Heliocentris

Renewable Energy Trainer

RENEWABLE ENERGY TRAINER

EXPERIMENT BOOKLET

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1. INTRODUCING THE TRAINING

1.1. GENERAL INTRODUCTION

Figure-1 Renewable Energy Training Set: Overall View

The renewable energy training set is a computer-assisted training set that allows solar energy, wind energy and hydrogen fuel cell applications.

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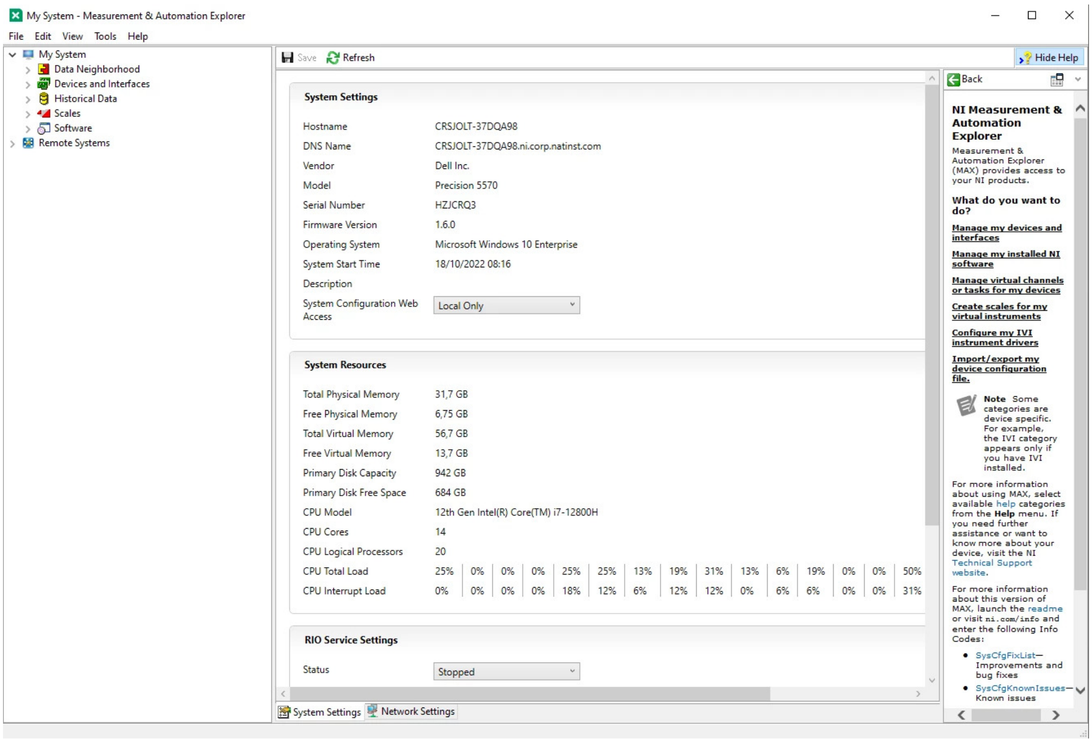
A. NI MAX Application

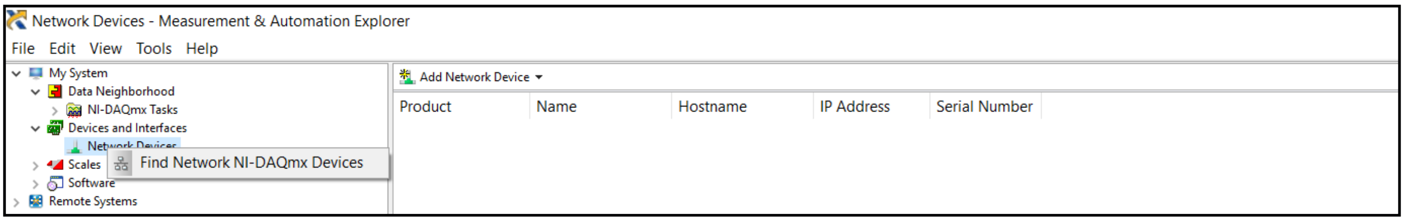
• To use the DATA ACQUISITION Module, install the interface application on your computer with the NI Daq Card CD supplied with the training kit.

• After installation, run the  application.

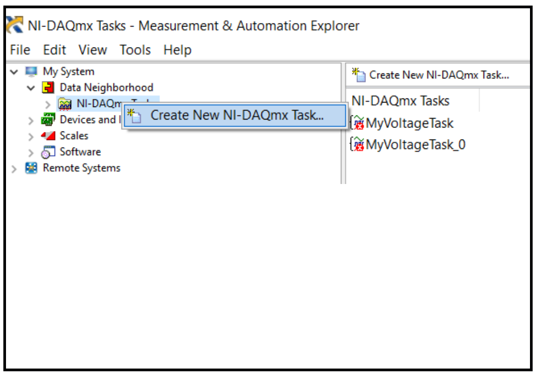
• The NI MAX main screen opens.

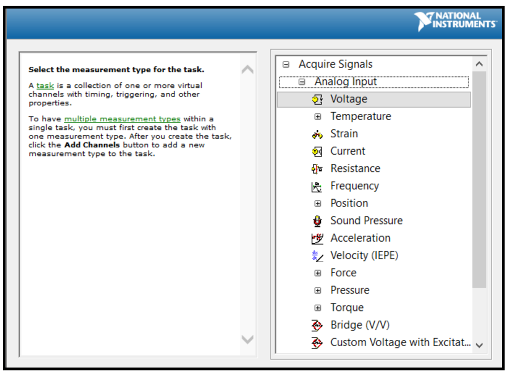


• If the device is connected to the computer, the daq device is displayed.



• Create a new task so you can read the data.





• Ölçülmek istenilen değere uygun seçeneği seçin ve uygun girişleri atayın. Ölçüm ekranı açılacaktır.

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HYDROFILL® PRO

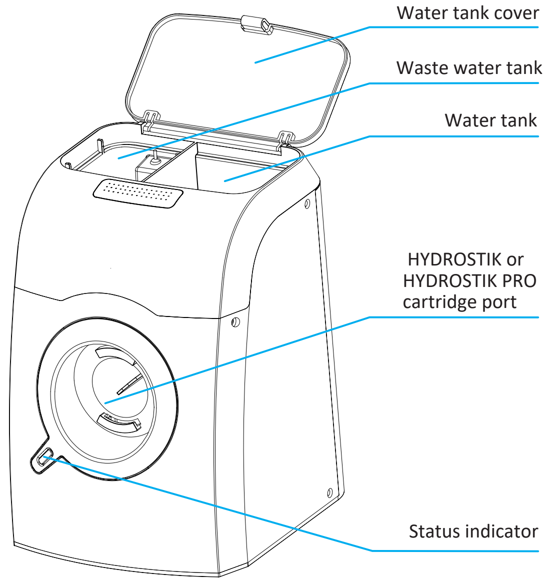
USER MANUAL

WARNING

- **Do not tamper with, or disassemble the HYDROFILL PRO**
- **Keep HYDROFILL PRO away from fire, open flame, or heat sources**
- **Keep HYDROSTIK or HYDROSTIK PRO cartridge away from fire, open flame, or heat sources**
- **Keep HYDROFILL PRO away from children**
- **Keep HYDROFILL PRO in upright position**
- **Add de-ionized or distilled water carefully to avoid over-filling the water tank**
- **Keep HYDROFILL PRO in a ventilated location during operation**
- **Do not ingest the powder (malic acid) contained in the maintenance kit, keep away from children**
- **Keep all electrical connections dry at all times**

SYSTEM OVERVIEW

The HYDROFILL PRO system uses a proton exchange membrane (PEM) electrolyzer to recharge Horizon's HYDROSTIK and HYDROSTIK PRO metal hydride cartridges automatically.



(a) HYDROFILL PRO unit

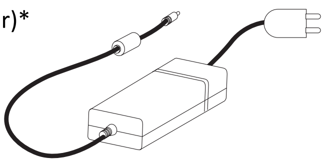
SYSTEM FEATURES

- Quiet, safe and convenient hydrogen supply
- Compatible with HYDROSTIK and HYDROSTIK PRO cartridge
- High hydrogen purity 99.99%
- Optional DC solar or wind power supply
- Connects to AC power

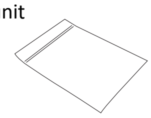
INCLUDED IN THIS BOX

a. HYDROFILL PRO unit
b. AC-DC adapter cord
c. Maintenance kit (malic acid powder)*
d. User Manual

*Additional malic acid powder maintenance kits can be purchased from Horizon. Contact support@horizonfuelcell.com.



