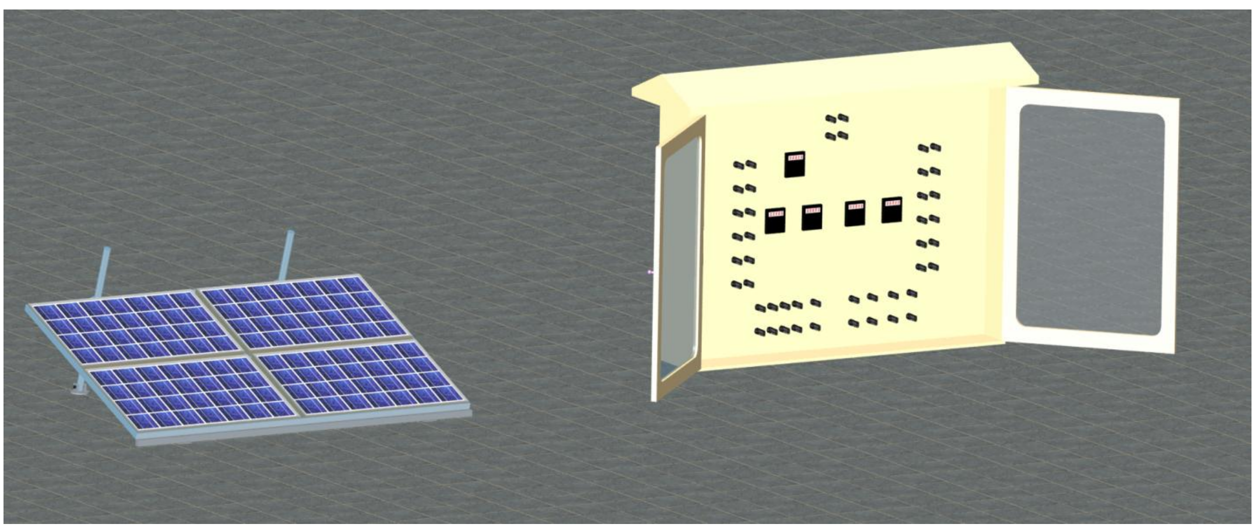
ULTRAWATT SYSTEMS

DC-DC & DC-AC Converter System

Indian Institute of Technology, Bombay

Operation & Learning Manual



This manual is intended to act as a Lab Manual of the DC-DC & DC-AC Converter System installed at Bombay (Indian Institute of Technology). The purpose of this document is to provide basic knowledge to start, operate or maintain the system and identify the sampling activities to evaluate the system performance

Content

1. Study of Series & Parallel Combinations of Solar modules

Contents

Objectives

To connect PV modules in series and parallel combinations.
Study over the variation in output with series and parallel combinations across the solar panel.

Expected outcomes of the experiment:

- Ability to connect the PV modules in the series / parallel combination.
- Ability to understand the output voltage and current requirement for the requirement loads by changing the series/parallel combination of the PV module.

Theory:

PV modules are connected in series or in parallel in order to achieve higher power output. These combinations of PV modules is called 'PV array'. The main objective of this experiment is to connect PV modules in series and parallel combinations in order to increase the current or voltage of PV module array. When there is need to increase the voltage of a PV array, many PV modules are connected in series; and when there is need to increase the current of a PV array the PV modules are connected in parallel. By increasing both current and voltage in PV array, overall we increase the power.

Series Connections of Solar Cells

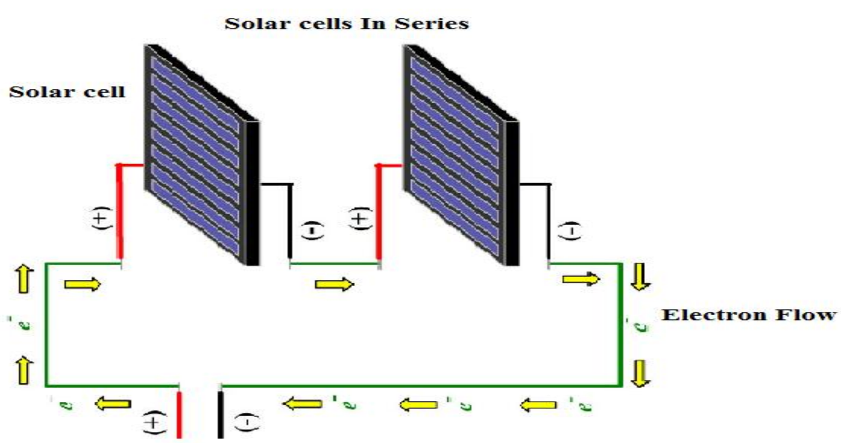


Figure 1 Series Connections of PV Cells

Series connection of solar cell is achieved by connecting the opposite polarity of the cells together. As shown in figure 1. The negative terminal of one module is connected to the positive terminal of other module. In series combination the current across two cells remain the same but the voltage across two cells gets added.

Parallel Connections of Solar Cells

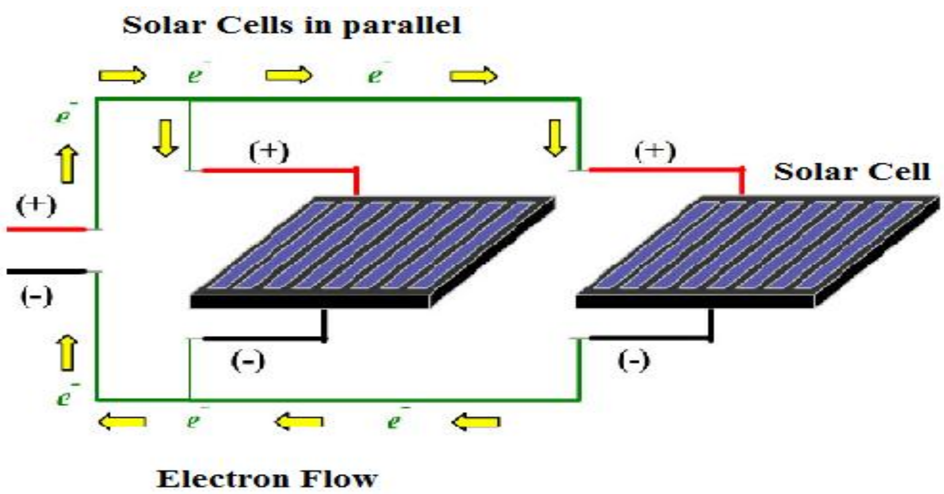


Figure 2 Parallel Connections of Solar Cells

Parallel connection of solar cell is achieved by connecting the same polarity of the cells together as shown in figure 2. The positive terminals of both the modules are connected together and the negative terminals of both the modules are connected together. In parallel connection of solar cells the voltage across both the cells remains same whereas current of individual module gets added.

Depending on the need the PV cells can be connected in series or in parallel combinations. In this way, we can achieve higher voltage as well as higher current than what a single cell can provide. When the PV power requirement is more than few hundred watts, the PV modules need to be connected in both series as well as parallel combination.

Measurement:

Equipments Required:

Sr. No.	Unit	Technical Specifications	Quantity
1.	C-Si PV module	100Wp	4
2.	Ammeter	0-20 ADc	1
3.	Voltmeter	0-100 Vdc	3

Methodology for Experiment

1. Clean the dust particles (if any) present on the PV module.
2. Initially before starting the experiment ensure voltmeter and ammeter are in off position.
3. Turn on the setup for performing the experiment.
4. First make the appropriate series connection of the PV module with the suitable connectors in the control box.
5. Connect the positive terminal of the one PV module to the negative terminal of another PV module and so on for different series connection of the PV modules.
6. Connect the output of the series combination to the common output to measure the voltage and current.
7. Measure the value of the open circuit voltage (V_{OC}) and note down the reading.
8. To measure the short circuit current (I_{SC}) across the PV module you need to short the connections by connecting the negative terminal of the common output to the P1 negative and note down the readings.
9. Disconnect the series combination of the PV module and make the appropriate parallel connection of the PV module in the series parallel control box.
10. Connect the positive terminals of PV modules together and negative terminals of the PV modules together for the parallel connection of the PV modules.
11. Connect the output of the parallel combination to the common output to measure the voltage and current.
12. Measure the value of the open circuit voltage (V_{OC}) and note down the readings.
13. To measure the short circuit current (I_{SC}) across the PV module you need to short the connections by connecting the negative terminal of the common output to the P1 negative and note down the readings.
14. Disconnect all the connection made for the parallel combination of PV module and switch off the setup.

Observation table:

Table 1 Measure the value of the open circuit voltage and short circuit current across the PV module in series combination

Sr. No.	Open circuit voltage (V_{OC})	Short circuit current (I_{SC})	Power (Wp)
1			
2			
3			
4			

Table 2 Measure the value of the open circuit voltage and short circuit current across the PV module in parallel combination

Sr. No.	Open circuit voltage (V_{OC})	Short circuit current (I_{SC})	Power (Wp)
1			
2			
3			
4			

Result:

Conclusion:

Precautions:

- Do not attempt to alter the internal connections of the tool.
- Never attempt to make connections when the PV Modules are exposed to light.
- Complete the connections before switching on the set up.
- Check the connections twice before switching on the set up.
- Never connect or disconnect the cable or connector under load condition.
- Improper connections may lead to severe hazards.
- Do not open the door of the cabinet while performing the experiment.

2. Analysis of DC-DC Buck Converters.

Contents

Objective:

To convert and observe various DC voltages 17.5, 35, 70V to 6,12,24 V respectively using DC step down converter.

Expected outcomes of the experiment:

- Ability to understand the working of the DC to DC step down converter.
- Ability to obtain the desired DC voltages from the PV module by proper combinations of the PV modules.
- Ability to convert the obtained DC voltages from the PV module to the desired DC voltages by using the DC-DC converters.
- Ability to understand the various rated loads

Theory

DC to Dc converters:

DC-DC converters are electronic devices used whenever we want to change DC electrical power efficiently from one voltage level to another. They're needed because unlike AC, DC can't simply be stepped up or down using a transformer. In many ways, a DC-DC converter is the DC equivalent of a transformer.

An important point to remember about all DC-DC converters is that like a transformer, they essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power all comes from the input; there's no energy manufactured inside the converter. Quite the contrary, in fact some is inevitably used up by the converter circuitry and components, in doing their job.

$$Pin = Pout + Plosses$$

Where P_{in} is the power fed into the converter, P_{out} is the output power and P_{losses} is the power dissipated inside the converter. With the use of more efficient converters there would be minimum losses, and P_{out} would be approximately equal to P_{in}. Therefore,

$$Vin\ x\ Iin = Vout\ x\ Iout$$

Or by re-arranging, we get:

$$\frac{Vout}{V\ in} = \frac{Iin}{Iout}$$

In other words, if we step up the voltage we step down the current, and vice-versa. Of course there's no such thing as a perfect DC-DC converter, just as there are no perfect transformers. So we need the concept of efficiency, where:

$$Efficiency\ (\%) = \frac{Pout}{Pin}\ x\ 100$$

Buck Converter:

A buck converter is a voltage step down and current step up converter. The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a transistor and a diode). In the idealized converter, all the components are considered to be perfect. Specifically, the switch and the diode have zero voltage drop when on and zero current flow when off and the inductor has zero series resistance. Further, it is assumed that the input and output voltages do not change over the course of a cycle (this would imply the output capacitance as being infinite)

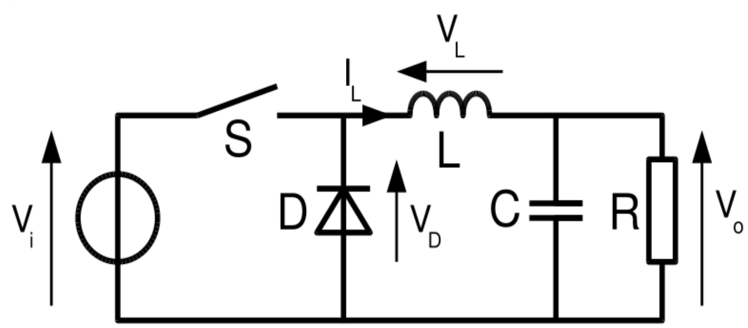


Figure 1 Equivalent diagram of Buck Converter

Measurement

Equipments required

Sr. No.	Unit	Technical Specifications	Quantity
1.	C-Si PV module	100Wp	4
2.	DC-DC step down converter	17.5Vdc – 6Vdc	1
		35Vdc – 12Vdc	1
		70Vdc – 24Vdc	1
3.	Ammeter	0-10 A dc	1
4.	Voltmeter	0-100 V dc	2

Methodology for Experiment

1. Clean the dust particles (if any) present on the PV module.
2. Initially before starting the experiment ensure voltmeter and ammeter are in off position.
3. Turn on the setup for performing the experiment.
4. Turn OFF all the switches. and make sure everything is in switched off position
5. First connect the Module M1 to the output terminals, connect the panel output terminals to the P1 terminals.
6. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings.
7. Connect the P1 terminals to the input of the 17.5 - 6V (stepdown-1) converter. Connect the output terminals of the converter to the P2 terminals and note down the readings.
8. Turn OFF all the switches. and make sure everything is in switched off position
9. Now connect the Module M1 and M2 in series (35V) to the output terminals, connect the panel output terminals to the P1 terminals.
10. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings.
11. Connect the P1 terminals to the input of the 35 -12V (step down-2) converter. Connect the output terminals of the converter to the P2 terminals and note down the readings.
12. Turn OFF all the switches. and make sure everything is in switched off position
13. Now connect the Module M1, M2, M3, M4 in series (70V) to the output terminals, connect the panel output terminals to the P1 terminals.
14. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings.
15. Connect the P1 terminals to the input of the 70 -24V (step down-3) converter. Connect the output terminals of the converter to the P2 terminals and note down the readings.
16. Turn OFF all the switches and remove all the connectors.

Observation table:

Table 1 Measure the initial value of the open circuit voltage and short circuit current across the PV module.

Sr. No.	Open circuit voltage (V_{OC})	Short circuit current (I_{SC})	Power (Wp)
1			
2			
3			

Table 2 Measure the value of the voltage across the output of the DC-DC step-up converter

Sr. No.	Type of Converter	Input voltage (V_i)	Output voltage (V_o)	Input Current (I_i)
1	17.5-6			
2	35-12			
3	70-24			

Result:

Conclusion:

Precautions:

- Do not attempt to alter the internal connections of the tool.
- Never attempt to make connections when the PV Modules are exposed to light.
- Complete the connections before switching on the set up.
- Check the connections twice before switching on the set up.
- Never connect or disconnect the cable or connector under load condition.
- Improper connections may lead to severe hazards.
- Do not open the door of the cabinet while performing the experiment.

3. Analysis of DC-DC Boost Converters.

Contents

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Objective:

To convert and observe various DC voltages 17.5, 35, 70V to 24, 48, 96 V respectively using DC step up converter.

Expected outcomes of the experiment:

- Ability to understand the working of the DC to DC step up converter.
- Ability to obtain the desired DC voltages from the PV module by proper combinations of the PV modules.
- Ability to convert the obtained DC voltages from the PV module to the desired DC voltages by using the DC-DC converters.
- Ability to understand the various rated loads

Theory

DC to Dc converters:

DC-DC converters are electronic devices used whenever we want to change DC electrical power efficiently from one voltage level to another. They're needed because unlike AC, DC can't simply be stepped up or down using a transformer. In many ways, a DC-DC converter is the DC equivalent of a transformer.

An important point to remember about all DC-DC converters is that like a transformer, they essentially just change the input energy into a different impedance level. So whatever the output voltage level, the output power all comes from the input; there's no energy manufactured inside the converter. Quite the contrary, in fact some is inevitably used up by the converter circuitry and components, in doing their job.

$$Pin = Pout + Plosses$$

Where P_{in} is the power fed into the converter, P_{out} is the output power and P_{losses} is the power dissipated inside the converter. With the use of more efficient converters there would be minimum losses, and P_{out} would be approximately equal to P_{in}. Therefore,

$$Vin\ x\ Iin = Vout\ x\ Iout$$

Or by re-arranging, we get:

$$\frac{Vout}{V\ in} = \frac{Iin}{Iout}$$

In other words, if we step up the voltage we step down the current, and vice-versa. Of course there's no such thing as a perfect DC-DC converter, just as there are no perfect transformers. So we need the concept of efficiency, where:

$$Efficiency\ (\%) = \frac{Pout}{Pin} x\ 100$$

Boost Converter:

A boost converter is a DC-DC power converter with an output voltage greater than its input voltage. It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element, a capacitor, inductor, or the two in combination. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple. The basic principle of a Boost converter consists of 2 distinct states (see figure 1):

In the On-state, the switch S will be close, resulting in an increase in the inductor current;
In the Off-state, the switch is open and the only path offered to inductor current is through the flyback diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.

.The input current is the same as the inductor current as can be seen in figure. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

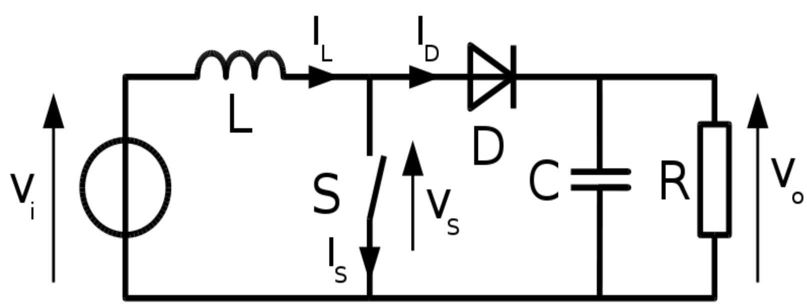

Figure 1 Equivalent diagram of Boost Converter

Measurement

Equipments Required

Sr. No.	Unit	Technical Specifications	Quantity
1.	C-Si PV module	100Wp	4
2.	DC-DC step up converter	17.5Vdc – 24Vdc	1
		35Vdc – 48Vdc	1
		70Vdc – 96Vdc	1
3.	Ammeter	0-10 A dc	1
4.	Voltmeter	0-100 V dc	2

Methodology for experiment

1. Clean the dust particles (if any) present on the PV module.
2. Initially before starting the experiment ensure voltmeter and ammeter are in off position.
3. Turn on the setup for performing the experiment.
4. Turn OFF all the switches. and make sure everything is in switched off position
5. First connect the Module M1 to the output terminals, connect the panel output terminals to the P1 terminals.
6. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings.
7. Connect the P1 terminals to the input of the 17.5 - 24V (step up-1) converter. Connect the output terminals of the converter to the P3 terminals and note down the readings.
8. Turn OFF all the switches. and make sure everything is in switched off position
9. Now connect the Module M1 and M2 in series (35V) to the output terminals, connect the panel output terminals to the P1 terminals.
10. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings.
11. Connect the P1 terminals to the input of the 35 -48V (step up-2) converter. Connect the output terminals of the converter to the P3 terminals and note down the readings.
12. Turn OFF all the switches. and make sure everything is in switched off position
13. Now connect the Module M1, M2, M3, M4 in series (70V) to the output terminals, connect the panel output terminals to the P1 terminals.
14. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings.
15. Connect the P1 terminals to the input of the 70 -96V (step up-3) converter. Connect the output terminals of the converter to the P3 terminals and note down the readings.
16. Turn OFF all the switches and remove all the connectors.

Observation table:

Table 1 Measure the initial value of the open circuit voltage and short circuit current across the PV module.

Sr. No.	Open circuit voltage (V_{OC})	Short circuit current (I_{SC})	Power (Wp)
1			
2			
3			

Table 2 Measure the value of the voltage across the output of the DC-DC step-up converter

Sr. No.	Type of Converter	Input voltage (V_i)	Output voltage (V_o)	Input Current (I_i)
1	17.5-24			
2	35-48			
3	70-96			

Result:

Conclusion:

Precautions:

- Do not attempt to alter the internal connections of the tool.
- Never attempt to make connections when the PV Modules are exposed to light.
- Complete the connections before switching on the set up.
- Check the connections twice before switching on the set up.
- Never connect or disconnect the cable or connector under load condition.
- Improper connections may lead to severe hazards.
- Do not open the door of the cabinet while performing the experiment.

4. Analysis of DC –AC Conversion

Contents

Objective

To convert and observe 12VDC to 230V AC using DC-AC converter i.e. inverter.

Expected outcomes of the experiment:

- Ability to understand the working of the Inverter.
- Ability to obtain the desired DC voltages from the PV module by proper combinations of the PV modules.
- Ability to convert the obtained DC voltages from the PV module to the desired AC voltages by using the Inverters.
- Ability to understand the analysis of AC Power

Theory:

Solar Inverter:

A solar inverter, or PV inverter, converts the variable direct current (DC) output of a photovoltaic (PV) solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network. It is a critical component in a photovoltaic system, allowing the use of ordinary commercial appliances. Solar inverters have special functions adapted for use with photovoltaic arrays, including maximum power point tracking and anti-islanding protection.

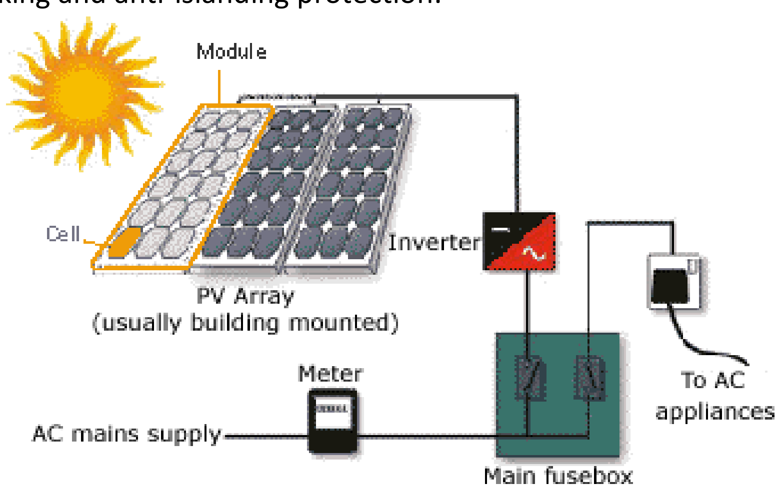

Figure 1 Setup for Solar Inverter

Solar inverters may be classified into three broad types:

- **Stand-alone inverters**, used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source, when available. Normally these do not interface in any way with the utility grid, and as such, are not required to have anti-islanding protection.
- **Grid-tie inverters**, which match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply, for safety reasons. They do not provide backup power during utility outages.
- **Battery backup inverters** are special inverters which are designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage, and are required to have anti-islanding protection.
- **Solar pumping inverters**, advanced solar pumping inverters convert DC voltage from the solar array into AC voltage to drive submersible pumps directly without the need for batteries or other energy storage devices. By utilizing MPPT (maximum power point tracking), solar pumping inverters regulate output frequency to control speed of the pumps in order to save pump motor from damage.

Measurement

Equipments Required:

Sr.No.	Unit	Technical Specifications	Quantity
1.	C-Si PV module	100Wp	4
2.	Converter	35-12V	1
3.	Inverter	12 Vdc to 230VAC	1
4.	Ammeter	0-10 A DC	1
5.	Voltmeter	0-100 V DC	2

Methodology for Experiment

1. Clean the dust particles if any present on the PV module.
2. Initially before starting the experiment ensure voltmeter and ammeter are in off position.
3. Turn on the setup for performing the experiment.
4. Our first task is to make appropriate series connection of PV module.
5. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings.
6. Now connect the Module M1 and M2 in series (35V) to the output terminals, connect the panel output terminals to the P1 terminals.
7. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings.
8. Connect the P1 terminals to the input of the 35 -12V (step down-2) converter. Connect the output terminals of the converter to the Inverter Input terminals.
9. Connect Inverter output terminals to P4 terminals.
10. Note down the readings of input voltage and AC voltage. In this way analyze the performance of the DC-AC converter.
11. Turn OFF all the switches and remove all the connectors.

Observation table:

Table 3 Measure the initial value of the open circuit voltage and short circuit current across the PV module

Open circuit voltage (V_{OC})	Short circuit current (I_{SC})

Table 4 Measure the value of the voltage across the output of the inverter.

Sr. No.	Type of Converter	Input voltage (Vi)	Output voltage (Vo)	Output Current (Io)	Power
1	35-12			N.A.	
2	12-230AC				

Result:

Conclusion:

Precautions:

- Do not attempt to alter the internal connections of the tool.
- Never attempt to make connections when the PV Modules are exposed to light.
- Complete the connections before switching on the set up.
- Check the connections twice before switching on the set up.
- Never connect or disconnect the cable or connector under load condition.
- Improper connections may lead to severe hazards.
- Do not open the door of the cabinet while performing the experiment.

5. Analysis of effect of single Axis Tracking

Contents

Objective:

- To measure and estimate the parameters like short circuit current and open circuit voltage across the PV module at various angles.
- To measure the output voltage across the DC-DC (step up/step down) converters & inverters at the various angles.

Expected outcomes of the experiment:

- Ability to install the PV module at the various angles.
- Understanding the sun tracking of the PV module.
- Ability to identify the effect of sun tracking on the output of the converters.

Theory:

Solar Cells

A solar cell is an electronic device which directly converts sunlight into electricity. Light shining on the solar cell produces both a current and a voltage to generate electric power. This process requires firstly, a material in which the absorption of light raises an electron to a higher energy state, and secondly, the movement of this higher energy electron from the solar cell into an external circuit. The electron then dissipates its energy in the external circuit and returns to the solar cell. A variety of materials and processes can potentially satisfy the requirements for photovoltaic energy conversion, but in practice nearly all photovoltaic energy conversion uses semiconductor materials in the form of a p-n junction.

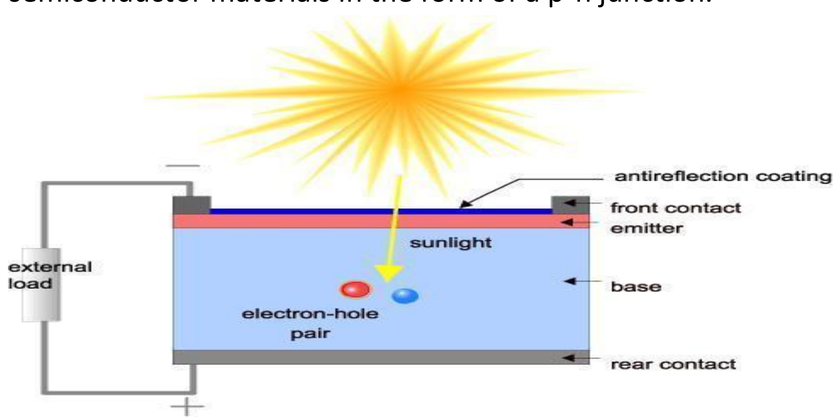

Figure 3 Solar Cell Junction

Intensity and Energy

For the purpose of solar power, the most significant measures are the intensity and energy delivered – one measure at a point in time, the other over a period of time.

At a point in time

Irradiance [W/m^2]: The intensity of solar radiation hitting a surface, which is the sum of the contributions of all wavelengths within the spectrum, expressed in units of Watts per m^2 of a surface.

Power [W]: Momentary total irradiance incident on a particular area.

Over a period of Time

Energy per unit area [kWh/m^2]: Energy per unit area is a measure of irradiance incident on a surface over a period of time.

Surface Orientation

As sunlight is smoothly distributed over whole areas, a mere figure for intensity is never sufficient without knowledge of the orientation of the surface in question. Typically, the orientation of a surface is described by the zenith angle, the angle between the sunbeam and the normal of the area. If the surface area is not perpendicular to the sunbeam (i.e.-zenith angle is not zero), a larger area is required to catch the same flow as the cross section of the sunbeam.

If I (θ) denotes the intensity on a surface with the sun in its zenith, the intensity, I, on an area where the sun is observed under the zenith angle θ (see figure) the intensity is reduced to

$$I(\theta) = I_0 \cos(\theta)$$

Values for θ range from 0° to 90°. Turning the face of the area away from the sun means less energy is flowing through that area.

Horizontal Surface	Surface that lies flat on the ground of the earth
South facing surface	The projection of the normal of the surface onto the ground points to South.
Perpendicular surface	Surface that is perpendicular to the sunbeam with sun in zenith at θ = 0°.

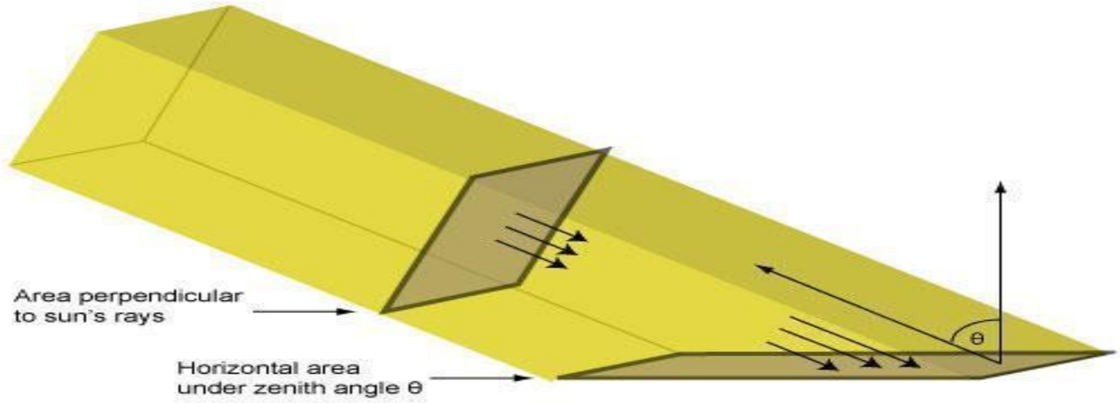

Figure 4 3D view of Incidence Angle

Solar Tracker:

A solar tracker is a device that orients a payload toward the sun. Payloads can be photovoltaic panels, reflectors, lenses or other optical devices. In flat-panel photovoltaic (PV) applications, trackers are used to minimize the angle of incidence between the incoming sunlight and a photovoltaic panel. Tracker systems follow the sun throughout the day to maximize energy output**.**

Single axis & Dual axis tracker:

Single-axis solar trackers rotate on one axis moving back and forth in a single direction. Different types of single-axis trackers include horizontal, vertical, tilted, and polar aligned, which rotate as the names imply. Dual-axis trackers continually face the sun because they can move in two different directions. Types include tip-tilt and azimuth-altitude. Dual-axis tracking is typically used to orient a mirror and redirect sunlight along a fixed axis towards a stationary receiver. Because these trackers follow the sun vertically and horizontally they help obtain maximum solar energy generation.

Measurement

Equipments Required

Sr.No.	Unit	Technical Specifications	Quantity
1.	C-Si PV module	100Wp	4
2.	DC-DC step up converter	17.5Vdc – 24Vdc	1
		35Vdc – 48Vdc	1
		70Vdc – 96Vdc	1
3.	DC- DC step down converter	17.5Vdc – 6Vdc	1
		35Vdc – 12Vdc	1
		70Vdc – 24Vdc	1
5.	Ammeter	0-10 Adc	1
6.	Voltmeter	0-100 Vdc	3

Methodology for Experiment

1. Clean the dust particles if any present on the PV module.
2. Initially before starting the experiment ensure voltmeter and ammeter are in OFF position.
3. Turn on the setup for performing the experiment.
4. Our first task is to make appropriate series/parallel connection of PV module.
5. Measure the value of the open circuit voltage (V_{OC}) and short circuit current (I_{SC}) across the PV module, and note down the readings at five different angles and fill the data in Table 1 &Table 2
6. Turn OFF all the switches and make sure all the connections are switched off.
7. Adjust the series combination of the PV module such that the input to the DC-DC step up converter is 17.5V
8. Measure the value of the output voltage across the DC-DC step up converter1 i.e. across the voltmeter V2 at five different angles and fill the data in Table 3.
9. Now turn off the all the switches and make sure everything is in switched off position.
10. Adjust the series/parallel combination of the PV module such that the input to the DC-DC step up converter is 35 V.
11. Measure the value of the output voltage across the DC-DC step up converter2 i.e. across voltmeter V2 at five different angles and fill the data in Table 3.
12. Repeat the step 9.
13. Adjust the series/parallel combination of the PV module such that the input to the DC-DC step up converter is 70 V
14. Measure the value of the output voltage across the DC-DC step up converter3 i.e. across voltmeter V2 at five different angles and fill the data in Table 3
15. Now repeat all the steps for step-down converter for 5 different angles and fill the data in Table 4.

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In this way analyze the performance of the DC-DC step up/down converter for the various inputs.

Observation table

All Panels are in Series

Table 5 Measure the value of the open circuit voltage and short circuit current across the PV module at different angles

Sr. No.	Angle (˚)	Open circuit voltage (V_{OC})	Short circuit current (I_{SC})	Power(Wp)
1				
2				
3				
4				
5				

All Panels are in Parallel

Table 6 Measure the value of the open circuit voltage and short circuit current across the PV module at different angles

Sr. No.	Angle (˚)	Open circuit voltage (V_{OC})	Short circuit current (I_{SC})	Power(Wp)
1				
2				
3				
4				
5				

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Table 7 Measure the value of the step up converters across the PV module at different angles

Sr. No.	Angle (˚)	Input Voltage	Output Voltage
1			
2			
3			
4			
5			

Table 8 Measure the value of the step down converters across the PV module at different angles

Sr. No.	Angle (˚)	Input Voltage	Output Voltage
1			
2			
3			
4			
5			

Result

Conclusion

Precautions:

- Do not attempt to alter the internal connections of the tool.
- Never attempt to make connections when the PV Modules are exposed to light.
- Complete the connections before switching on the set up.
- Check the connections twice before switching on the set up.
- Never connect or disconnect the cable or connector under load condition.
- Improper connections may lead to severe hazards.
- Do not open the door of the cabinet while performing the experiment.

6. Study of Solar Micro Inverter

Contents

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Objective

To Study the effect of the micro inverter.

Expected outcomes of the experiment:

- Ability to understand the working of the micro inverter.
- Ability to understand the requirement of the micro inverter.

Theory:

Solar Microinverters

A **solar micro-inverter**, or simply **microinverter**, is a device used in photovoltaics that converts direct current (DC) generated by a single solar module to alternating current (AC). The output from several Microinverters is combined and often fed to the electrical grid. Microinverters contrast with conventional string and central solar inverters, which are connected to multiple solar modules or panels of the PV system.

Microinverters have several advantages over conventional inverters. The main advantage is that small amounts of shading, debris or snow lines on any one solar module, or even a complete module failure, do not disproportionately reduce the output of the entire array. Each microinverter harvests optimum power by performing maximum power point tracking for its connected module.

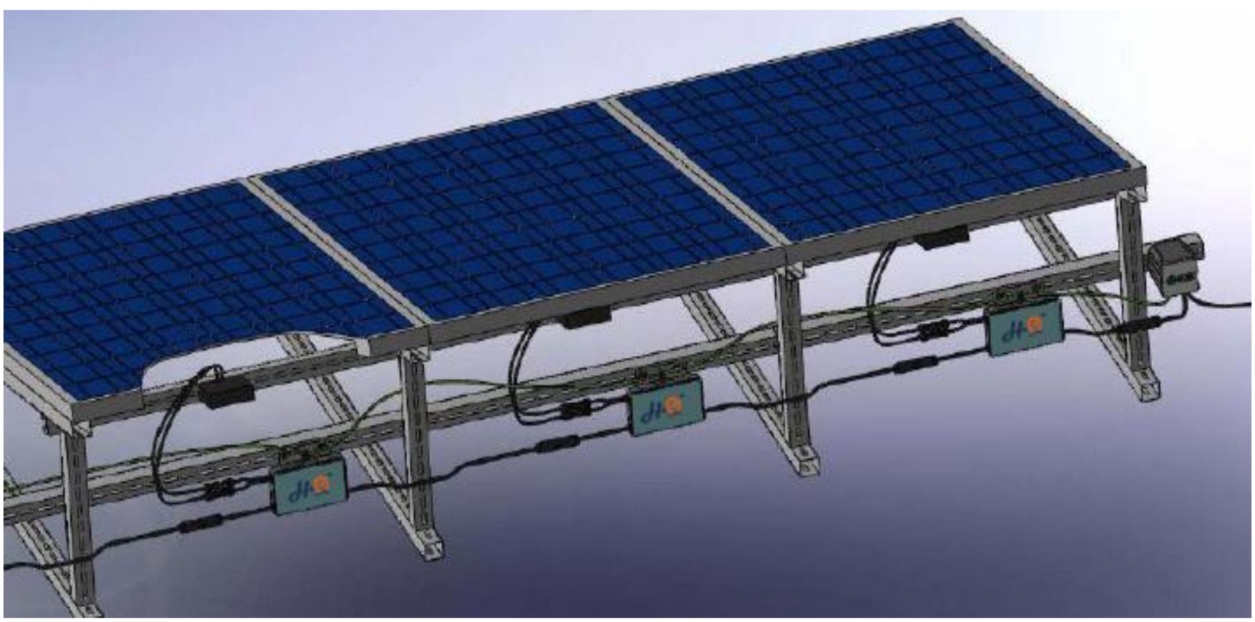

Figure 5 Schematic of solar micro inverter installation

1. **Single phase grid tie PV micro inverter:**
   Micro inverter transmits DC power to AC power from single panel to grid directly. The high speed, high precision phase lock and network synchronization technology. achieving transmit energy so easy. Our micro Inverter is high efficiency, high power density and high reliability.

2. **Electronic load:** The theory of grid connected type electronic load is that regard grid tie Inverter as a load for measured equipment with grid inverter instead of resistance loading can feed the power output of the equipment for testing to grid with the form grid connecting.

3. **Single phase grid tie PV inverter:** The unstable DC power from PV panel through HM to transform single phase pure sine wave AC power feed-in grid for loads working.

4. **Single phase off grid PV inverter:** The unstable DC power from PV panel through HMB to transform single phase pure sine wave AC power to loads, excess power charge to battery automatically; and when solar power is lacking, battery will make up the rest or serve as complete power source. SMB supports Grid or AC generator backup. Switching time between PV/Grid/Battery for Standard configuration unit is less than 5ms. The charger mode Is 3 steps: CC, CV and FC automatically.

5. **Single phase on & off grid auto switch:** The unique innovative technology of HMS inverter succeeds in realizing grid tie and off grid two nodes auto switch. Grid tide mode is preferred always. When the grid and PV panel running well, HMS will feed in the power to loads, at the same time charging battery, and the excess power will feed-in grid; when grid has fault, after very short time, HMS inverter will switch to stand-alone mode. In off grid case, PV power is preferred, if solar power is not enough, battery will make up the rest in short time, If PV voltage still cannot rise again, battery will take over panel as power source.

6. **Three phase grid tie PV inverter:-** The unstable DC power from PV panel through HM3 to transform three phase pure sine wave AC power feed-In grid for bads working.HM3 has MPPT function, using three phase invert SVPWM voltage vector algorithm to feed power into grid

Connection with Grid

The Microinverter we will be using for observation is On Grid Microinverter

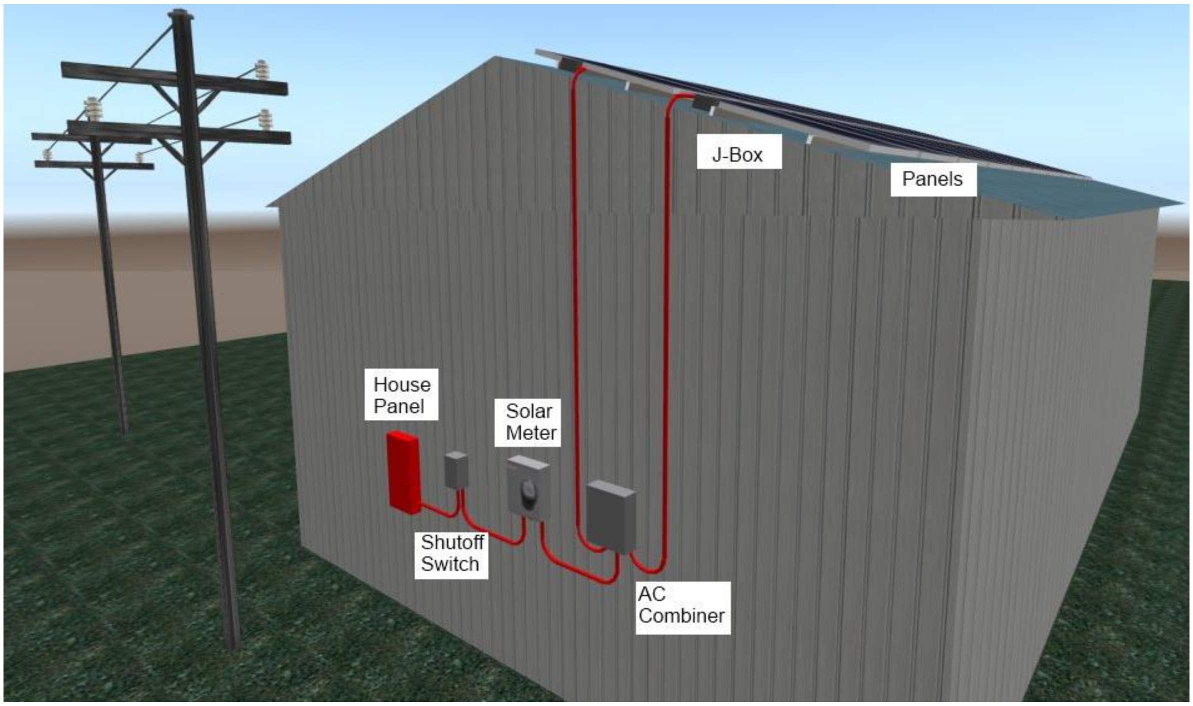

Figure 6 Layout of Micro inverter

Measurement

Equipments Required:

Sr. No.	Unit	Technical Specifications	Quantity
1.	C-Si PV module	250Wp	4
2.	Micro Inverter	240W,230V	4

Methodology for Experiment

1. Clean the dust particles if any present on the PV module.
2. Connect the panel 1 to micro inverter.
3. Observe the light indication of the micro inverter
4. Provide some shadow on the panel1 and observe the light indication of the micro inverter.
5. Now connect the panel 2 to the micro inverter and repeat the step 3 and 4.

Observation Table:

Panel No.	Shadow	Indication
1		
2		

Result:

Conclusion:

Precautions:

- Do not attempt to alter the internal connections of the tool.
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- Complete the connections before switching on the set up.
- Check the connections twice before switching on the set up.
- Never connect or disconnect the cable or connector under load condition.
- Improper connections may lead to severe hazards.
- Do not open the door of the cabinet while performing the experiment.