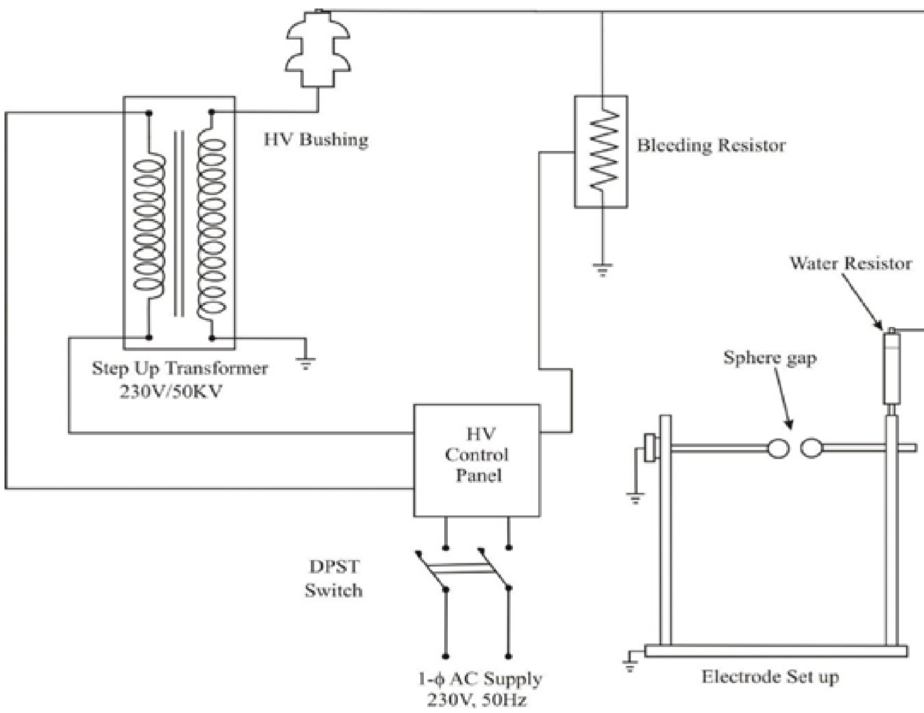
6.5 Background

The insulators are so designed that flashover along its surface takes place at a much lower voltage compared to the complete breakdown or puncture voltage of the insulating material. This is necessary because surface flashover does not cause permanent damage to the insulator; where as a puncture or breakdown of dielectric renders the insulator completely unusable. At the same time the dry as well as wet creep age lengths of the insulator is designed in such a manner so as to achieve a high surface flashover voltage.

6.6 Procedure

1. Cut the insulation sheet to different diameters
2. Place the insulation sheet between the electrodes.
3. Confirm physical contact of electrode with insulation sheet
4. Confirm proper connection between H.V. transformer and the electrode. Confirm the connection and earthing wire to H.V.and sphere gap assembly.
5. Apply voltage using dimmer-stat and observe the spark over on the material.
6. This voltage is recorded as breakdown voltage and measurements are taken at different thickness.

6.7 Circuit Diagram



6.8 ProbingFurtherQuestions

1. What is the breakdown voltage of an insulator?
2. What is insulator breakdown?
3. How does voltage affect insulation?
4. How does an insulator work?

Material used - Insulation Paper:

S. No	Thickness (mm)	Breakdown Voltage of insulation KIT (kV)	Breakdown Voltage of S Sphere Gap Unit in (kV)

Material used - thermocol:

S. No	Thickness (mm)	Breakdown Voltage of insulation KIT (kV)	Breakdown Voltage of S Sphere Gap Unit in (kV)

LAB-7 Determination of Breakdown Voltage of Liquid Insulator

7.1 Introduction

Transformer Oil is high quality electrical insulating oil. It is manufactured using specially selected base stocks to help provide protection against oxidation and sludge formation. It is recommended for use as an electrical insulating oil in applications such as transformers, oil immersed switch gear, circuit breakers, oil filled capacitors, tap changers, reclosures and fuses,

7.2 Objective

By the end of this lab, the student should learn test oil transformer determines the dielectric strength of oil.

7.3 Prelab Preparation:

Read the material in the textbook that describes operation of Transformer. Prior to coming to lab class, have glance of the Procedure.

7.4 Equipment needed

1. Dielectric Oil testing Kit

7.5 Background

Good insulating properties, achieved by high dielectric strength and low dielectric losses are the result of careful control in manufacture and handling. High dielectric strength ensures good insulation of electrical conductors and prevention of arcing between electrodes under the voltage stresses encountered in normal insulating oil service. Low loss tangent minimizes energy loss due to the changing polarity of the alternating current. Good heat transfer and fluid flow characteristics are obtained as a result of low viscosity and pour point. This assures effective cooling of transformer cores and windings, and ease of operation of switches, circuit breakers, pumps, regulators, and load tap changer mechanisms. Good oxidation stability minimizes development of sludge and acidity in storage and service.

7.6 Procedure

1. The oil is poured in a container known as test cell the electrodes are polish spheres perfectly of brass arranged horizontally a suitable gauge is used to adjust the gap.

2. While pouring the oil sample the test cell(container should)be thoroughly cleaned and the moisture and sypended particles should be avoided in fig shown below and experimental setup for finding out the dielectric strength of the give sample of oil

3. The voltmeter is the connected on the primary side of high voltage side transformer for calibration

4. Adjust the gap between the spheres is to 4MM with the help of gauge then pour transformer oil till a depth slurries are immersed.

5. Then increase the voltage gradually and continuously till a flashover of the gap is seen on the MCB apparatus note down this voltage. This voltage is known as rapidly applied voltage

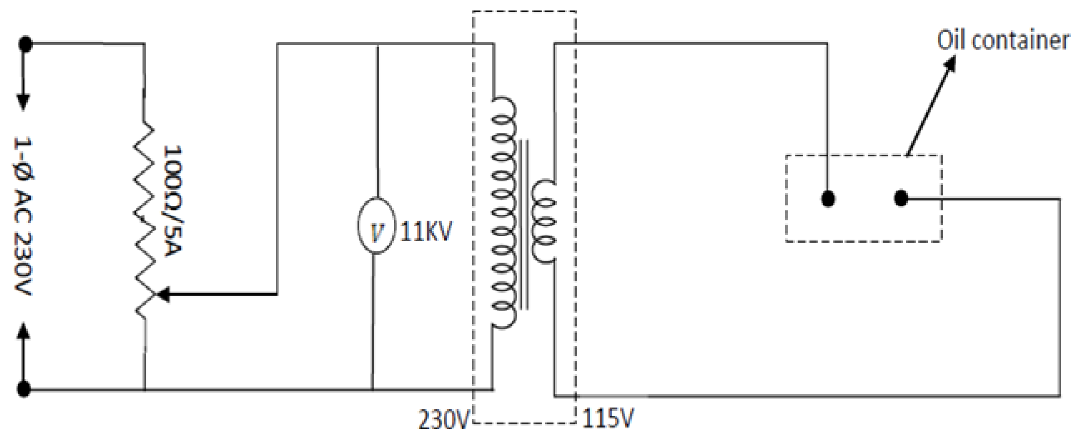
6. The breakdown of the gap has taken please mainly due to field effect. The thermal effect is main as the time of application is short

7. Next bring the voltage back Zero and star with 40 percentage of rapidly applied voltage and weight for one min.sec if the flashover by take occurred if not increase the voltage every time by of the rapidly applied voltage and wait for one min till the flash over is seen on the MCB trips. Note the voltage

8. Repeat the experiment with different values of voltage

9. The acceptable value is 30KV for 4mm and 2.5mm for 11KV the oil should be set for secondly.

7.7 Circuit Diagram



7.8 Tabular Column

7.9 ProbingFurtherQuestions

1. What is the purpose of doing BDV test on transformer oil?

2. What is the oil used in transformer?

3. What is PCB transformer oil?

S.No.	Dielectric Voltage	Average Value
1		
2		
3		

4. What is meaning of breakdown strength of insulators?

LAB-8 Characteristics of Solar Panel

8.1 Introduction

A solar cell produces small power, in range of less than a watt to few Watts. But for our applications we need the power in tens of Watts, kilowatts and sometime megawatts. Therefore, in order to generate larger power using solar cells, many solar cells are connected together to make a PV module. A solar PV module comes in various power ratings, ranging from few watts to few hundred watts. The most common technology for solar PV modules uses crystalline Si solar cells.

8.2 Objective

By the end of this lab, the student should learn the Current – Voltage (I-V) Characteristics of solar panel.

8.3 Prelab Preparation:

Read the material in the textbook that describes solar panel. Prior to coming to lab class, have glance of the Procedure.

8.4 Equipment needed

1. 11. Solar Photovoltaic (PV) Module
2. 22. DC Voltmeter
3. 33. DC Ammeter
4. 44. Rheostat
5. 55. Multi-meter

8.5 Background

The most common technology for solar PV modules uses crystalline Si solar cells. The crystalline Si solar cells are fabricated using two types of crystalline Si wafers (1) mono-crystalline and (2) multi-crystalline. The mono-crystalline Si solar cells are either circular in shape of pseudo-square, while the multi-crystalline Si cells are normally square or rectangular. Due to their shape the solar PV modules made using mono-crystalline cell have empty space between the cells while the solar PV modules.

8.6 Procedure

1. 11. Select the ammeter, voltmeter and rheostat ratings as per the circuit diagram, so that you get 20 uniformly spaced points on the voltage – current (V-I) characteristics.

2. 22. A low resistance is connected to obtain points near the short circuit condition, a high resistance to obtain points near the open circuit condition, and an intermediate value to obtain the maximum power point.

3. 33. Vary the resistance in steps to obtain the V-I characteristics.

4. 44. Obtaining the open circuit and short circuit points by actually opening and shorting the terminals.

5. 55. Vary the insulation in three steps. Note: In a solar simulator, this can be done by switching off same lamps. Under natural sun light, this can be done by changing the inclination. Increase the supply voltage in steps and measure the current. Again make sure you get equally spaced points on the curve.

8.7 Using PSCAD:

1. 11.1. Set the radiation and cell temperature valus of both arrays to be the same (ex. radiation -800 W/m**2 and Cell temparature - 50 C)

2. Simulate an observe the I-V curve

3. Reduce the radiation to PVarray-1 using the slider to emulate shading of a single cell

4. Observe the new I-V curve

8.8 Circuit Diagram

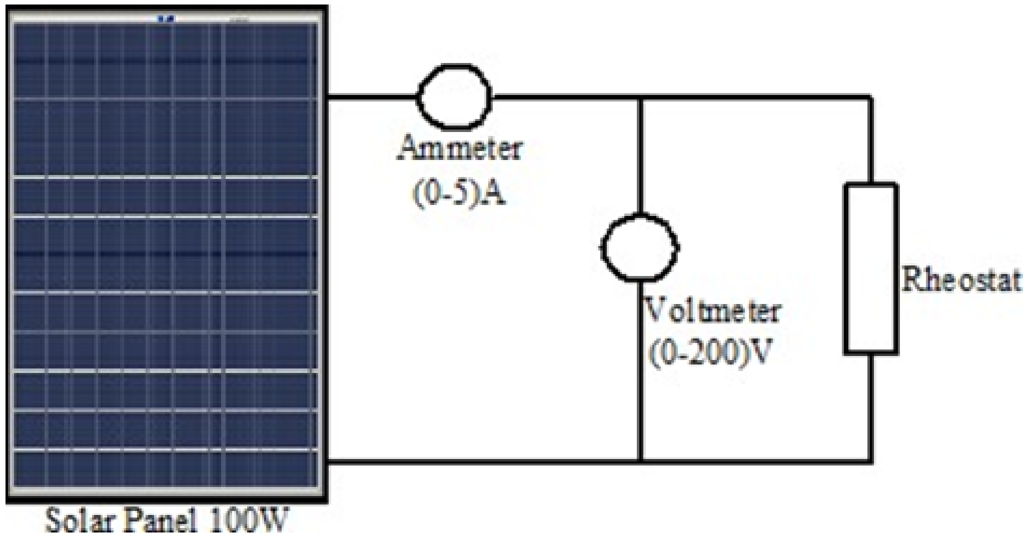


Figure 8.1: Circuit diagram to determine VI characteristics of solar panel .

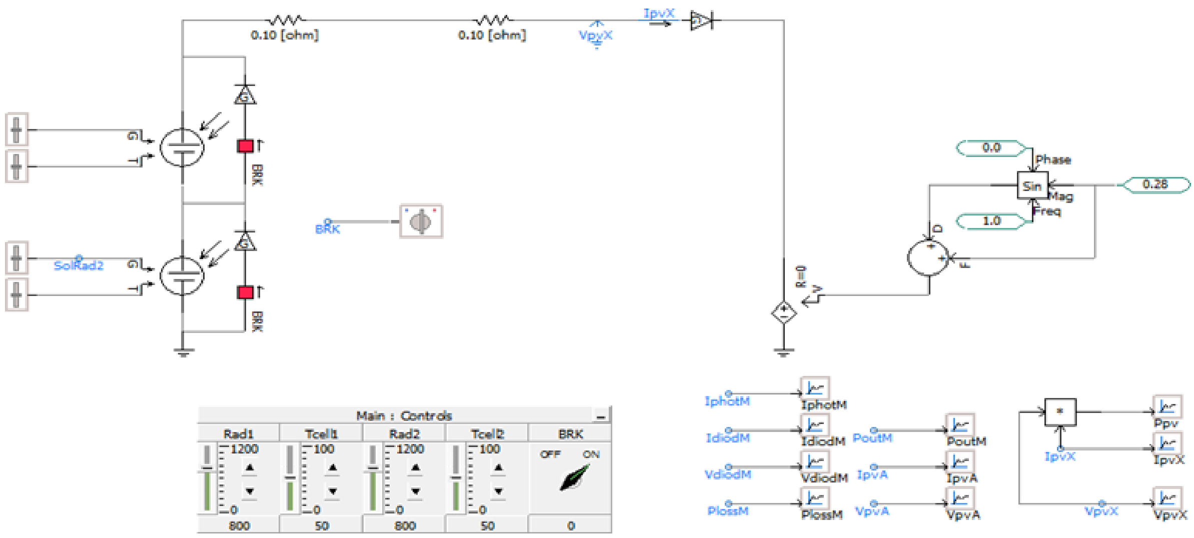


Figure 8.2: Circuit diagram to determine VI characteristics of solar panel using P .

8.9 ProbingFurtherQuestions:

1. 11. What is photovoltaics (solar electricity) or PV?
2. 22. What are the components of a photovoltaic (PV) system?
3. 33. What's the difference between PV and other solar energy technologies?
4. 44. What is the material used to design the solar panel?

LAB-9 Solar Inverter

9.1 Introduction

Inverters are power electronic devices, which convert DC (typically low voltage) into AC (at 230 V, 50 Hz) as required for conventional appliances. There are generally two types of photovoltaic inverter available: stand- alone and grid-connected.

9.2 Objective

By the end of this lab, the student should learn about the off-grid solar inverter with battery charging controller.

9.2.1 Educational

9.3 Prelab Preparation:

Read the material in the textbook that describes operation of solar inverter .Prior to coming to lab class, have glance of the Procedure.

9.4 Equipment needed

Write the text here

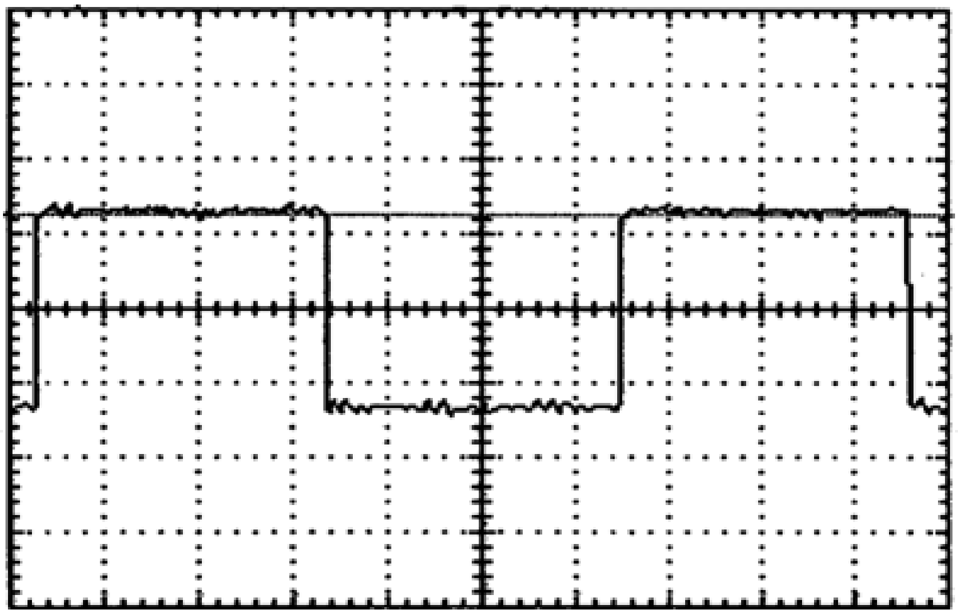
9.5 Background

Stand-alone, or battery supplied, inverters are demand driven - they provide any power or current up to the rating of the inverter and assuming that there is enough energy in the battery. These inverters are being used increasingly to operate household appliances and other "normal" 230 V equipment. The question as to the maximum size for which a single central inverter for all electrical devices is still the best solution, is a matter of philosophy. The central inverter must be in operation all the time. In this case, it is important that the inverter itself has a very low internal consumption

9.6 Theory:

9.6.1 Square Wave Inverters:

The square wave inverter derives its name from the shape of the output waveform as shown in the figure Square wave inverters were the original "electronic" inverter. The first versions use a mechanical vibrator type switch to break up the low voltage DC into pulses. These pulses are then applied to a transformer where they are stepped up. With the advent of semiconductor switches the mechanical vibrator was replaced with "solid state" transistor switches. Nowadays,



the most common circuit topology, which is used to produce a square wave output, referred to as “push-pull”. Square wave inverters run simple electric motors, but not much else, and will require a lot of energy to do so. Also, this kind of inverters is low quality. The price of better quality inverters is low enough to make the use of these unattractive.

9.6.2 Square Wave Inverters:

A sine wave inverter puts out an AC equal to what you get from utility grid, a smooth sine wave. A ’mains’ quality pure sine wave output is necessary for some applications such as running electronics or audio equipment. Two common topologies that are used to produce sine wave output are push-pull and H-Bridge. True sine wave inverters can run all types of load and are now available which are powerful, efficient and affordable! Their disadvantage is their cost, which is higher than the cost of the other kinds of inverters.

9.6.3 GRID-CONNECTED INVERTERS:

Grid-connected inverters are supply driven - they provide all the power supplied from a DC source to the grid or mains. Therefore, in grid-connected systems, the solar inverter is the connecting link between the solar generator and the AC grid, while the characteristics of the inverter have a decisive influence on the performance of the grid connected photovoltaic system. Generally, grid-connected inverters operate at a higher DC voltage than stand alone inverters. Grid-connected inverters should NOT be connected to batteries and stand-alone inverters should NOT be connected directly to PV or the grid. Smaller systems with few appliances may have only DC power, but recent advances in inverter design, efficiency, and reliability have increased the potential of solar systems considerably. With the use of modern high efficiency AC lighting the majority of, if not all, loads can be operated on AC especially in larger installations. We can use both AC and DC where each is most effective and economical - many DC appliances use less power than their AC equivalents (especially refrigeration, lighting and electronics) - but DC appliances tend to be harder to find and more expensive.

9.6.4 Working of Grid Connected Inverter

The grid-connected inverter must convert the direct current from the solar modules to alternating current synchronous with the grid. It must also be optimally matched to the I-V characteristic of the solar generator. Therefore, in PV applications the inverter will automatically adjust the PV array loading to provide peak efficiency of the solar panels by means of maximum power point tracking (MPPT). Inverters automatically shutdown in the event of:

1. High/Low grid AC-voltage
2. High/Low grid frequency
3. Grid Failure
4. Inverter malfunction

9.7 Circuit Diagram

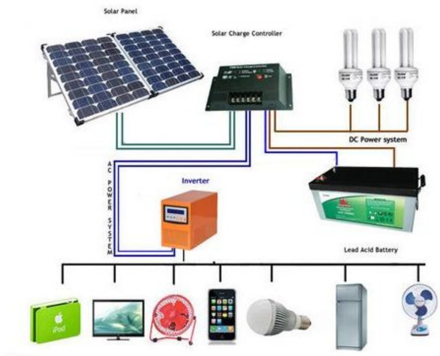


Figure 9.1: Off grid solar system with battery charging control .

9.8 ProbingFurtherQuestions

1. What is the functioning of power inverter?
2. What is the difference between a solar inverter and power inverter?
3. What Capacity of Inverter is good for Your Home?
4. What do we need inverter or UPS?

LAB-10 Effect of Shading on Solar Pannel Performance

10.1 Introduction

Energy demand in India as well as the globe is increasing day by day. This demand cannot be met only by the conventional sources. As a result, several alternative energy sources are being explored. Solar energy is one such promising source which has great potential to meet the growing need. Photo Voltaic (PV) technology is commonly used to generate electricity using sun's energy .A Photo Voltaic (PV) system consists of an array of solar panels to convert solar energy to electricity. Each solar panel is an arrangement of PV cells, made up of semiconductor materials. The capacity of PV cell can be estimated by knowing cell efficiency and fill factor

10.2 Objective

By the end of this lab, the student should learn the Series parallel connections of solar panels and effect of shading.

10.3 Prelab Preparation:

Read the material in the textbook that describes operation of Series parallel connections of solar panels and effect of shading. .Prior to coming to lab class, have glance of the Procedure.

10.4 Equipment needed

1. Flood Light
2. Card Board
3. Digital Multi Meter
4. Decade Resistance Box

10.5 Background

Over the years, solar energy has been gaining ground as a source of electricity. Photovoltaic cells convert sunlight directly to electricity. Photovoltaic (PV) cells utilize semi – conductor technology to convert solar radiation directly into an electric current which can be used or stored. Photovoltaic is a combination of two words "Photo" from Greek root meaning, light and "Voltaic" from volt which is the unit used to measure Electric potentials at a given point .The Photovoltaic effect was first noted by a French Physics that certain material would produce small amount of Electric field, ALBERT EINSTEIN described the nature of light and photovoltaic technology that it was too expensive to gain wider spread use in 1954 .Sunlight is made up of tiny particles called photons which are being converted to electrical energy. Every hour, enough of this energy reaches the world to meet the world's energy demand for the whole world. Photovoltaic panels consists of many solar cells, these are made of materials like silicon

10.6 Procedure:

10.6.1 To study the performance of the solar panel under various shading conditions:

1. Connect the circuit as shown in the figure.
2. Initially, note the voltage and current values of the solar panel.
3. Use the card board to cover the solar panel and record the voltage and current readings
4. Repeat the procedure for various types of panels with different shaded of lighting.
5. Connect PV cells in series and take the reading for various shading conditions
6. Connect PV cells in parallel and take the reading for various shading conditions

10.6.2 To study the performance of the solar panel under various shading conditions using PSCAD:

1. Close the breaker switch to (ie. by-pass diodes are present)
2. Set the radiation and cell temperature valus of both array to be the same (ex. Radiation: 800 W/m**2 and Cell temperature: 50 C)
3. Investigate the shading effect for different shading levels
4. Simulate an observe the I-V curve
5. Reduce the radiation to PVarray-1 using the slider to emulate shading of a single cell
6. Observe the new I-V curve

Note: If bypass diodes are not provided, the available power drops drastically even when a single module experiences shading.

10.7 TABULAR COLUMN:

10.8 ProbingFurtherQuestions

1. What happens if PV cell is shaded?
2. What happens if PV cells are connected in series and shaded?
3. What happens if PV cells are connected in parallel and shaded?
4. What happens when the PV cell is heated?

Coverage	0%	25%	50%	75%	100%
Voltage (volts)					
Current (amps)					

Figure 10.1: Effect of shading on cell current .

Coverage	0%	25%	50%	75%	100%
Voltage (volts)					
Current (amps)					

Figure 10.2: Effect of shading on cell current and voltage (PV cells in series) .

Coverage	0%	25%	50%	75%	100%
Voltage (volts)					
Current (amps)					

Figure 10.3: Effect of shading on cell current and voltage (PV cells in parallel) .

LAB-11 Effect of Temperature and Tilt Angle on Solar Pannel

11.1 Introduction

PV panels collect solar radiation directly from the sun, from the sky, and from sunlight reflected off the ground or area surrounding the PV panel. Orienting the PV panel in a direction and tilt to maximize its exposure to direct sunlight will optimize the collection efficiency. The panel will collect solar radiation most efficiently when the sun's rays are perpendicular to the panel's surface. The angle of the sun varies throughout the year, as illustrated. Therefore, the optimal tilt angle for a PV panel in the winter will differ from the optimal tilt angle for the summer. This angle will also vary by latitude.

11.2 Objective

By the end of this lab, the student should learn the effect of surrounding temperature and tilt angle on the performance solar PV panel.

11.3 Prelab Preparation:

Read the material in the textbook that describes operation tilt angle on the performance solar PV pane .Prior to coming to lab class, have glance of the Procedure.

11.4 Equipment needed

1. Flood Light
2. Digital Multi Meter
3. Decade Resistance Box

11.5 Background

In some PV lighting systems such as solar garden lights or small post-top luminaires, the PV panels are incorporated directly into the luminaire housing and cannot be moved or oriented in a particular direction. In these types of systems, the PV panels are typically oriented horizontally, facing the sky. However, many larger PV lighting systems are designed to allow a system installer to tilt the PV panel at an angle from horizontal and to orient the PV panel in a particular direction. In these types of systems, a system specifier or installer should first determine the optimal tilt angle and orientation of the PV panel for the system's location.

11.6 Procedure:

11.6.1 To Study the effect of Temperature:

1. Connect the circuit as shown in the figure.
2. Initially, note the voltage and current values of the solar panel.
3. Gradually increase the value of temperature, by increasing the intensity of the light.
4. At each and every step note the maximum voltage, current, short circuit current and open circuit voltage.
5. Repeat the procedure for various types of panels with different shaded of lighting.

11.6.2 To Study the effect of Tilt Angle on Solar Panel:

1. Place the solar panel as shown in Figure.
2. Make sure all the wires are properly connected as shown in Figure.
3. Make sure the panel is well secured and it does not fall.
4. Connect the digital multi-meter (DMM) to the solar panel Set the dialer to V=200. Record the DC voltage reading.
5. Record your results in the table below as you tilt the panel manually. Make sure you dont drop the panel.
6. Record the values for all seven angles. Note that Power can be calculated as P=V*I and has the unit of Watts.

11.6.3 Tabular Column:

S.No	Angle (Degrees)	Voltage (V)
1	0 to the sunlight	
2	15 to the sunlight	
3	30 to the sunlight	
4	45 to the sunlight	
5	60 to the sunlight	
6	75 to the sunlight	
7	90 to the sunlight	

11.6.4 Constant Frequency and Variable Pulse width:

11.7 ProbingFurtherQuestions

1. Is the output of solar panel DC or AC?

S. No	T_{ON}(sec)	T_{OFF}(sec)	Duty Cycle (%)	V_O(Volts)
1				
2				
3				
4				
5				
6				
7				

2. What are three benefits of using solar power?
3. How does temperature affect the efficiency of a PV cell?
4. Does more light produce more current? Explain

LAB-12 Design of Solar Panel

12.1 Introduction

Solar photovoltaic system or Solar power system is one of renewable energy system which uses PV modules to convert sunlight into electricity. The electricity generated can be stored or used directly, fed back into grid line or combined with one or more other electricity generators or more renewable energy source. Solar PV system is very reliable and clean source of electricity that can suit a wide range of applications such as residence, industry, agriculture, livestock, etc.

12.2 Objective

By the end of this lab, the student should learn the solar panel design using solar cells by interconnecting them to get desired voltage and power rating.

12.3 Prelab Preparation:

Read the material in the textbook that describes operation tilt angle on the performance solar PV pane .Prior to coming to lab class, have glance of the Procedure.

12.4 Equipment needed

1. PV module
2. Solar charge controller
3. Inverter
4. Battery
5. Load
6. Auxiliary energy

12.5 Background

As the demand for solar electric systems grows, progressive builders are adding solar photovoltaics (PV) as an option for their customers. Emphasis will be placed on information that will be useful in including a grid-connected PV system in a bid for a residential or small commercial building. We will also cover those details of the technology and installation that may be helpful in selecting subcontractors to perform the work, working with a designer, and directing work as it proceeds.

12.6 Procedure:

Determine power consumption demands

The first step in designing a solar PV system is to find out the total power and energy consumption of all loads that need to be supplied by the solar PV system as follows:

1. 1.8. Calculate total Watt-hours per day for each appliance used: Add the Watt-hours needed for all appliances together to get the total Watt-hours per day which must be delivered to the appliances.

2. 1.9. Calculate total Watt-hours per day needed from the PV modules: Multiply the total appliances Watt- hours per day times 1.3 (the energy lost in the system) to get the total Watt-hours per day which must be provided by the panels.

Size the PV modules

Different size of PV modules will produce different amount of power. To find out the sizing of PV module, the total peak watt produced needs. The peak watt (Wp) produced depends on size of the PV module and climat of site location. We have to consider "panel generation factor" which is different in each site location. For Thailand, the panel generation factor is 3.43. To determine the sizing of PV modules, calculate as

follows: Calculate the total Watt-peak rating needed for PV modules:

Divide the total Watt-hours per day needed from the PV modules (from item 1.2) by 3.43 to get the total Watt-peak rating needed for the PV panels needed to operate the appliances.

Calculate the number of PV panels for the system:

Divide the answer obtained in item 2.1 by the rated output Watt-peak of the PV modules available to you. Increase any fractional part of result to the next highest full number and that will be the number of PV modules required. Result of the calculation is the minimum number of PV panels. If more PV modules are installed, the system will perform better and battery life will be improved. If fewer PV modules are used, the system may not work at all during cloudy periods and battery life will be shortened.

Inverter sizing

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery. For stand-alone systems, the inverter must be large enough to handle the total amount of Watts you will be using at one time. The inverter size should be 25-30For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

Battery sizing

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years. The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days. To find out the size of battery, calculate as follows:

Calculate total Watt-hours per day used by appliances. Divide the total Watt-hours per day used by 0.85 for battery loss. Divide the answer obtained in item 4.2 by 0.6 for depth of discharge. Divide the answer obtained in item 4.3 by the nominal battery voltage.

Multiply the answer obtained in item 4.4 with days of autonomy (the number of days that you need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery.

Battery Capacity (Ah) = Total Watt-hours per day used by appliances x Days of autonomy (0.85 x 0.6 x nominal battery voltage)

Solar charge controller sizing

The solar charge controller is typically rated against Amperage and Voltage capacities. Select the solar charge controller to match the voltage of PV array and batteries and then identify which type of solar charge controller is right for your application. Make sure that solar charge controller has enough capacity to handle the current from PV array.

For the series charge controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration).

According to standard practice, the sizing of solar charge controller is to take the short circuit current (Isc) of the PV array, and multiply it by 1.3 Solar charge controller rating = Total short circuit current of PV array x 1.3

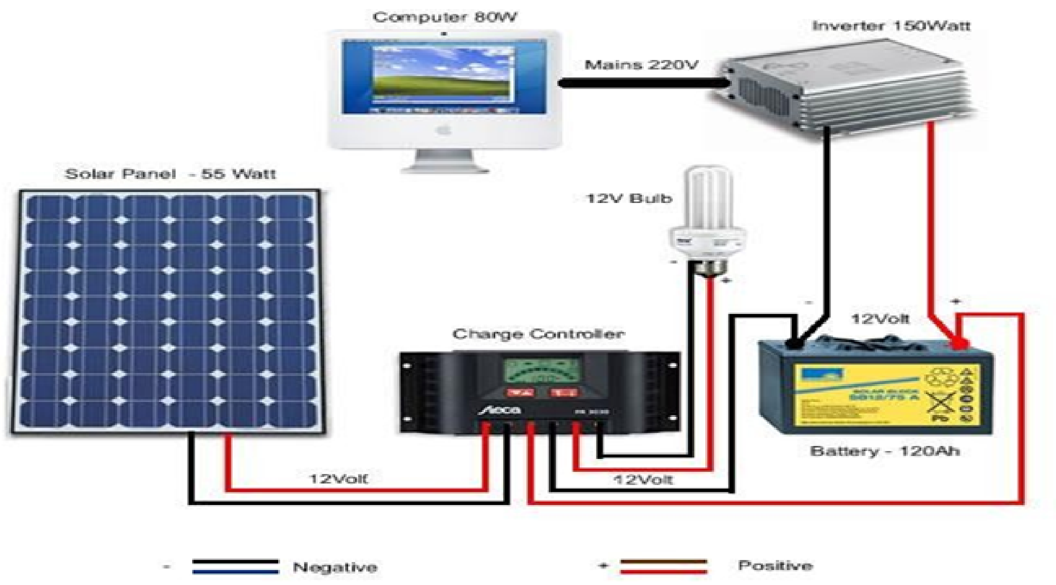


Figure 12.1: Schematic Diagram of Experimental set up .

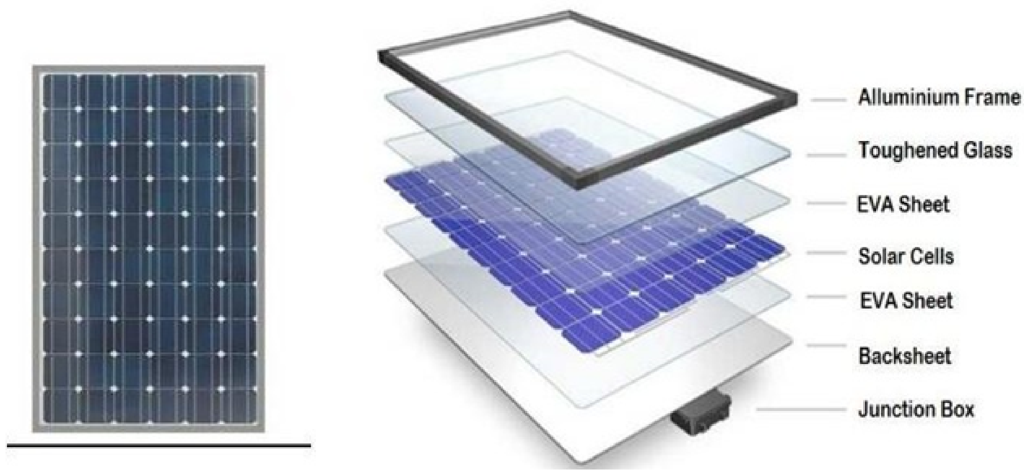


Figure 12.2: Design of solar PV cell .

12.7 ProbingFurtherQuestions

1. How can I generate electricity from a solar cell?

2. What is the life time of a solar PV module?

3. Why solar cell is reverse biased?

4. What is the difference between photo diode and a solar cell

LAB-13 Data Acquisition Using Digital Simulation

13.1 Introduction

Energy demands are steadily increasing, leading to excessive consumption of fossil energy resources. Indeed, to meet the energy needs of today's society, it is necessary to find more sustainable, effective and clean solutions for the environment. Among renewable energies sources, solar energy is considered the most fascinating source that could balance this gap between the consumption and the production, thanks to the remarkable decreasing in its cost and the advancement in this technology. With modern monitoring and control systems, this technology becomes a reliable source of energy.

13.2 Objective

By the end of this lab, the student should learn the Data acquisition using temperature, voltage and irradiation with sensors of solar panel using digital simulation

13.3 Prelab Preparation:

Read the material in the textbook that describes Data acquisition using temperature, voltage and irradiation with sensors .Prior to coming to lab class, have glance of the Procedure.

13.4 Equipment needed

1. Desktop with MATLAB

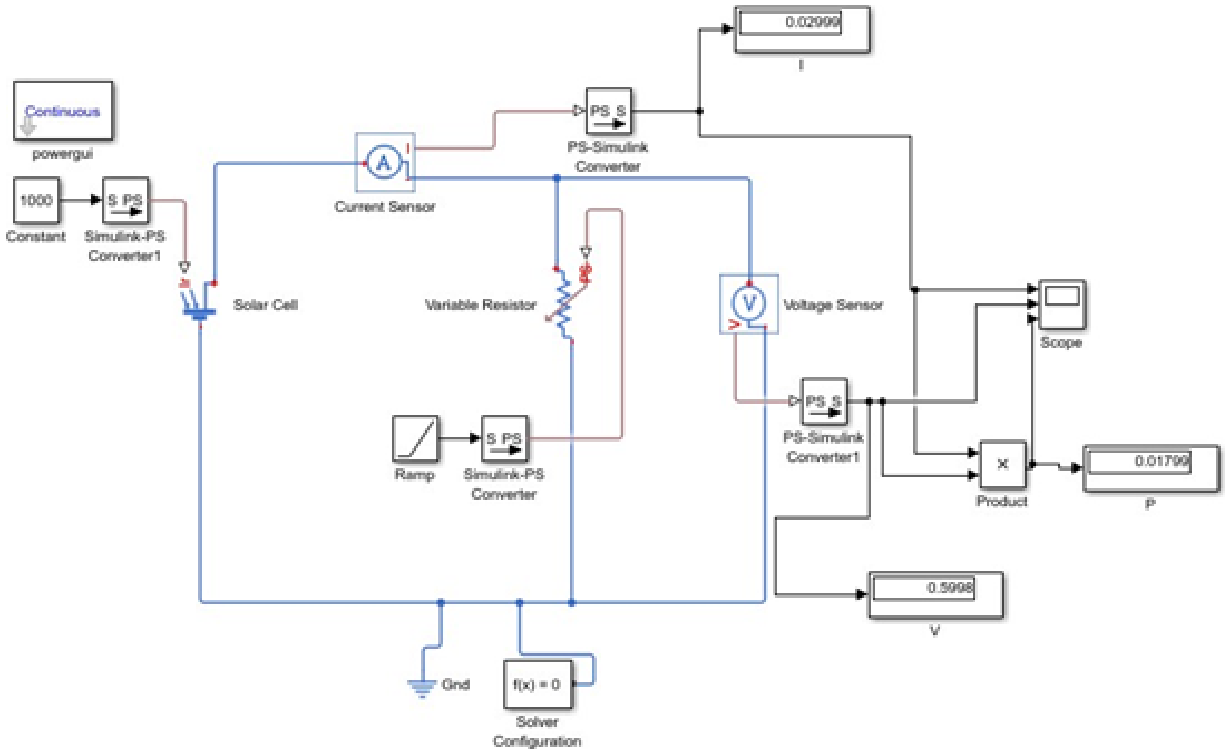
13.5 Background

As the energy demand and the environmental problems increase, the natural energy sources have become very important as an alternative to the conventional energy sources. The renewable energy sector is fast gaining ground as a new growth area for numerous countries with the vast potential. Solar energy plays an important role as a primary source of energy, especially for rural area.

13.6 Procedure:

1. Open MATLAB command window.
2. Initially, note the voltage and current values of the solar panel.
3. Gradually increase the value of temperature, by increasing the intensity of the light.
4. At each and every step note the voltage, current, power readings.

5. Note down for different temperature values.



13.7 ProbingFurtherQuestions

1. A converter which can operate in both 3 pulse and six pulse modes is?
2. What is the interval for SCRs triggering in three phase semi converter?
3. What is the interval for SCRs triggering in three phase full converter?
4. What is the function of freewheeling diode in three phase converters?

LAB-14 Maximum Power Point Tracker Using Digital Simulation / PSCAD

14.1 Introduction

It is the simplest method of MPPT to implement. In this method only voltage is sensed, so it is easy to implement. In this method power output of system is checked by varying the supplied voltage. If on increasing the voltage, power is also increases then further lower-case delta is increased otherwise start decreasing the lower-case delta Similarly, while decreasing voltage if power increases the duty cycle is decreased.

14.2 Objective

By the end of this lab, the student should Implementation of maximum power point tracker using perturbs and observe algorithm using digital simulation.

14.3 Prelab Preparation:

Read the material in the textbook that describes maximum power point tracker. Prior to coming to lab class, have glance of the Procedure.

14.4 Equipment needed

1. Desktop with MATLAB

14.5 Background

PV energy conversion system is to continuously tune the system so that it draws maximum power from the solar array regardless of weather or load conditions. Previously buck, boost and buck-boost converters are used to transfer the power generated by PVA to load . In literature it is reported that direct control of Ćuk converter minimizes power loss and avoids the discontinuous conduction. The limitation of PI controller is observed by some of the. The PI controller increase complexity of system. In this work direct control of duty cycle using MPPT technique is explored.

14.6 Procedure:

1. Open MATLAB command window.

2. Construct the block diagram as shown in the circuit diagram.

3. Double click on the MATLAB function (subsystem) block and write the code for P and O algorithm using the flow chart.
4. Change the values of irradiance and temperature and observe the output.

14.7 Using PSCAD:

1. Connect the circuit as shown in above fig
2. Set the radiation and cell temperature values (ex. radiation 1000 W/m**2 and Cell temparature 250 C)
3. Simulate an observe the I-V curve
4. Vary the irradiance values and observe the new readings

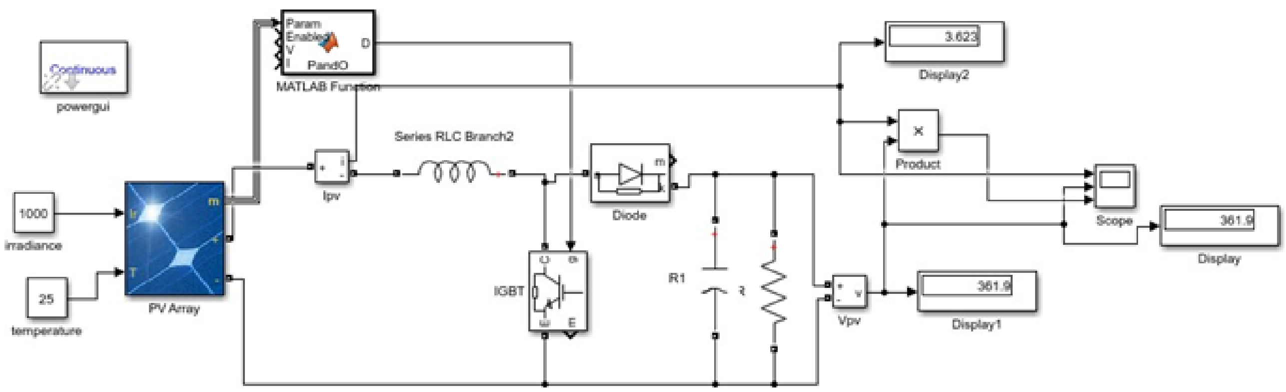


Figure 14.1: P and O method of algorithm for MPPT for boost converter in MATLAB .

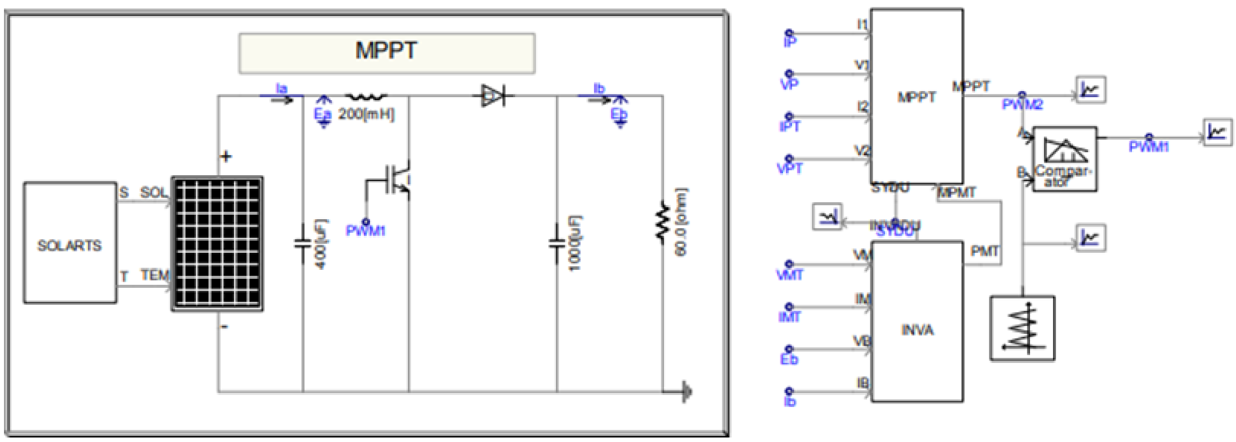


Figure 14.2: MPPT simulation diagram in PSCAD .

function D = PandO(Param, Enabled, V, I) Dinit = Param(1); Dmin = Param(3); deltaD = Param(4); dataType = 'double';

14.8 ProbingFurtherQuestions

1. What is working principle of boost converter?
2. What is meant by MPPT?
3. What are the different MPPT techniques used?
4. What is PWM?