(b) AC-DC adapter



(c) Maintenance kit

SPECIFICATIONS

Stack type	Proton exchange membrane electrolysis cell
Dimensions (W x D x H)	145 x 153 x 208 mm (5.7 x 6 x 8.2 in)
Weight	1.8Kg ±5% (3.97Lbs ±5%)
Rated power	≤23W
Input voltage	DC: 10V-19V
Water input	De-ionized or distilled water
Water temperature	10-40°C (50-104°F)
Water consumption	Approx. 20ml/hr (1.2in^3/hr)
Hydrogen outputp ressure	0-3.0 MPaG (0-435.11 PSI)
Hydrogen generation capacity	Up to 3L/hr (0-183 in^3/hr)
Purity	99.99%
Compatible cartridge	HYDROSTIK and HYDROSTIK PRO
Refilling time for one cartridge	Around 4 hours (at 25C ambient temperature)

STATUS INDICATOR LIGHTS

Green	Red	System Status
on		HYDROSTIK or HYDROSTIK PRO cartridge is full
on 1 second, off 1 second		Waiting to fill HYDROSTIK or HYDROSTIK PRO cartridge
	on	HYDROSTIK or HYDROSTIK PRO cartridge is being filled
	on 1 second, off 3 seconds	Add maintenance kit (malic acid)
	on 1 second, off 1 second	Add water or empty waste water tank

OPERATION INSTRUCTIONS

1. Open the water tank cover located at the top of the unit (Fig. A). Carefully add de-ionized or distilled water** EXACTLY up to the ridge level inside the water tank as shown below in Fig. B. Close the cover.

Fig. A

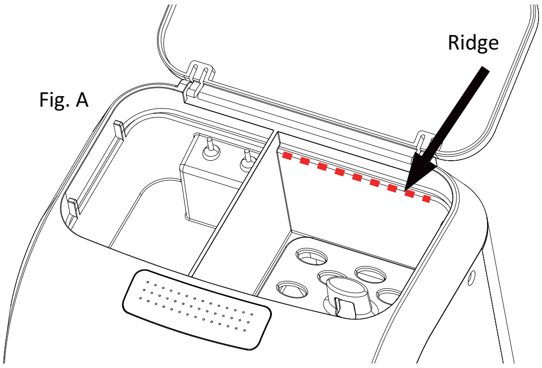
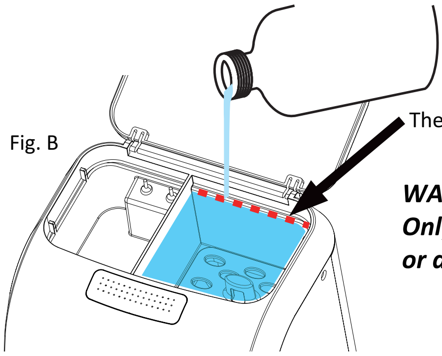


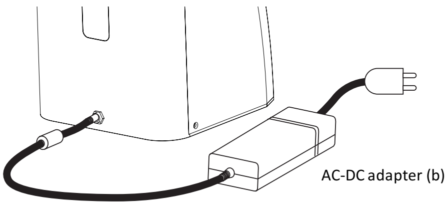
Fig. B



WARNING: Only use de-ionized or distilled water.

2. Connect the AC-DC adapter to the unit (Fig. C).
Once plugged in to an AC point, the unit's status indicator light should start to flash green.

Fig. C



3. Fully insert the HYDROSTIK or HYDROSTIK PRO cartridge into the HYDROFILL PRO unit by turning it clockwise into the cartridge port until firmly secured. During the insertion process, the green indicator light may turn red to indicate a connection (Fig D), but continue turning to make sure the HYDROSTIK or HYDROSTIK PRO is firmly secured (Fig E). Secure the HYDROSTIK or HYDROSTIK PRO tightly to the unit, but be careful not to apply excessive force.

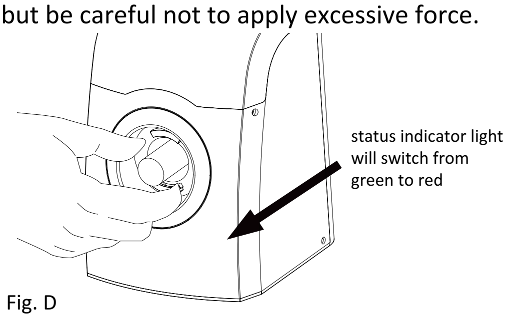


Fig. D

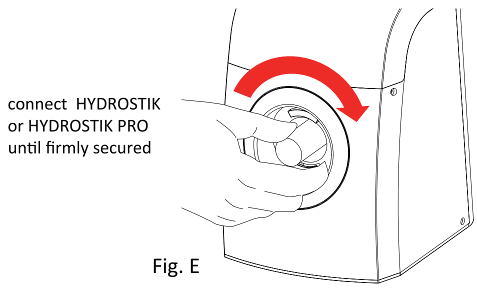


Fig. E

4. While the indicator light is RED, your HYDROSTIK or HYDROSTIK PRO cartridge is being filled with hydrogen. The HYDROSTIK or HYDROSTIK PRO cartridge is fully charged when the indicator lights GREEN. When completed, disconnect the HYDROSTIK or HYDROSTIK PRO cartridge from the HYDROFILL PRO (turn anti-clockwise to disconnect). *Note: 1. It will be normal to hear short bursts or puffs during the refilling procedure, due to water being purged from the system from time to time.*
2. It will be normal to hear the sound of air being released when the HYDROSTIK or HYDROSTIK PRO is disconnected from the HYDROFILL PRO.

5. Disconnect the HYDROFILL PRO from the AC and empty the water tank if you will not use the HYDROFILL PRO for more than one week. If more cartridges need to be charged, repeat step 3.

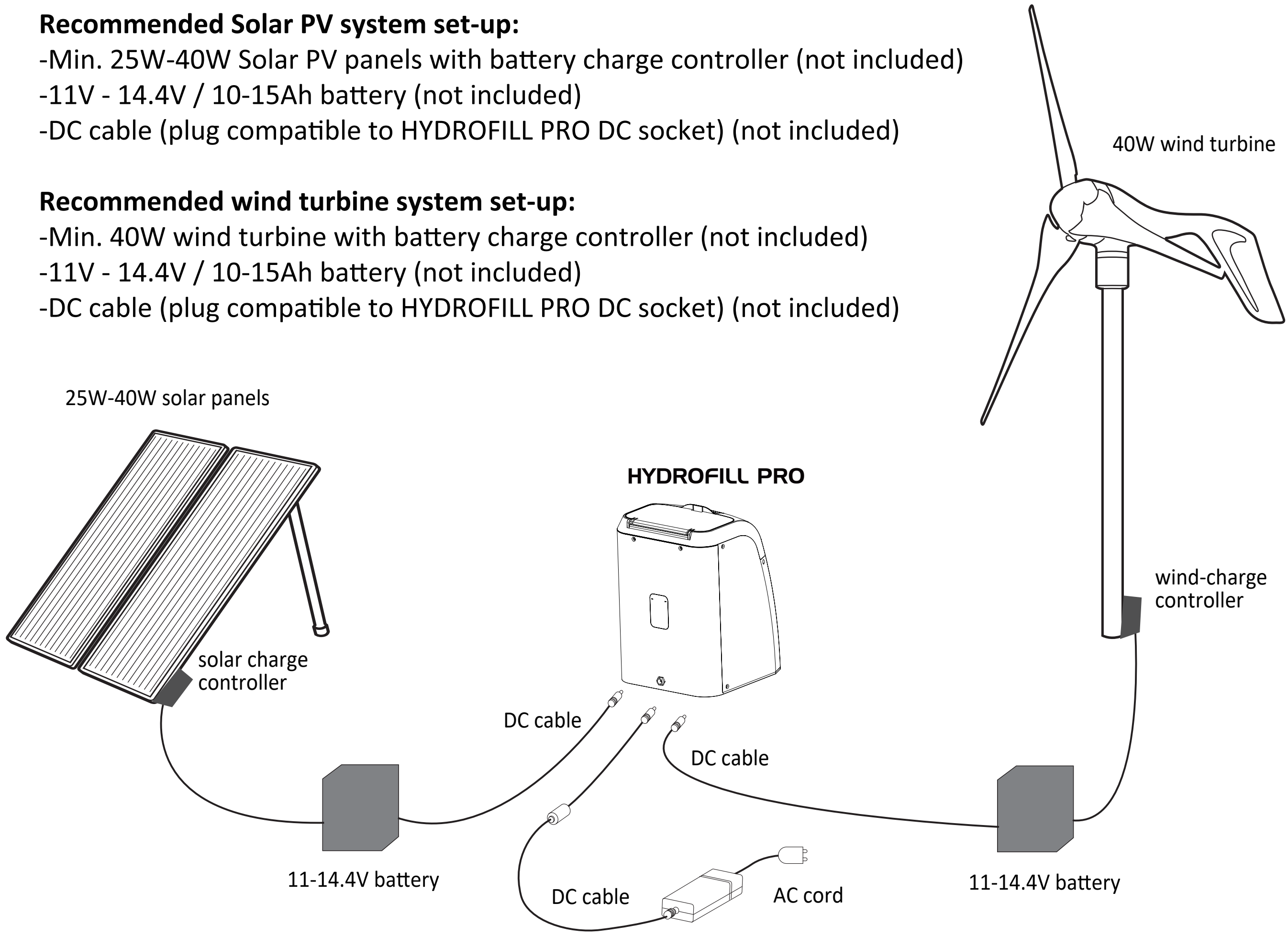
2

SWITCHING FROM AC TO DC SOLAR OR WIND POWER OPTIONS

HYDROFILL PRO can be powered by using the standard (included) AC to DC power cable (b), or can be connected to renewable power sources such as solar PV or small wind turbines. Both sources should include a battery buffer to regulate power supplied to the HYDROFILL PRO.

Recommended Solar PV system set-up:
-Min. 25W-40W Solar PV panels with battery charge controller (not included)
-11V - 14.4V / 10-15Ah battery (not included)
-DC cable (plug compatible to HYDROFILL PRO DC socket) (not included)

Recommended wind turbine system set-up:
-Min. 40W wind turbine with battery charge controller (not included)
-11V - 14.4V / 10-15Ah battery (not included)
-DC cable (plug compatible to HYDROFILL PRO DC socket) (not included)



USEFUL INFORMATION / MAINTENANCE

- Only use **<u>de-ionized or distilled water.</u>**
- Around 4 hours operation are required to fully charge a cartridge.
- If the red status indicator light alternates between red for 1 second and off for 3 seconds, carefully add the entire contents of one maintenance kit bag (c) into the water tank without disconnecting the cartridge. Allow the HYDROFILL PRO to charge the HYDROSTIK or HYDROSTIK PRO cartridge for more than 1 hour. This procedure will help improve the performance of the HYDROFILL PRO.
- If the LED light alternates red for 1 second and off for 1 second, check the water level of the water tank and waste water tank. Either add water to the water tank or remove water from the waste water tank as required. Follow set up instructions carefully.
- The HYDROFILL PRO can still run and generate hydrogen even if the LED light alternates between red for 1 second and off for 3 seconds, but HYDROSTIK or HYDROSTIK PRO charging time will be slower.

TROUBLESHOOTING

1. The status indicator light does not flash green after the power supply cord is connected.
SOLUTION: Check the connection between the AC-DC adapter and the power supply.

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C. Luxmetre User Manual

• Hold the button briefly to turn the device on and off.

• The LUX FC key is used to measure lux or fc.

Illuminance is a measure of how much luminous flux is spread over a given area. One can think of luminous flux (measured in lumens) as a measure of the total “amount” of visible light present, and the illuminance as a measure of the intensity of illumination on a surface. A given amount of light will illuminate a surface more dimly if it is spread over a larger area, so illuminance is inversely proportional to area when the luminous flux is held constant.

One lux is equal to one lumen per square metre:

1 lux = 1 lm/m2 = 1 cd·sr/m2 1 fc = 10.76391 lux

• If you want to lock a value on the screen, press the HOLD BL button. If you want to see the instant value on the screen, press the HOLD BL button again.

• The MAX MIN key is used to capture the maximum lux value or the minimum lux value in the environment.

Function	Range	Resolution	Accuracy	Description
Illumination	0~9999 Lux	1 Lux	±(4%rdg+8dgts)	(regulate in the standard of 2856K color temperature flat lamp) Note: 1FC=10.76 Lux
	⩾10000 Lux	10 Lux	±(5%rdg+10dgts)	
Range	0~199,999 Lux			Auto-ranging
Sampling Time			0.5s	Refresh sampling in 0.5s
Overload Indication			OL	Shows “OL”
MAX/MIN Measurement			MAX/MIN	Shows “MAX/MIN”
Data Hold			HOLD	Shows “HOLD”
Backlight			BL	Manually on and off
Auto Power Off			5mins	Automatically power off after 5mins without operation
Low Battery			3.0~3.5V	Shows low battery prompt when power is 3.0~3.5V

1.2. PHOTOVOLTAIC PANEL – LIGHT SOURCE MODULE

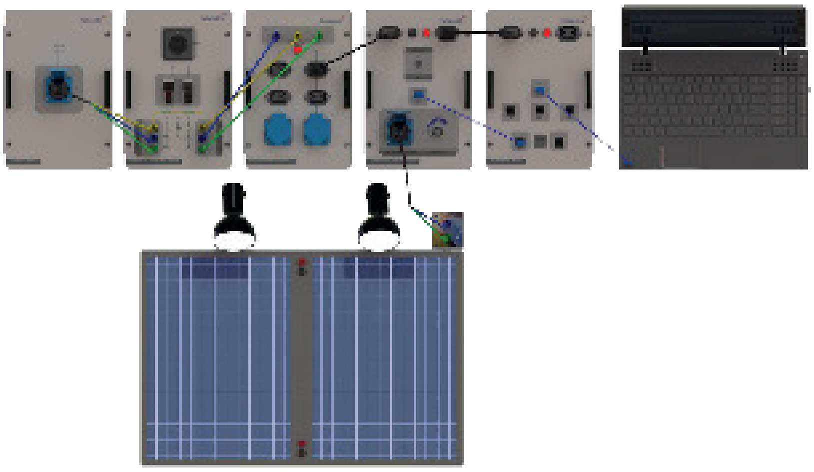

Figure-1 Photovoltaic panel – light source module

It is a module developed specifically to allow experiments on the photovoltaic panel in laboratory environments. Light power and angle of incidence are easily adjustable.

1.3. WIND TURBINE MODULE

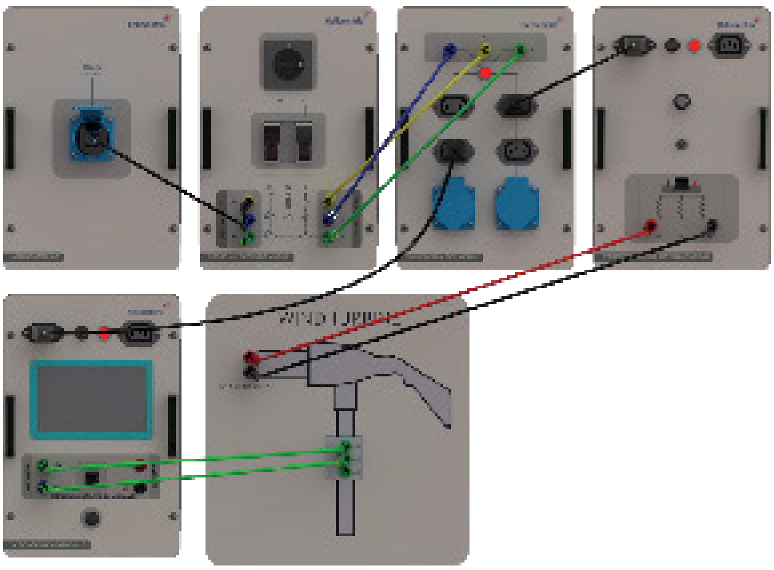

Figure-1 Wind turbine module

It is a module developed specifically to allow experiments on the wind turbine in laboratory environments. Wind velocity is easily adjustable.

1.4. MONOPHASE SWITCHING MODULE

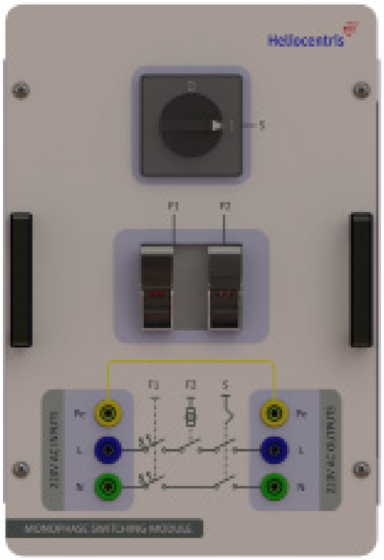

Figure-1 Overall View of the Module

It is a switch and fuse module designed for general purposes. It is recommended for use before the energy distribution module. The module is equipped with an on-off type pack breaker, a residual-current relay and an automatic fuse.

1.5. ENERGY DISTRIBUTION MODULE

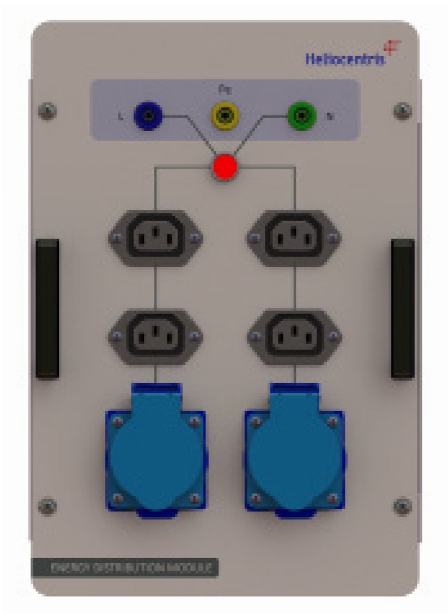

Figure-1 Overall View of the Module

It is the energy distribution module designed to meet the power requirements of the modules used on the training set. The module can be energized by a banana plug or a power cord with an IEC connector. The module is equipped with 4 IEC connectors and 2 sockets with safety covers. The presence or absence of energy on the module is indicated by a LED placed on the module. Figure-2 demonstrates the joint operation of monophase switching module and energy distribution module.

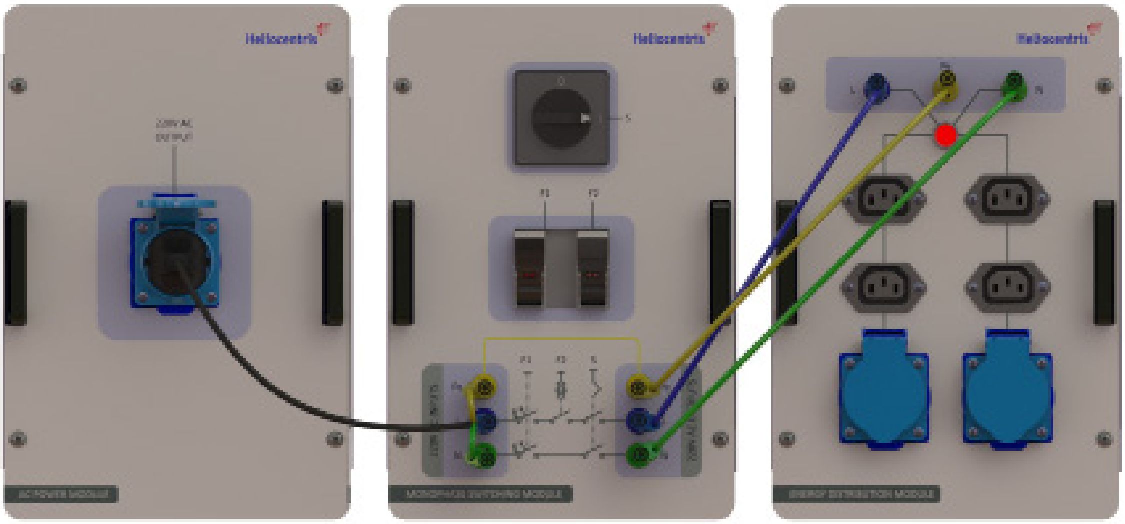

Figure-2 Joint operation of the two modules

1.6. ACCUMULATOR MODULE

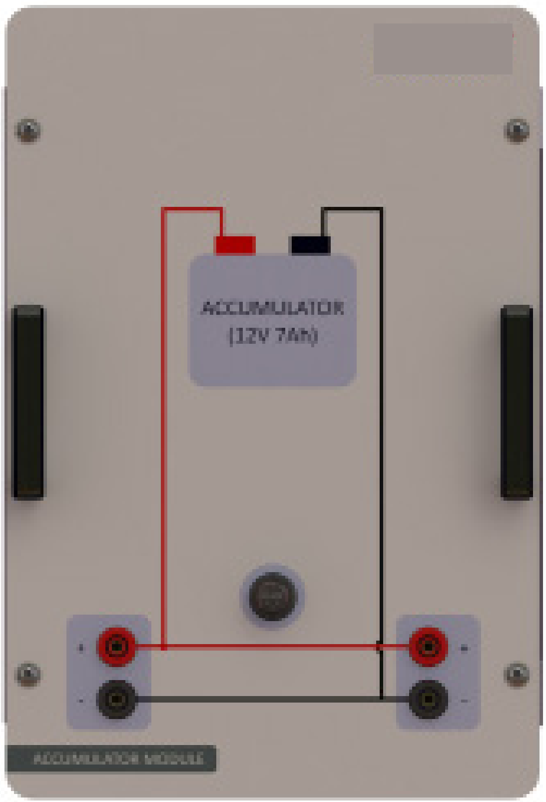

Figure-1 Overall View of the Module

It is a maintenance-free dry accumulator module with a value of 12V / 7Ah. It is equipped with an automatic fuse for short circuit protection. For accurate experimentation, the accumulator needs to be charged. It won't be possible to conduct experiments especially with the accumulators which haven't been used for a long while. It is for this reason that charging the accumulator at regular intervals is advised. (Accurate results will be drawn especially if the charging process starts at least 4 hours prior to the experiment.)

1.7. ANALOG MEASUREMENT MODULE

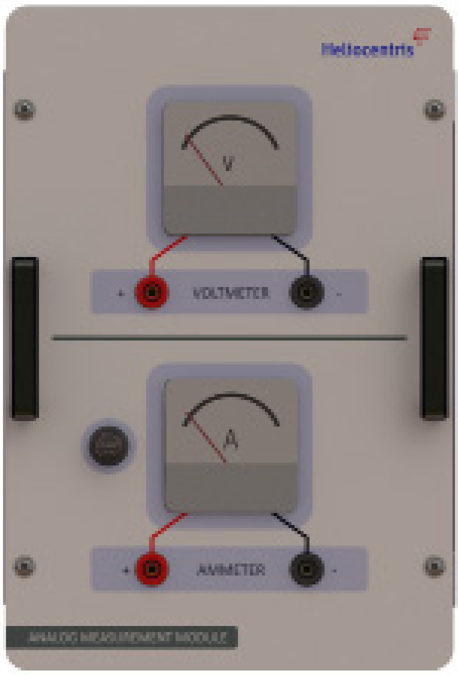

Figure-1 Overall View of the Module

It comprises an ampermeter and a voltmeter for general purposes. Taking the measurement range of the measurement devices into consideration, the module needs protection from high current (max. 5A) or voltage (max. 30V). Measurement direction, too, needs to be taken into consideration. An exemplary circuit is given in figure-2 to demonstrate the connection of the module to a circuit.

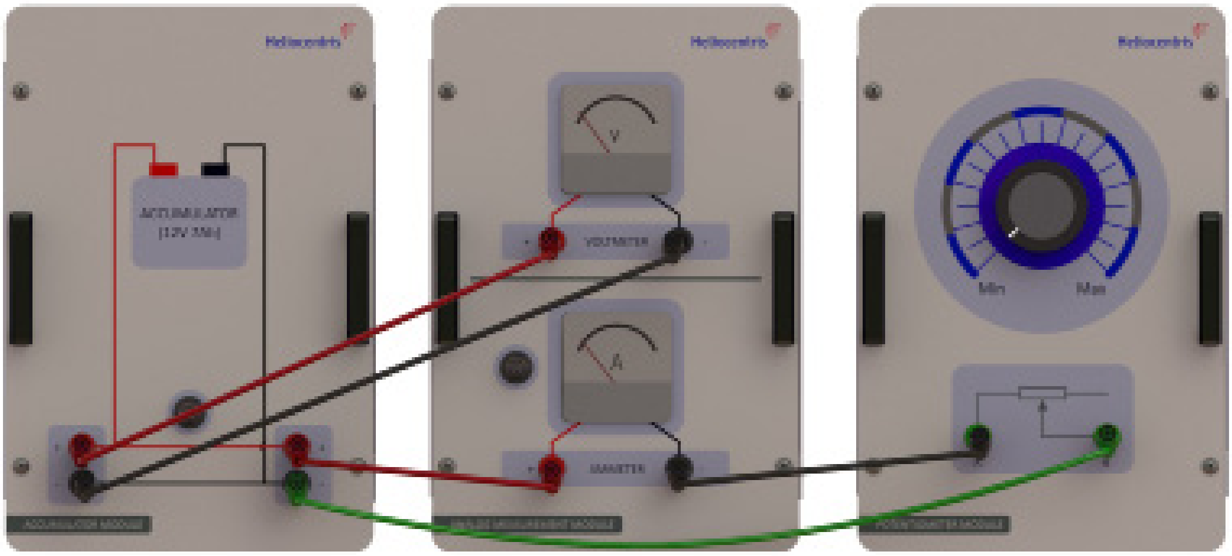

Figure-2

1.8. AC/DC MEASUREMENT MODULE

Figure-1 Overall View of the Module

It comprises an ampermeter and a voltmeter for general purposes. The measurements taken can be transferred to a computer through the RS485 junction point. The exemplary circuit given in figure-2 can be used along with the PC Interface Module for successful transfer to a computer.

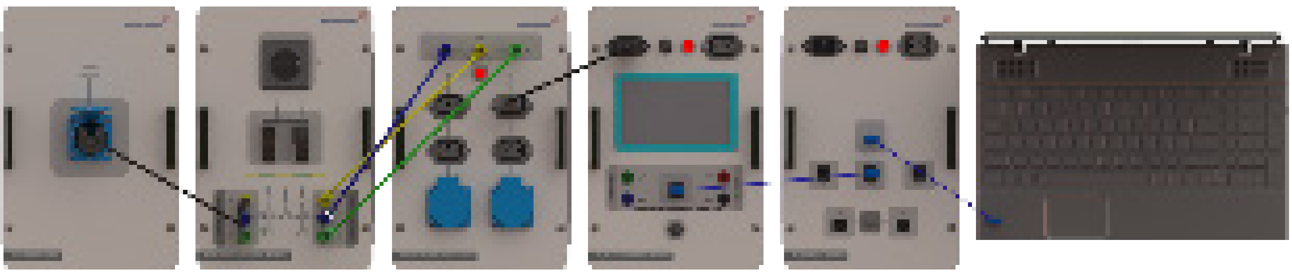

Figure-2

1.9. POTENTIOMETER MODULE

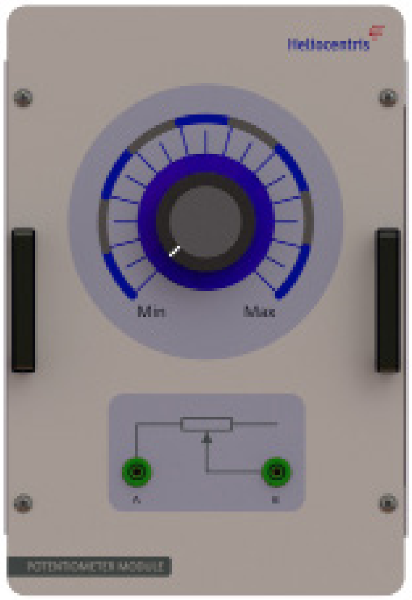

Figure-1 Overall View of the Module

It is a load module designed for general purposes. Having a value of 1K / 500W, the module should not be allowed more current passage than the indicated power value. Resistance value should be adjusted slowly and manually, avoiding fast resistance changes.

1.10. LAMP MODULE (12V DC)

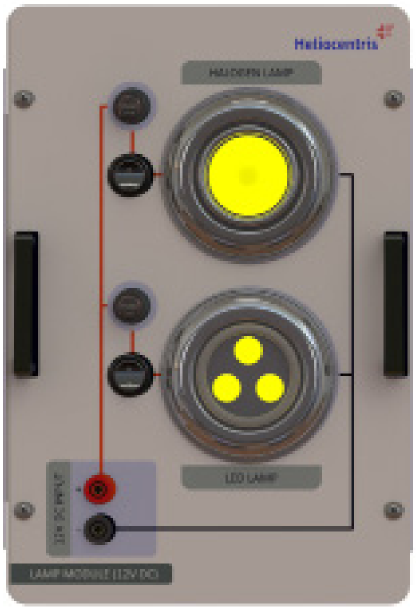

Figure-1 Overall View of the Module

It is a load module designed for general purposes. There is a halogen lamp and a LED on the module which can be switched separately. If the operating voltage exceeds 12V, the lamps might get damaged. Please note that the lamps might be hot while operating. Two lamps draw approximately 4mA current under 12V.

1.11. LAMP MODULE (220V AC)

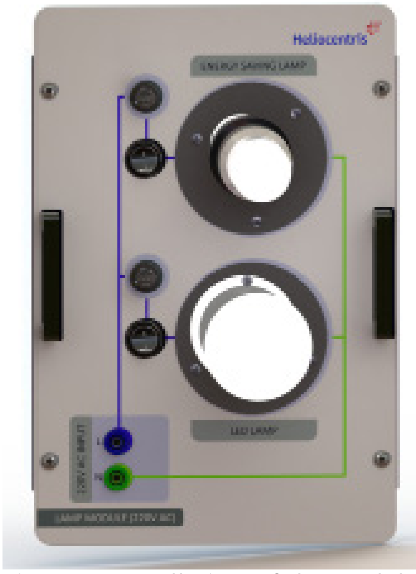

Figure-1 Overall View of the Module

It is a load module designed for general purposes. There is a saving lamp and a LED on the module which can be switched separately. If the operating voltage exceeds 220V, the lamps might get damaged. Please note that the lamps might be hot while operating. Two lamps draw approximately 220mA current under 220 V.

1.12. AC ENERGY ANALYZER MODULE

Figure-1 View of the Module

Various measurements can be made with the module in which there is a Siemens PAC 3100 energy analyzer.

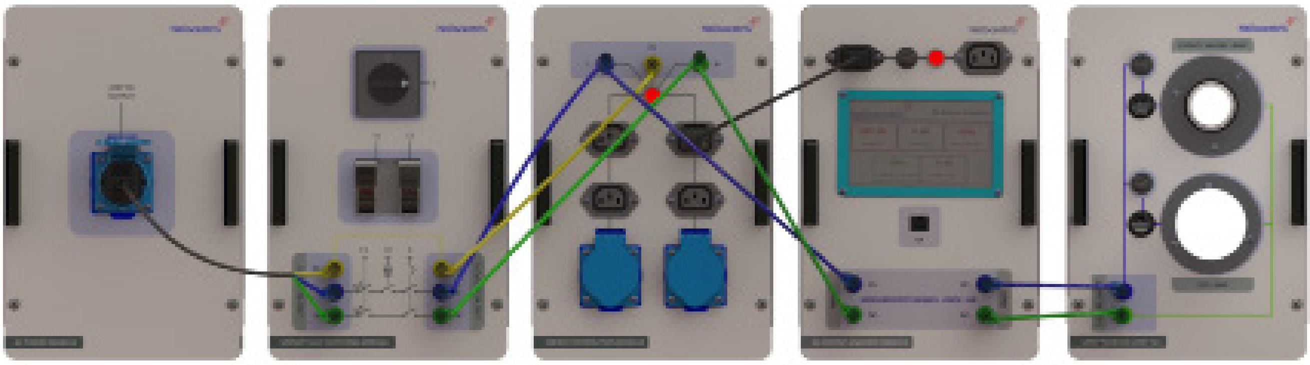

Figure-2 Sample connection made with the Module

There are current transformers within the module with a ratio of 1:5 for current measurement. Various loads such as the voltage between the module and phase, the voltage between the phase and neutral, the current between phases, neutral current, apparent, active and reactive powers, power factors, frequency etc. can be measured. The measurements as seen in figure-2 are applicable. A sample connection made with the module can be seen in figure-3. The RS485 port on the module and all data that are read with the analyzer can be transferred via MODBUS RTU.

1.13. ISOLATED MEASUREMENT MODULE

Figure-1 Overall view of the module

It enables an accurate and a safe measurement by providing a high electrical and optical isolation between the load and the signal. Measurements that may be done with a differential prop or a dispersed oscilloscope chassis can be properly conducted. Two-channel module and the load current as well as the current flow can be simultaneously examined.

A sample connection made with the module can be seen in figure-2. The load current and the current flow are screened by an oscilloscope by using the CH1 channel. Data read on the oscilloscope screen shall be multiplied by appropriate ratios as level X1, X0,1 and X0,01 weakens the signal.

For instance, if the X0,1 level is used, the signal measured by an oscilloscope shall be multiplied by 10 as the signal on this phase is weakened by a ratio of 1:10. The connections between the oscilloscope and the module shall be made with a bifurcated BNC connector.

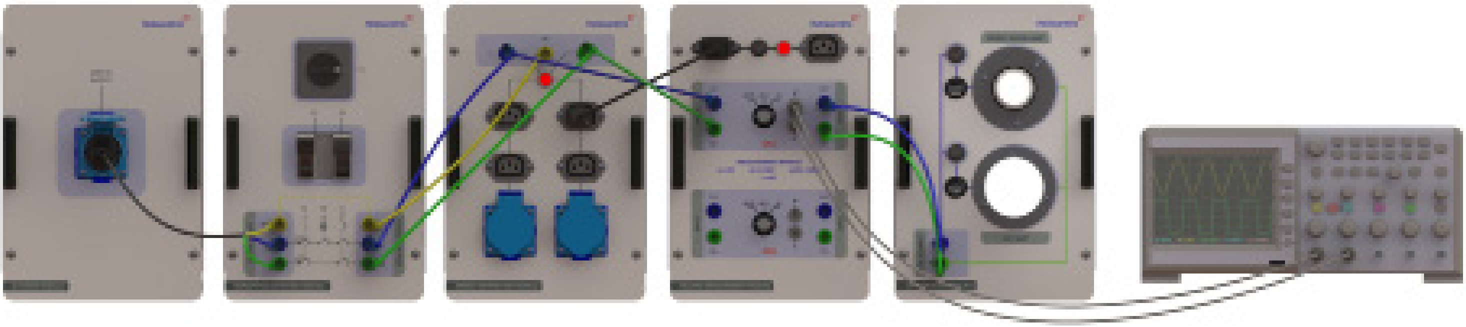

Figure-2 Sample connection of the Module

1.14. DATA ACQUISITION MODULE

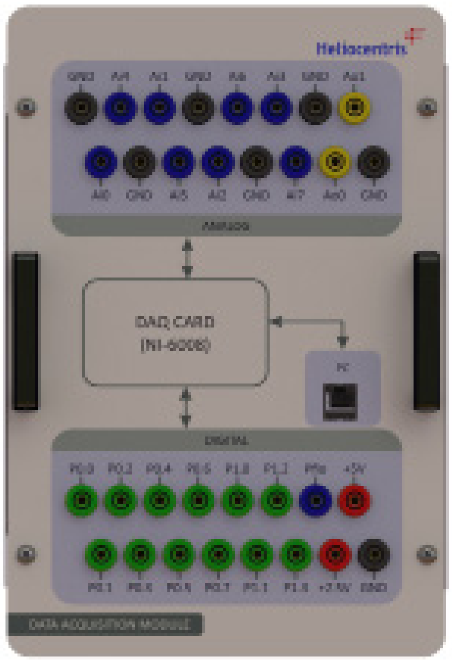

Figure-1 Overall View of the Module

NI6008 type DAQ card of the National Company is applied in the module. Other signals are speedily transferred to computers via USB connection with this card. The module can measure 12 bits with differential connection. It has the sampling ratio of 10KS/s.
The network signal is isolated and weakened by Isolated Measurement Module and applied to DAQ card in the sample connection. The signal measured by DAQ card is transferred to the computer with a USB. You may use the LabView software for instrumentation with the computer.

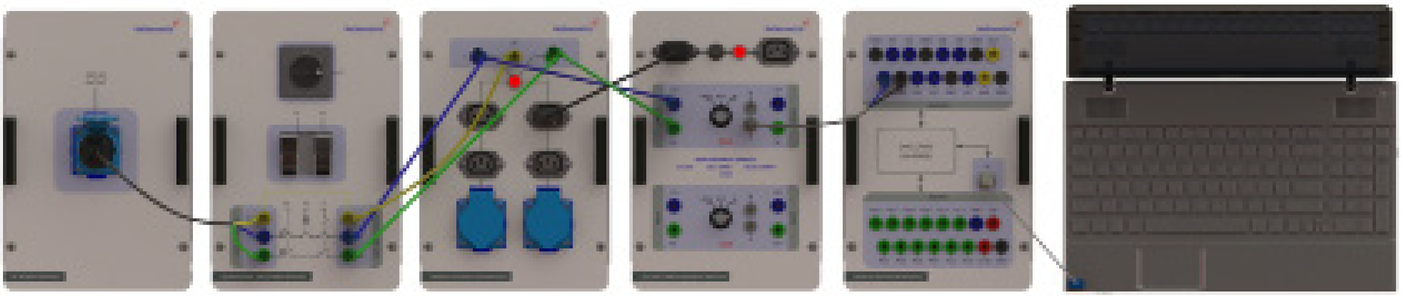

Figure-2 Sample connection of the Module

1.15. PC INTERFACE MODULE

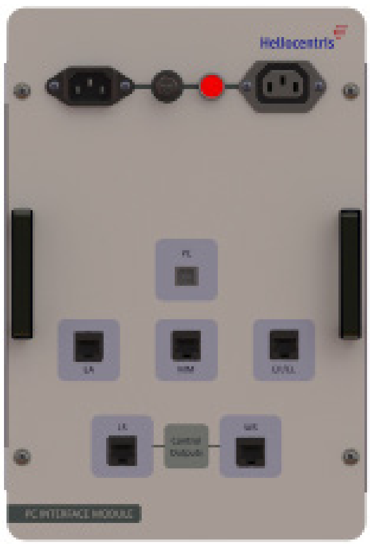

Figure-1 Overall View of the Module

This is the module used for conducting experiments with the special computer software designed for the training set. There are special cable sets designed for each connection point. RS485(1) connection point is used for AC Energy Analyzer module and it enables the transfer of analyzer data to the computer. RS845(2) connection point is used to read the voltmeter and ammeter data from the AC/DC measurement module. RS232 connection point is used for the setting of the Electronic Load Module to the intended resistance value. While control inputs are used for the measurement of analog data between 0-10V, control outputs are used to control the Light Source Control Module and the Wind Simulator Module. It controls the AoO Light Source Control Module and the Ao1 Wind Simulator Module. The PC connection is made via USB.

1.16. WIND SIMULATOR MODULE

Figure-1 Overall view of the Module

This module is used to control the wind turbine manually or via the computer. The simulation of speeds between 0-15m/s can be done in laboratory environment with this module. Sample connection of the module on manual mode can be seen in figure-2. After setting the key at MANUAL, it is possible to set the wind speed in 10 different positions between 0-15m/s with the SPEED potentiometer.

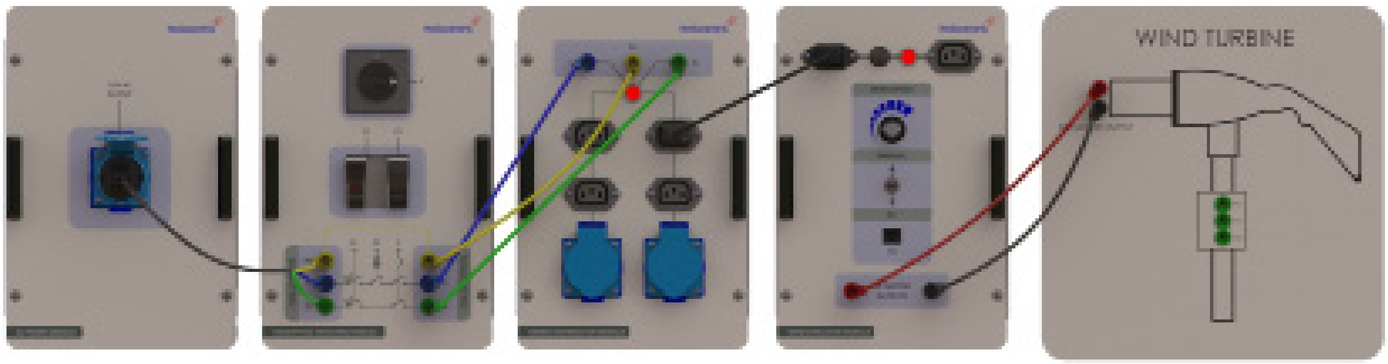

Figure-2

Sample connection of the module in PC mode can be seen in figure-3. After setting the key at PC mode, it is possible to set the wind speed between 0-15m/s via the software.

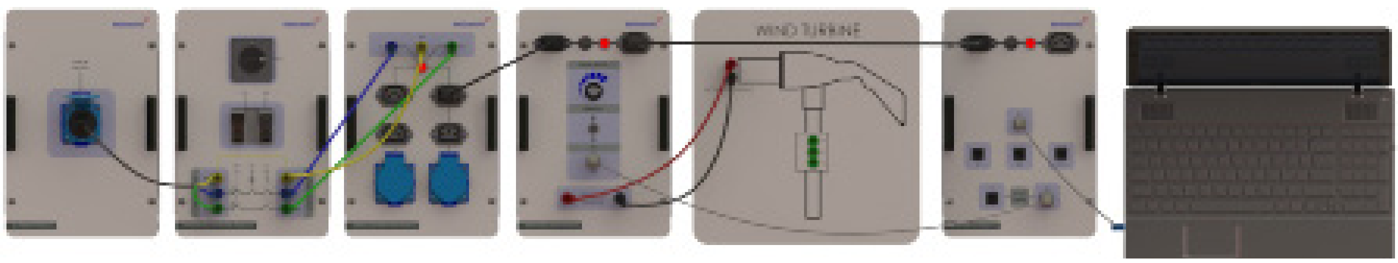
Figure-3

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1.17. LIGHT SOURCE CONTROL MODULE

Figure-1 Overall view of the Module

This is the module used to control the light source manually or via the computer. With this module, a solar simulation can be made with a light intensity between 0-7000lux in laboratory environment. Sample connection of the module at manual mode can be seen in figure-2. After setting the key at MANUAL, it is possible to set the light density in 10 different positions between 0-7000lux with the DIMMER potentiometer.

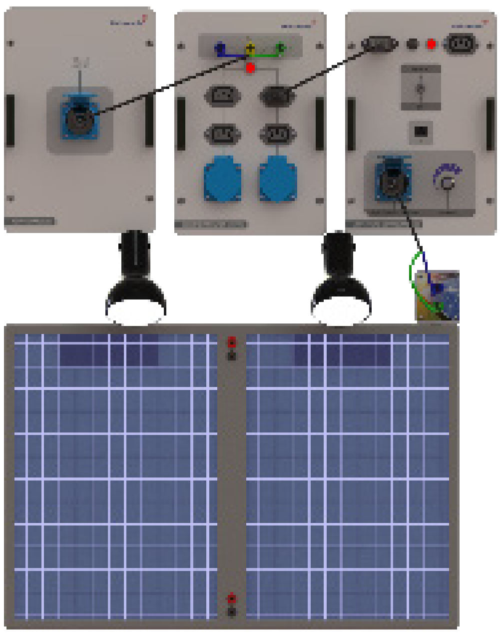


Figure-2

Sample connection of the module in PC mode can be seen in figure-3. It is possible to adjust the light intensity over the software after setting the key at PC mode.

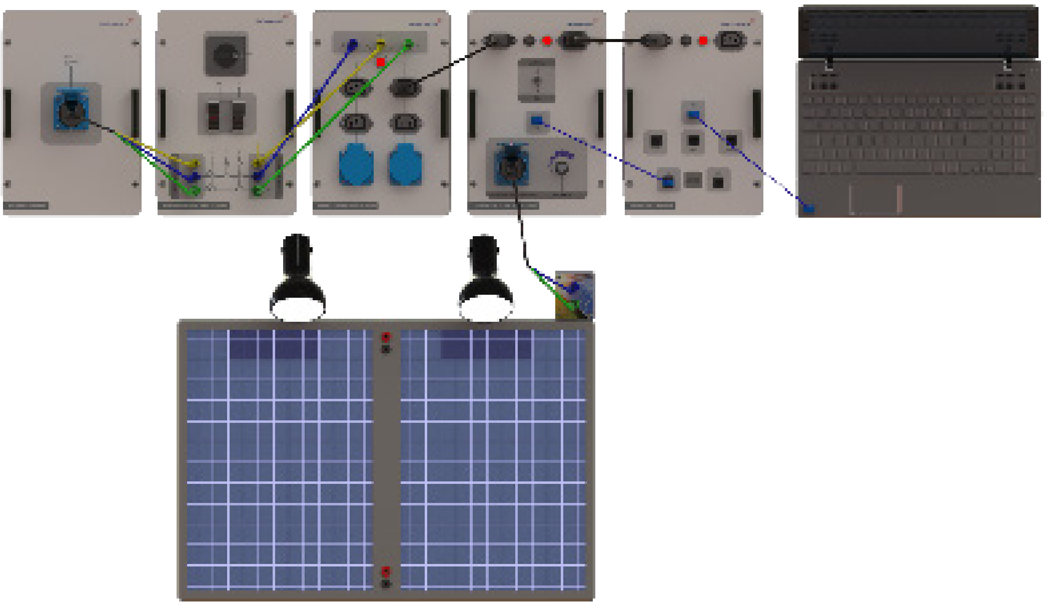


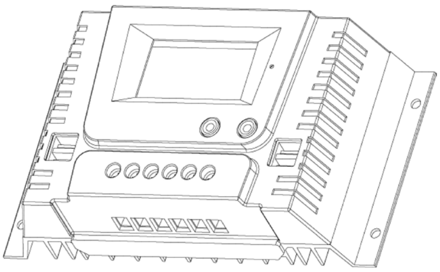
Figure-3

1.18. SOLAR CHARGE REGULATOR MODULE

Figure-1 Overall view of the Module

This is the module that charges the battery and the light source with PWM. It transfers the energy received from the solar panel to the accumulator. It might be directly connected to DV, when necessary. The charge regulator used in the module has the automatic 12V/24V detection feature and panel voltage up to 50V may be applied. The main connection of the Solar Charge regulator can be seen in figure-2.

INTELLIGENT SOLAR CHARGE CONTROLLER
USER'S MANUAL



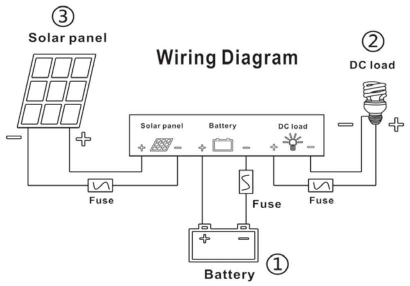
Thank you for choosing this series Solar Charge Controller. Please read this Manual carefully before using the product.

1. Product Features:

This series controller is a PWM charge controller with built in LCD that adopts the most advanced digital technique. The multiple load control modes enable it can be widely used on solar off grid system, traffic signal, solar street light, etc.

- System voltage of battery 12V/24V or 12V/24V/36V/48V automatic recognition;
- Intelligent 4 stages PWM charging: Bulk, Absorption, Equalize, Float;
- LCD display with Back-lighting shows device's operating data and working condition;
- Humanized simple button operation; Adjustable charge-discharge control parameters;
- Support more kinds of battery: Lead-acid battery (Sealed, Gel, Flooded) and Lithium battery (LiCoMnNiO2, LiFePO4);
- Multiple load control modes: 24Hours Working Control, Light Control, Light and Dual Time Control;
- Automatic temperature compensation and accumulated function of charge and discharge KWH;
- Double USB output 5V/2A;
- Perfect electronic protections.

2. System Connection:



2-1. Order of Connection:

① Connected with Battery first; ② Connected with Load; ③ Connected with Solar Panel.

NOTE:

① This series is a positive ground controller. Any positive connection of Solar Panel, Load or Battery can be earth grounded.

② The fuse should be installed as close to battery as possible, the suggested distance is about 150mm;

③ If inverter or other load with big start current is necessary in system, please connect it with Battery, not solar controller;

④ When disconnecting the system, the order will be reversed.

3. Operation:

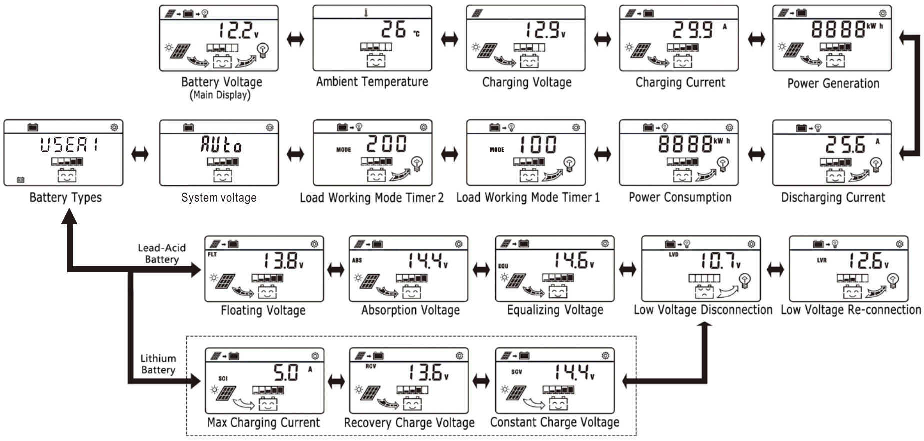
3-1. LCD Symbol:

Icon	Meaning	Icon	Meaning	Icon	Meaning
	Day		Data Relates to Charging	FLT	Float Charging
	Night		Data Relates to Discharging	ABS	Absorption Charging
	Charging		Data Relates to Temperature	EQU	Equalizing Charging
	No Charging		Data Adjustable	SCI	Max Charging Current
	Load On		Data not Adjustable	RCV	Recovery Charging Voltage
	Load Off	SLD	Sealed Battery	SCV	Constant Charging Voltage
	System Works Normally	GEL	GEL Battery	LVD	Low Voltage Disconnection Voltage
	System Works Abnormally	FLD	Flooded Battery	LVR	Low Voltage Re-connection Voltage

3-2. Button Function:

Modes	Operation
Browse Interface	Short press button "＋" or "－".
Load On/Off	When load in 24H working mode, short press button "－" in Main interface.
Parameter Setting	In the settable interface, long press button "＋" into setting, and then short press "＋" or "－" to set parameter, long press button "＋" to save and exit. (Long press button "－" to cancel the parameter and back to last setting)
Factory Reset	Long Press button "＋" 5s in the interface of Ambient Temperature.

3-3. Browse Interface:



NOTE:

① After connected with Battery, LCD will go into an interface that automatically recognizes the battery voltage level, 3 seconds later, it will enter to the main interface of LCD;

② Equalizing charge will be after every 90 times Floating charge, or one charge in three months;

③ Under the interface of Accumulated KWH, long press button "＋" to clear the value;

④ When no operation 30s, the interface will be back to main interface, and back-light will be turned off.

3-4. Battery Types:

Under the interface of battery types, long press button "＋" into the type setting, then short press button "＋" or "－" to choose battery type, and then long press "＋" again to save and exit.

Icon	Battery Type
SLD	Sealed Battery (Default)
GEL	
FLD	
USER1	
3.2-4	
3.2-5	
3.7-3	LiCoMnNiO2: 3.7V 3S /6S /9S /12S
3.7-4	LiCoMnNiO2: 3.7V-4S /8S /12S /1
USER2	Lithium Battery (User-defined)

3-5. Battery voltage automatic identification range:

Battery Types	Lead-Acid Battery	Lithium Battery			
		LiFePO4 3.2V-4	LiFePO4 3.2V-5	LiCoMnNiO2 3.7V-3	LiCoMnNiO2 3.7V-4
12V System	≤17.6V	≤18V	≤22.5V	≤15.9V	≤21.2V
24V System	≤29.9V	≤30.4V	≤38V	≤26.9V	≤35.8V
36V System	≤42.1V	≤42.8V	≤53.5V	≤37.8V	≤50.4V
48V System	＞42.1V	＞42.8V	＞53.5V	＞37.8V	＞50.4V

3-6. Control parameters of Lead-acid battery:

Lead-Acid Battery Types	SLD				GEL				FLD			
Battery Voltage Level	12V	24V	36V	48V	12V	24V	36V	48V	12V	24V	36V	48V
Float Charging Voltage	13.8V	27.6V	41.4V	55.2V	13.8V	27.6V	41.4V	55.2V	13.8V	27.6V	41.4V	55.2V
Absorption Charging Voltage	14.4V	28.8V	43.2V	57.6V	14.2V	28.4V	42.6V	56.8V	14.6V	29.2V	43.8V	58.4V
Equalizing Charging Voltage	14.6V	29.2V	43.8V	58.4V	NO				14.8V	29.6V	44.4V	59.2V
Charging time of Absorption/Equalizing	2 Hours											

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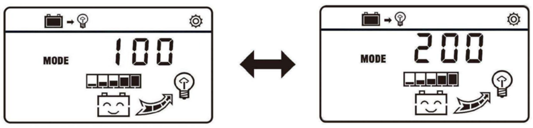
Lead-Acid Battery Types	SLD / GEL / FLD			
Battery Voltage Level	12V	24V	36V	48V
Low Voltage Disconnection	10.7V	21.4V	32.1V	42.8V
Low Voltage Re-connection	12.6V	25.2V	37.8V	50.4V
Load Over-Voltage Disconnection	16V	32V	48V	64V
Load Over-Voltage Re-connection	15.5V	31V	46.5V	62V

3-7. Control parameters of Lithium battery:

Lithium Battery Type	LiFePO4							
Icon	**3.2-4**				**3.2-5**			
Battery Serial Number	**4S**	**8S**	**12S**	**16S**	**5S**	**10S**	**15S**	**20S**
Recovery Charging Voltage	13.6V	27.2V	40.8V	54.4V	17V	34V	51V	68V
Constant Charging Voltage	14.4V	28.8V	43.2V	57.6V	18V	36V	54V	72V
Stop Charging Current	0.1A				0.1A			
Low Voltage Disconnection	11.2V	22.4V	33.6V	44.8V	14V	28V	42V	56V
Low Voltage Re-connection	12.8V	25.6V	38.4V	51.2V	16V	32V	48V	64V
Load Over-Voltage Disconnection	18.5V	37V	55.5V	74V	18.5V	37V	55.5V	74V
Load Over-Voltage Re-connection	18V	36V	54V	72V	18V	36V	54V	72V

3-8. Load Working Modes：

Under the load mode setting interface, long press button "＋", when Timer 1 or Timer 2 begin flashing, short press button "＋" or "－" to set parameter, then long press button "＋" to save and exit.



Load Working Mode Timer 1 Load Working Mode Timer 2

Icon	Load Working Mode Timer 1	Icon	Load Working Mode Timer 2
100	Reverse light control mode (The load stops working at dark and working at dawn)	**200**	Light control & Dual period mode is not activated, unable to enter the setting
101h~115h	Light control & dual time mode: the load is automatically turned on when it is dark, and it is automatically turned off when it is dawn. The 1h-15h on this page is used to setting the working time of the load after dark	**201h~215h**	After activating the light control & Dual period mode, you can enter this page to set 1H ~ 15h to control the working hours of the load before dawn
116	Light control mode	**117**	Load 24 hours

4. Protections:

- Solar Panel Reverse-Polarity:

If the solar panel is connected with controller in reversed polarity, controller will not be damaged and will work as normal when correctly connected.

- Battery Reverse-Polarity:

If the battery is connected with controller in reversed polarity (solar controller is not connected with solar panel), controller will not be damaged and will work as normal when correctly connected.

- Battery Reverse-Discharge:

Controller is able to protect battery from reversed discharging to solar panel at night.

- Over-Heating Protection:

Once the internal temperature is detected to be higher than a certain value by the controller, it will stop charging the battery and then recharging the battery automatically after the temperature drop to a certain value.

- Battery Over-Current:

Controller will stop charging when excess current is detected from the solar panel, and recharging automatically after 2 min.

- Load Over-Load:

The load will be turned off when the output current of load exceeds its rated current for a while, and turned on automatically after 2 min.

- Load Short-Circuit:

Controller will be in protection state when the load is short circuit, and recharging automatically after 2 min.

- Battery Low-Voltage:

Controller will turn off the load when the battery voltage is lower than the value preset for low-voltage disconnection, and turn on the load when the battery voltage reaches the value preset for low-voltage re-connection. The value for low-voltage disconnection and low-voltage re-connection can be set by users in a certain range.

- Battery Over-Voltage:

Controller will turn off the load when the battery voltage is higher than the value preset for over-voltage protection, and turn on the load when the battery voltage is 1V lower than the value preset for over-voltage protection.

- