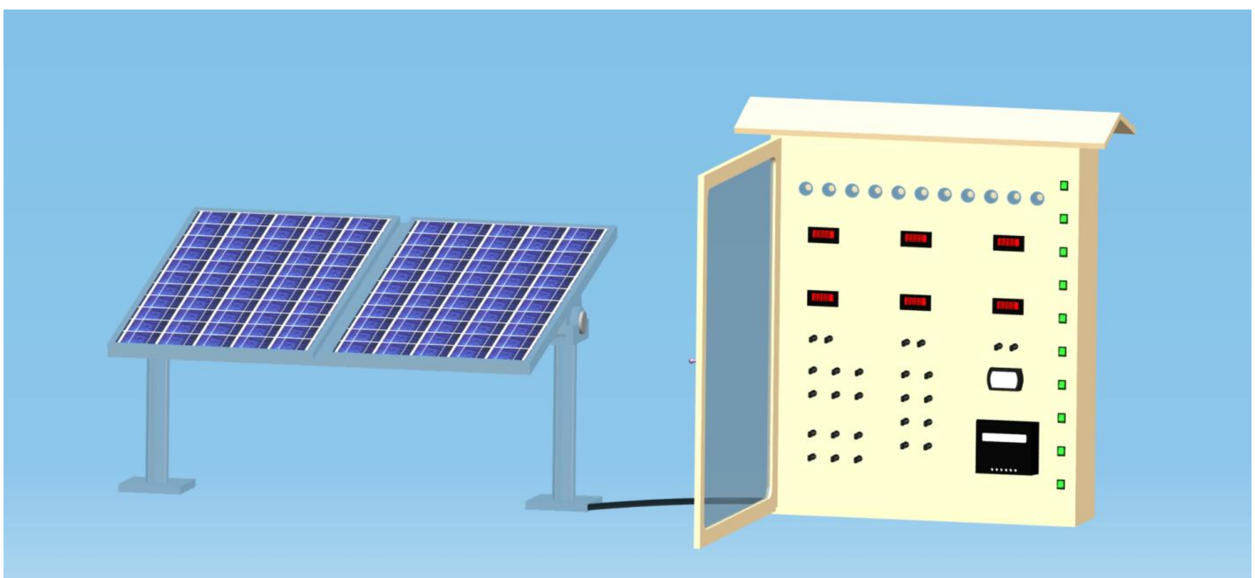
ENELEK POWER PVT. LTD.

MPPT Training System IIT-Bombay

Indian Institute of Technology, Bombay

Operational & Learning Manual



This manual is intended to act as a Lab Manual of the Charge Controller 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

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1. Performance analysis of MPPT

Contents

Objectives:

- Comparison between electrical parameters of module with MPPT.
- Change in operating point of modules with MPPT with variation in load.
- Comparison between charging points of battery with MPPT.

Expected outcome of experiment:

- Ability to plot I-V Curve and find out P_{max}.
- Ability to understand the load variation leading to different power requirements.
- Ability to understand the maximum power extraction from PV Module with the use of MPPT Charge controller.

Theory:

Charge controller:

The primary function of a charge controller in a stand-alone photovoltaic (PV) system is to protect the battery from overcharge and over discharge. Any system that has unpredictable loads, user intervention optimized or undersized battery storage (to minimize initial cost) or any characteristics that would allow excessive battery overcharging or over discharging requires a charge controller. Lack of a controller may result in shortened battery lifetime and decreased load availability.

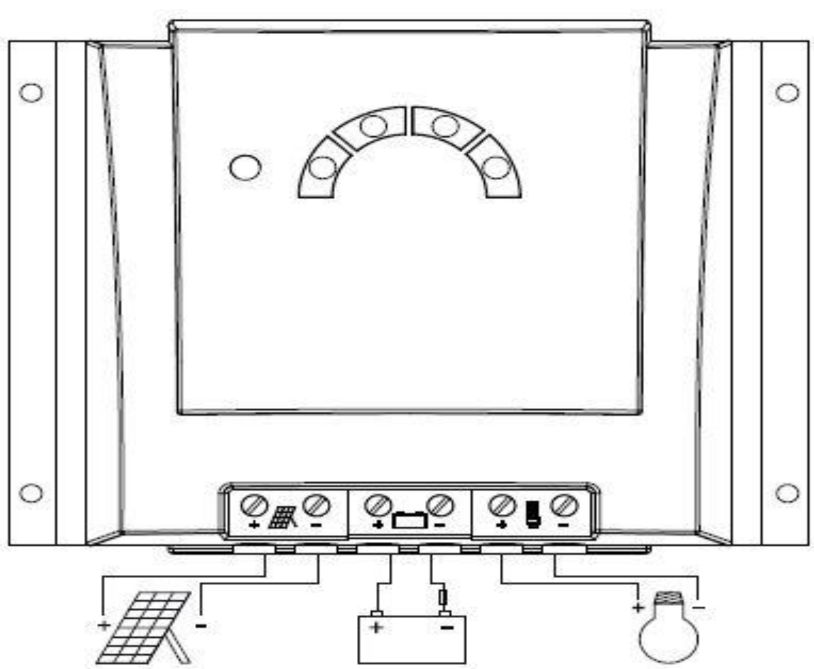


Figure 1 MPPT Charge Controller

MPPT Charge Controller:

MPPT stands for Maximum Power Point Tracking, and it relates to the solar cell itself. Each solar cell has a point at which the current (I) and voltage (V) output from the cell result in the maximum power output of the cell. In the diagram below the curve is an example of the standard output expected from a solar cell, the Maximum Power Point is at the position marked on the diagram.

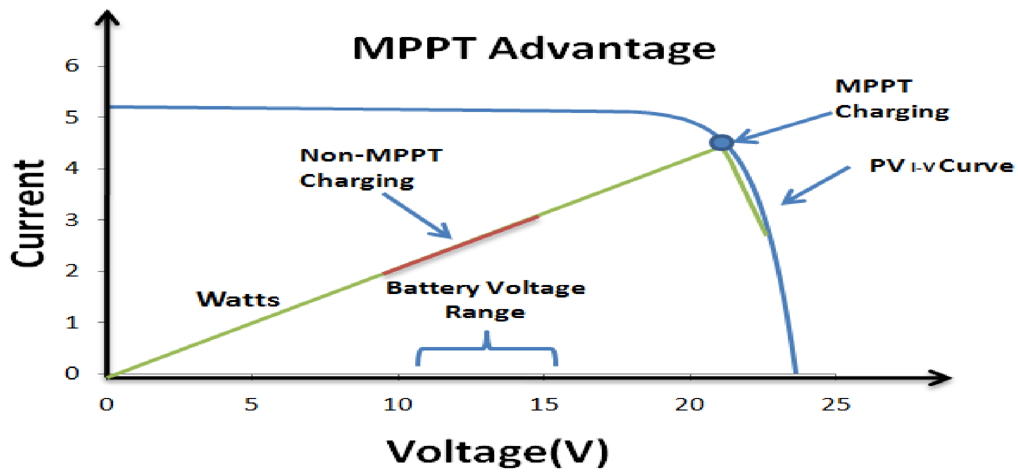


Figure 2 Effect of MPPT charge controller

The principle is that if the output from the cell can be regulated to the voltage and current levels needed to achieve a power output at this point, then the power generated by the solar cell will be used most efficiently.

Working of MPPT-

A Maximum Power Point Tracking solar regulator will simulate the load required by the solar panel to achieve the maximum power from the cell. The regulator will work out at which point the cell will output the maximum power and derive from this the voltage and current outputs required for maximum power to be achieved. It will then calculate the load that it must simulate based on these voltage and current levels.

$$R = \frac{V}{I}$$

The regulator, now receiving the maximum amount of power in, will then regulate the output according to what it is designed for .MPPT ensures that you get the most power possible from your solar panels at any point in time. It is particularly effective during low light level conditions. These calculations result in an output that delivers maximum current at the required voltage at any point in time. During low light level situations it will compensate for the low light level and find the new point at which the solar cell delivers its maximum power output.

Measurement:

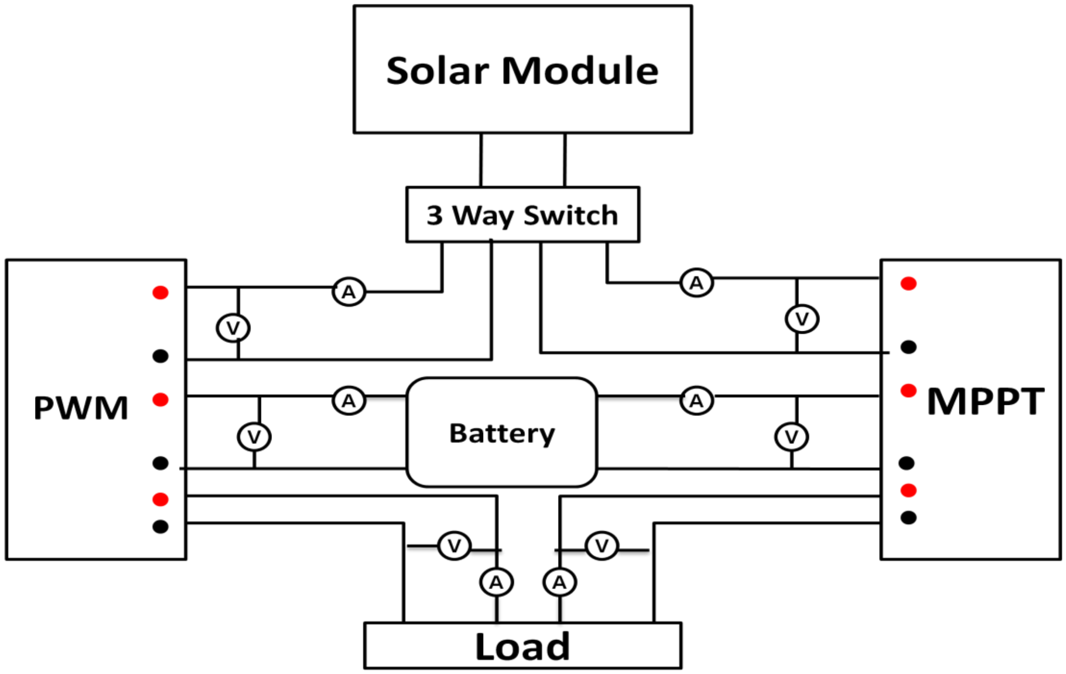


Figure 3 Single line diagram of control setup

Equipments Required:

Sr. No.	Unit	Technical Specifications	Quantity
1	PV Modules	100Wp	2
2	DC Voltmeter	0-45 V_{DC}	3
3	DC Ammeter	0-10 A_{DC}	3
4	MPPT	12V-24V , 20A-10A	1
5	PWM Charge controller	12V-24V, 10A	1
6	Battery	40 Ah	1
7	DC Load	20 W	10

Methodology of Experiment

1. Before starting the experiment note down the battery voltage in table 1
2. Connect the PV modules in series/parallel combination and note down the open circuit voltage and short circuit current in table2.
3. Cover the panels with shadow and Connect the battery at battery terminals shown in the control panel, then there indicates a green light in the MPPT charge controller.
4. Now connect the common output of the series/parallel connections of solar panel to series /parallel output shown in the control panel.
5. Now connect the Ammeter-1 +ve terminal to series/parallel output +ve terminal and Ammeter-1 –ve terminal to module output +ve terminal using Y-connector.
6. Now connect the MPPT system PV panel output to Module output shown in control panel and battery output of MPPT system to battery output shown in the control panel and load output of MPPT system to Load Output shown in control panel using connectors.
7. Now switch ON the system and note down the readings shown in voltmeter-1(PV panel voltage), voltmeter-2 (battery voltage), Ammeter-1(PV panel current) and Ammeter-2 (battery current).
8. Now switch ON the switches S1 to S10 (which are connected to L1 to L10) and note down the respected readings.
9. Now switch OFF the system and remove all the connectors.

CAUTION:

1. NEVER MEASURE CURRENT ON THE TERMINALS OF BATTERY.

2. NEVER CONNECT SERIES AND PARALLEL COMBINATION TOGETHER IT WILL CAUSE DAMAGE TO THE SYSTEM.

Observation table

Table 1 Check the battery terminal voltage before starting the experiment

Voltage (V)

Table 2 Measure the value of open circuit voltage and short circuit current

Open Circuit Voltage (Voc)	Short Circuit Current Isc

Table 3 Calculation of Voltage, Current and Power with MPPT charge controller

	MPPT Charge Controller		
	Voltage (V)	Current (I)	Power (W)
Pv Module			
Battery			

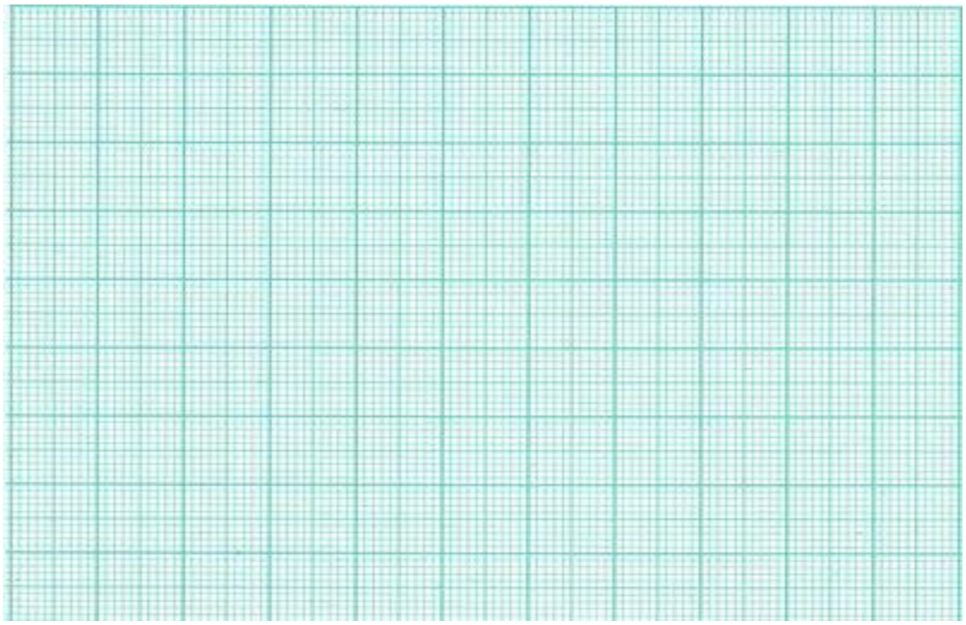
Table 4 Calculations of Voltage, Current and voltage with different load ratings

Sr. No.	Load (W)	MPPT Charge Controller Voltage (V)	Current (I)	Power (VxI=P)	Load Voltage (V)	Load Current (A)	Load Power
1.	20						
2.	40						
3.	60						
4.	80						
5.	100						
6.	120						
7.	140						
8.	160						
9.	180						
10.	200						

Results and Discussion:

1. By considering different load as given in the observation table 4 and plot the I-V curve for the same.
2. Obtaining the maximum power point (P_{max}) from the I-V characteristics.

Graph 1 Refer your readings in observation table 4 and plot the curve indicating load vs. Power relation



Conclusion:

Related Questions:

1. What is the need of Charge controllers in PV modules?
2. List out the benefits of using MPPTcharge controller?
3. How to choose MPPT charge controllers for PV modules and batteries?
4. Differentiate between PWM charge controllers and MPPT charge controllers on the basis of working principle, performance etc.
5. What advantages does MPPT gives in real world?

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
- Check the polarity of the battery before connecting
- Avoid unnecessary usage of switches for Dc bulb provided on the control box

2. Performance analysis of PWM

Contents

Objectives:

- Comparison between electrical parameters of module with PWM.
- Change in operating point of modules with PWM with variation in load.
- Comparison between charging points of battery with PWM.

Expected outcome of experiment:

- Ability to plot I-V Curve and find out P_{max}.
- Ability to understand the load variation leading to different power requirements.
- Ability to understand the maximum power extraction from PV Module with the use of PWM Charge controller.

Theory:

Charge controller:

The primary function of a charge controller in a stand-alone photovoltaic (PV) system is to protect the battery from overcharge and over discharge. Any system that has unpredictable loads, user intervention optimized or undersized battery storage (to minimize initial cost) or any characteristics that would allow excessive battery overcharging or over discharging requires a charge controller. Lack of a controller may result in shortened battery lifetime and decreased load availability.

PWM charge controller:

A charge controller, or charge regulator is basically a voltage and/or current regulator to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery. Most "12 volt" panels put out about 16 to 20 volts, so if there is no regulation the batteries will be damaged from overcharging. Most batteries need around 14 to 14.5 volts to get fully charged. Some charge controllers include a Low Voltage Disconnect (LVD) feature. This monitors the battery level and will disconnect any load connected to the battery if the voltage drops to a point where continued draw can cause permanent battery damage. This feature is a great protection for your deep cycle battery investment as a battery that has been discharged too deeply will have a far shorter serviceable life.

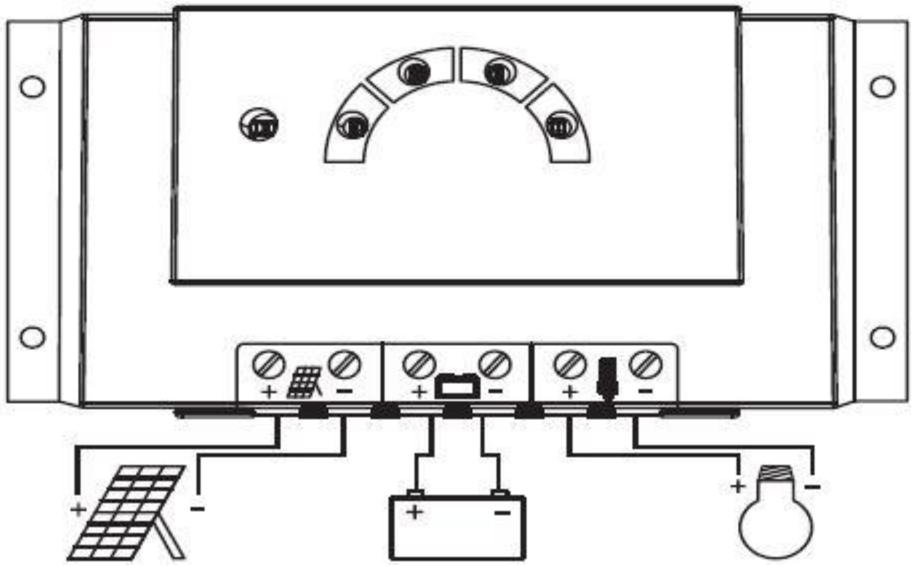


Figure 1 PWM Charge Controller

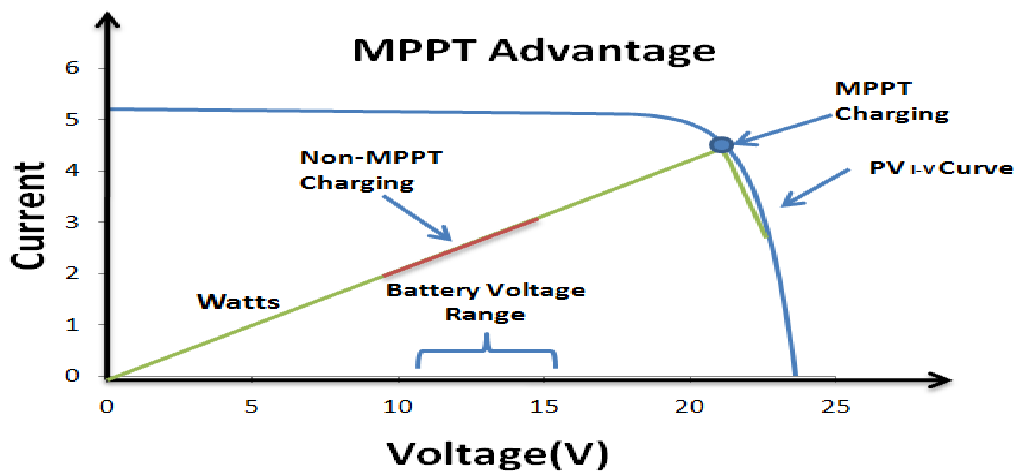


Figure 2 Effect of MPPT charge controller

Measurement:

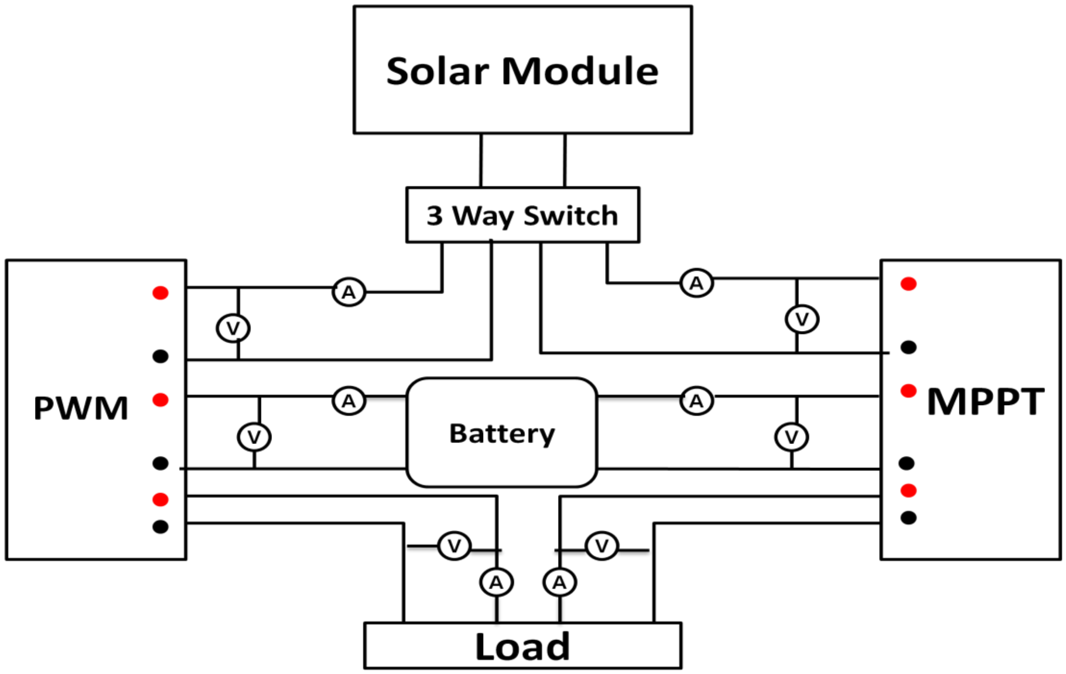


Figure 3 Single line diagram of control setup

Equipments required:

Sr. No.	Unit	Technical Specifications	Quantity
1	PV Modules	100Wp	2
2	DC Voltmeter	0-45 V_{DC}	3
3	DC Ammeter	0-10 A_{DC}	3
4	MPPT	12V-24V , 20A-10A	1
5	PWM Charge controller	12V-24V, 10A	1
6	Battery	40 Ah	1
7	DC Load	20 W	10

Methodology of Experiment

1. Before starting the experiment note down the battery voltage in table 1
2. Connect the PV modules in series/parallel combination and note down the open circuit voltage and short circuit current in table2.
3. Cover the panels with shadow and Connect the battery at battery terminals shown in the control panel, then there indicates a green light in the PWM charge controller.
4. Now connect the common output of the series/parallel connections of solar panel to series /parallel output shown in the control panel.
5. Now connect the Ammeter-1 +ve terminal to series/parallel output +ve terminal and Ammeter-1 –ve terminal to module output +ve terminal using Y-connector.
6. Now connect the PWM system PV panel output to Module output shown in control panel and battery output of PWM system to battery output shown in the control panel and load output of PWM system to Load Output shown in control panel using connectors.
7. Now switch ON the system and note down the readings shown in voltmeter-1(PV panel voltage), voltmeter-2(battery voltage), Ammeter-1(PV panel current) and Ammeter-2(battery current).
8. Now switch ON the switches S1 to S10 (which are connected to L1 to L10) and note down the respected readings.
9. Now switch OFF the system and remove all the connectors.

CAUTION:

3. NEVER MEASURE CURRENT ON THE TERMINALS OF BATTERY.

4. NEVER CONNECT SERIES AND PARALLEL COMBINATION TOGETHER IT WILL CAUSE DAMAGE TO THE SYSTEM.

Observation table

Table 1 Check the battery terminal voltage before starting the experiment

Voltage(V)

Table 2 Measure the value of open circuit voltage and short circuit current

Open Circuit Voltage (V_{oc})	Short Circuit Current (I_{sc})

Table 3 Calculation of Voltage, Current and Power with MPPT charge controller

	PWM Charge Controller		
	Voltage (V)	Current (I)	Power (W)
Pv Module			
Battery			

Table 4 Calculations of Voltage, Current and voltage with different load ratings

Sr. No.	Load (W)	PWM Charge Controller					
		Voltage (V)	Current (I)	Power (VxI=P)	Load Voltage (V)	Load Current (A)	Load Power
1.	20						
2.	40						
3.	60						
4.	80						
5.	100						
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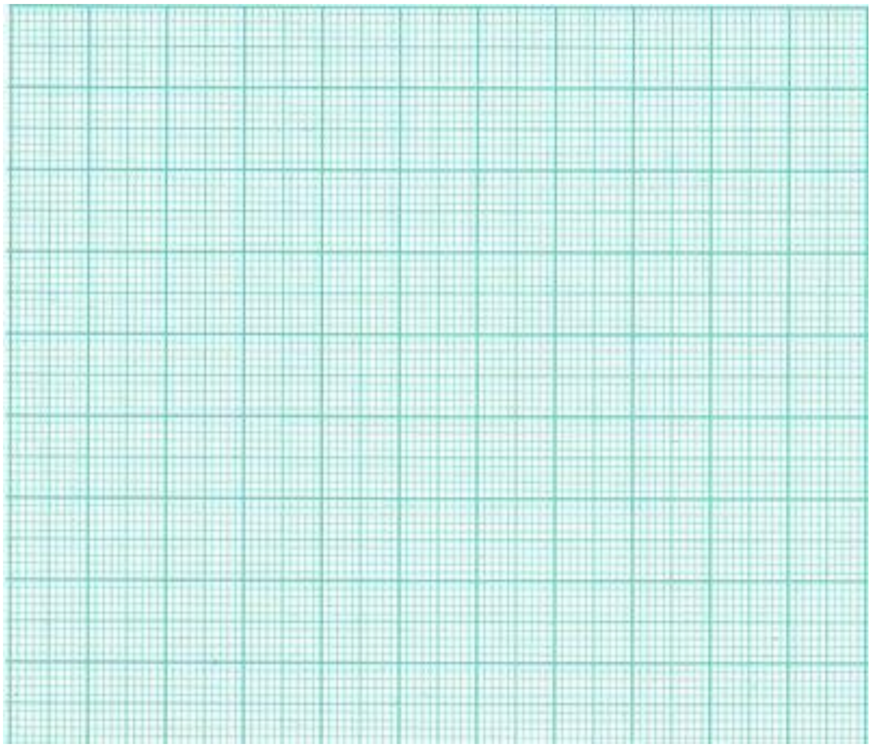
10.	200						

Results and Discussion:

1. By considering different load as given in the observation table 4 and plot the I-V curve for the same.
2. Obtaining the maximum power point (P_{max}) from the I-V characteristics.

Graph 1 Refer your readings in observation table 4 and plot the curve indicating load vs. Power relation



Conclusion:

Related Questions:

1. What is the need of Charge controllers in PV modules?
2. List out the benefits of using PWM charge controller?
3. How to choose PWM charge controllers for PV modules and batteries?
4. Differentiate between PWM charge controllers and MPPT charge controllers on the basis of working principle, performance etc.
5. What advantages does PWM gives in real world?

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
- Check the polarity of the battery before connecting
- Avoid unnecessary usage of switches for Dc bulb provided on the control box

3. Analysis of effect of Single Axis Tracking on MPPT

Contents

Objectives:

- Comparison between electrical parameters of module with and without MPPT.
- Change in operating point of modules with and without MPPT with variation in load.
- Comparison between charging points of battery with and without MPPT.

Expected outcome of experiment:

- Ability to plot I-V Curve and find out P_{max}
- Ability to understand the load variation leading to different power requirements
- Ability to understand the differences between operating point of MPPT and PWM charge controllers.
- Ability to understand the maximum power extraction from PV Module with the use of MPPT Charge controller or PWM Charge controller

Theory:

Charge controller:

The primary function of a charge controller in a stand-alone photovoltaic (PV) system is to protect the- battery from overcharge and over discharge. Any system that has unpredictable loads, user intervention optimized or undersized battery storage (to minimize initial cost) or any characteristics that would allow excessive battery overcharging or over discharging requires a charge controller. Lack of a controller may result in shortened battery lifetime and decreased load availability.

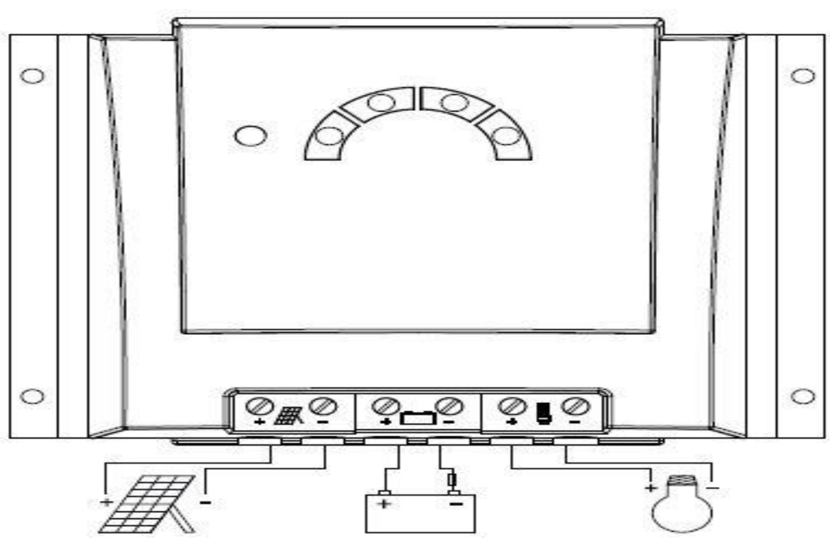


Figure 1 MPPT Charge Controller

MPPT Charge Controller:

MPPT stands for Maximum Power Point Tracking, and it relates to the solar cell itself. Each solar cell has a point at which the current (I) and voltage (V) output from the cell result in the maximum power output of the cell. In the diagram below the curve is an example of the standard output expected from a solar cell, the Maximum Power Point is at the position marked on the diagram.

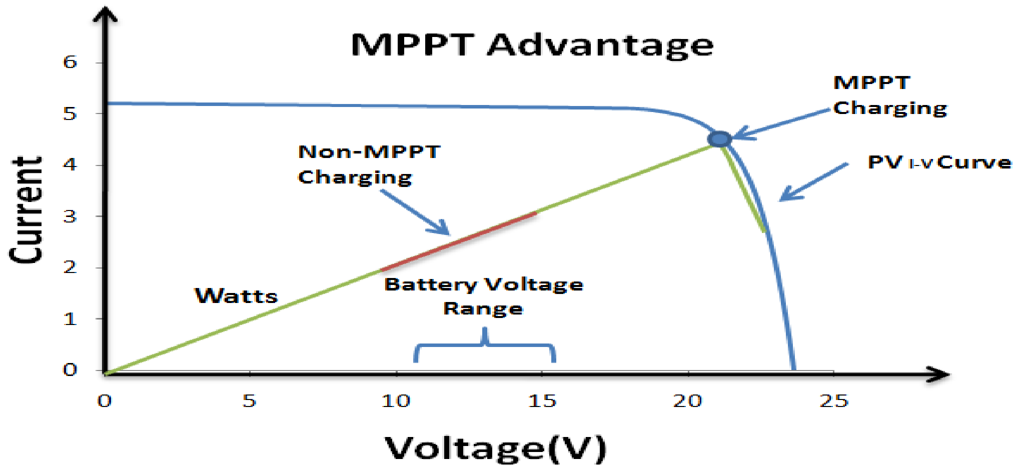


Figure 2 Effect of MPPT charge controller

The principle is that if the output from the cell can be regulated to the voltage and current levels needed to achieve a power output at this point, then the power generated by the solar cell will be used most efficiently.

Working of MPPT-

A Maximum Power Point Tracking solar regulator will simulate the load required by the solar panel to achieve the maximum power from the cell. The regulator will work out at which point the cell will output the maximum power and derive from this the voltage and current outputs required for maximum power to be achieved. It will then calculate the load that it must simulate based on these voltage and current levels.

$$R = \frac{V}{I}$$

The regulator, now receiving the maximum amount of power in, will then regulate the output according to what it is designed for .MPPT ensures that you get the most power possible from your solar panels at any point in time. It is particularly effective during low light level conditions. These calculations result in an output that delivers maximum current at the required voltage at any point in time. During low light level situations it will compensate for the low light level and find the new point at which the solar cell delivers its maximum power output.

Measurement:

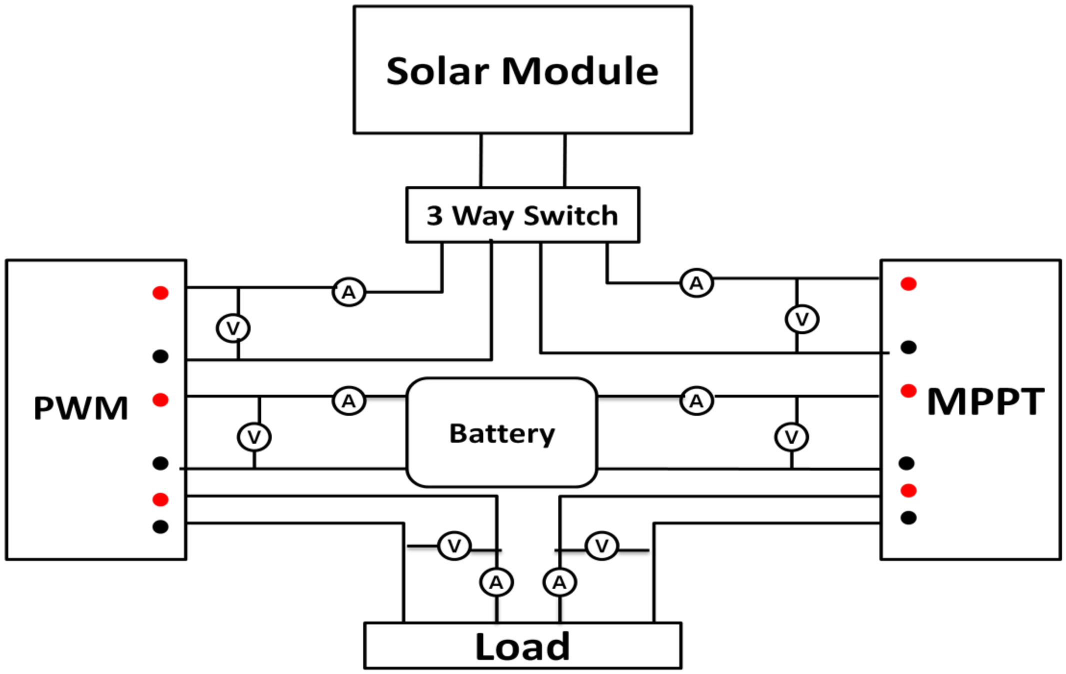


Figure 3 Single line diagram of control setup

Equipments Required:

Sr. No.	Unit	Technical Specifications	Quantity
1	PV Modules	100Wp	2
2	DC Voltmeter	0-45 V_{DC}	3
3	DC Ammeter	0-10 A_{DC}	3
4	MPPT	12V-24V , 20A-10A	1
5	PWM Charge controller	12V-24V, 10A	1
6	Battery	40 Ah	1
7	DC Load	20 W	10

Methodology for measurement:

1. Before starting the experiment note down the battery voltage in table 1
2. Adjust the tilt angle manually and connect the PV modules in series/parallel combination and note down the open circuit voltage and short circuit current in table2.
3. Cover the panels with shadow and Connect the battery at battery terminals shown in the control panel, then there indicates a green light in the MPPT charge controller.

4. Now connect the common output of the series/parallel connections of solar panel to series /parallel output shown in the control panel.
5. Now connect the Ammeter-1 +ve terminal to series/parallel output +ve terminal and Ammeter-1 –ve terminal to module output +ve terminal using Y-connector.
6. Now connect the MPPT system PV panel output to Module output shown in control panel and battery output of MPPT system to battery output shown in the control panel and load output of MPPT system to Load Output shown in control panel using connectors.
7. Now switch ON the system and note down the readings shown in voltmeter-1(PV panel voltage), voltmeter-2(battery voltage), Ammeter-1(PV panel current) and Ammeter-2(battery current).
8. Now change the angle manually and repeat the steps 3-7.
9. Repeat the step 8.
10. Now switch OFF the system and remove all the connectors.

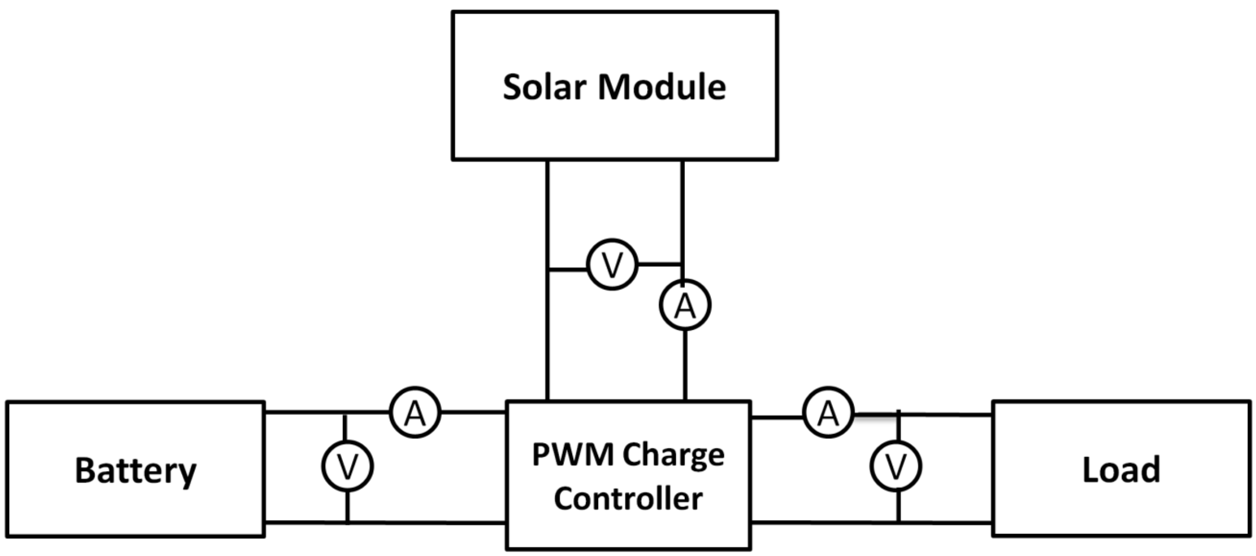


Figure 4 Circuit diagram of PWM charge controller

NOTE: CONNECTIONS ARE ALREADY INCORPORATED WITH USE OF CONTROL BOX (REFER INTERNAL WIRING DRAWING GIVEN ON PAGE). USER CAN USE THE CHANGEOVER SWITCH FOR SWITCHING BETWEEN CIRCUIT 1 AND CIRCUIT 2.

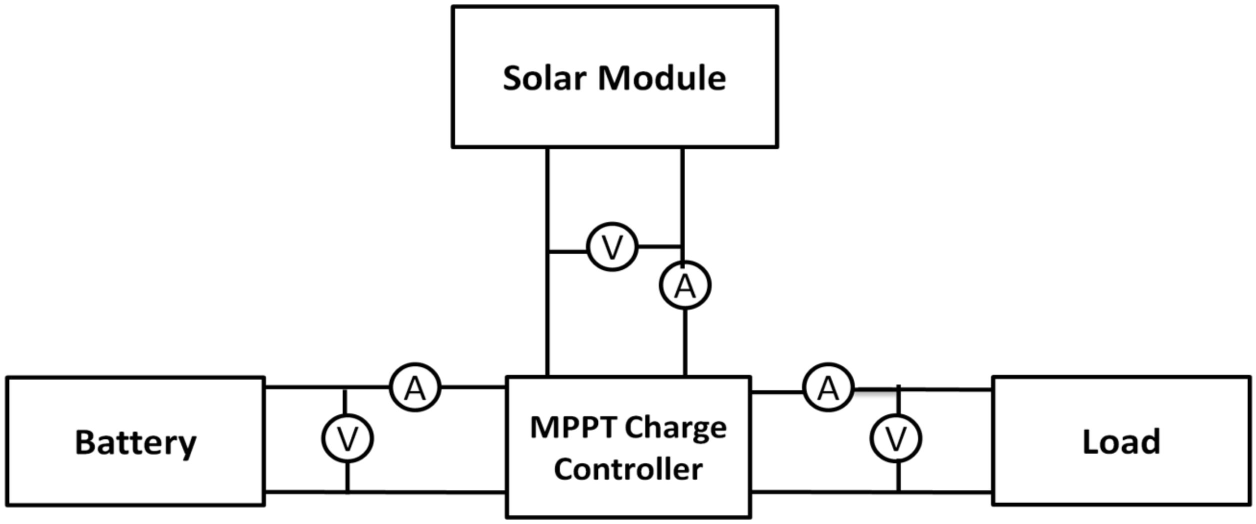


Figure 5 Circuit Diagram of MPPT charge controller

Observation Table

Table 1 Check the battery terminal voltage before starting the experiment

Voltage(V)

Table 2 Measure the value of open circuit voltage and short circuit current

Tilt angle	Open Circuit Voltage (V_{oc})	Short Circuit Current (I_{sc})

Table 3 Calculation of Voltage, Current and Power with MPPT charge controller

Tilt angle	PV			Battery		
	Voltage (V)	Current (I)	Power (VxI=P)	Voltage (V)	Current (I)	Power (VxI=P)

Results and Discussion:

1. Differentiate between I-V characteristics of PWM charge controller and MPPT and plot the I-V curve for the same.
2. Differentiate between I-V characteristics by considering different load as given in the observation table 4 and plot the I-V curve for the same.
3. Obtaining the maximum power point (P_{max}) from the I-V characteristics.Conclusion:

Related Questions:

1. What is the need of Charge controllers in PV modules?
2. List out the benefits of using PWM charge controller?
3. How to choose MPPT charge controllers for PV modules and batteries?
4. Differentiate between PWM charge controllers and MPPT charge controllers on the basis of working principle, performance etc.
5. What advantages does MPPT gives in real world?

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
- Check the polarity of the battery before connecting
- Avoid unnecessary usage of switches for Dc bulb provided on the control box

4. Analysis of effect of Single Axis Tracking on PWM

Contents

Objectives:

- Comparison between electrical parameters of module with PWM.
- Change in operating point of modules with PWM with variation in load.
- Comparison between charging points of battery with PWM.

Expected outcome of experiment:

- Ability to plot I-V Curve and find out P_{max}.
- Ability to understand the load variation leading to different power requirements.
- Ability to understand the maximum power extraction from PV Module with the use of PWM Charge controller.

Theory:

Charge controller:

The primary function of a charge controller in a stand-alone photovoltaic (PV) system is to protect the battery from overcharge and over discharge. Any system that has unpredictable loads, user intervention optimized or undersized battery storage (to minimize initial cost) or any characteristics that would allow excessive battery overcharging or over discharging requires a charge controller. Lack of a controller may result in shortened battery lifetime and decreased load availability.

PWM charge controller:

A charge controller, or charge regulator is basically a voltage and/or current regulator to keep batteries from overcharging. It regulates the voltage and current coming from the solar panels going to the battery. Most "12 volt" panels put out about 16 to 20 volts, so if there is no regulation the batteries will be damaged from overcharging. Most batteries need around 14 to 14.5 volts to get fully charged. Some charge controllers include a Low Voltage Disconnect (LVD) feature. This monitors the battery level and will disconnect any load connected to the battery if the voltage drops to a point where continued draw can cause permanent battery damage. This feature is a great protection for your deep cycle battery investment as a battery that has been discharged too deeply will have a far shorter serviceable life.

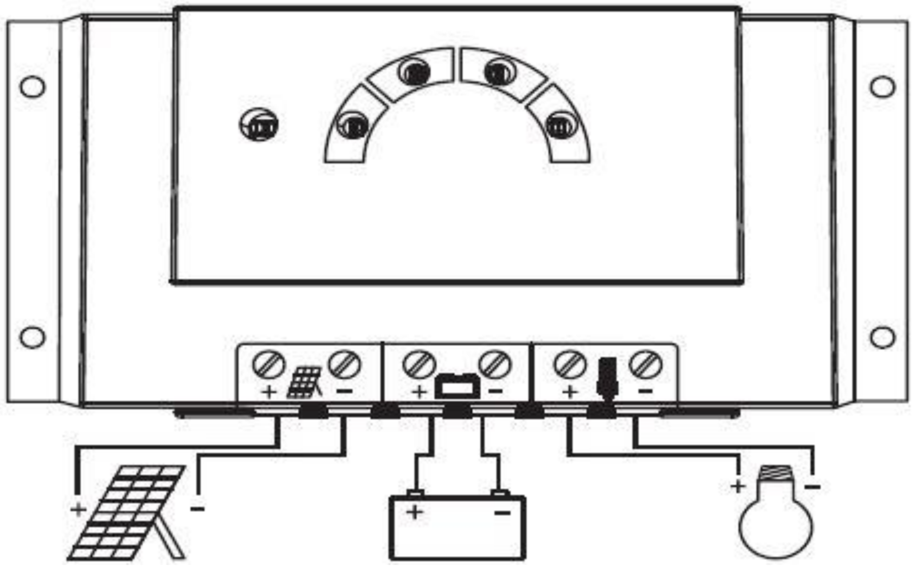


Figure 1 PWM Charge Controller

Measurement:

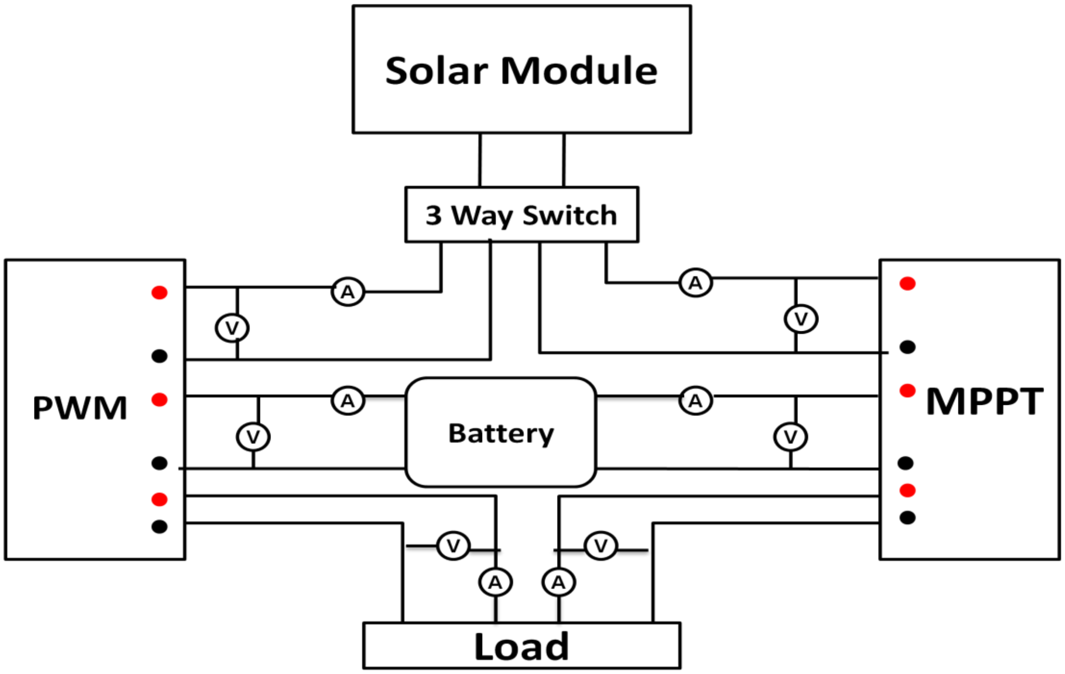


Figure 2 Single line diagram of the control setup

Equipments required:

Sr. No.	Unit	Technical Specifications	Quantity
1	PV Modules	100Wp	2
2	DC Voltmeter	0-45 V_{DC}	3
3	DC Ammeter	0-10 A_{DC}	3
4	PWM Charge controller	12V-24V, 10A	1
5	Battery	40 Ah	1
6	DC Load	20 W	10

Methodology for Experiment:

1. Before starting the experiment note down the battery voltage in table 1
2. Adjust the tilt angle manually and connect the PV modules in series/parallel combination and note down the open circuit voltage and short circuit current in table2.
3. Cover the panels with shadow and Connect the battery at battery terminals shown in the control panel, then there indicates a green light in the PWM charge controller.
4. Now connect the common output of the series/parallel connections of solar panel to series /parallel output shown in the control panel.
5. Now connect the Ammeter-1 +ve terminal to series/parallel output +ve terminal and Ammeter-1 –ve terminal to module output +ve terminal using Y-connector.
6. Now connect the PWM system PV panel output to Module output shown in control panel and battery output of PWM system to battery output shown in the control panel and load output of PWM system to Load Output shown in control panel using connectors.
7. Now switch ON the system and note down the readings shown in voltmeter-1(PV panel voltage), voltmeter-2(battery voltage), Ammeter-1(PV panel current) and Ammeter-2(battery current).
8. Now change the angle manually and repeat the steps 3-7.
9. Repeat the step 8.
10. Now switch OFF the system and remove all the connectors.

CAUTION:

1. **NEVER MEASURE CURRENT ON THE TERMINALS OF BATTERY.**
2. **NEVER CONNECT SERIES AND PARALLEL COMBINATION TOGETHER IT WILL CAUSE DAMAGE TO THE SYSTEM.**

Observation Table

Table 1 Check the battery terminal voltage before starting the experiment

Voltage(V)

Table 5 Measure the value of open circuit voltage and short circuit current

Open Circuit Voltage (V_{oc})	Short Circuit Current (I_{sc})

Table 6 Calculation of Voltage, Current and Power with PWM charge controller

Tilt angle	PV Panel			Battery		
	Voltage (V)	Current (I)	Power (VxI=P)	Voltage (V)	Current (I)	Power (VxI=P)

Results and Discussion:

1. By considering different load as given in the observation table 4 and plot the I-V curve for the same.
2. Obtaining the maximum power point (P_{max}) from the I-V characteristics.

Conclusion:

Related Questions:

1. What is the need of Charge controllers in PV modules?
2. List out the benefits of using PWM charge controller?
3. Differentiate between PWM charge controllers and MPPT charge controllers on the basis of working principle, performance etc.

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
- Check the polarity of the battery before connecting
- Avoid unnecessary usage of switches for Dc bulb provided on the control box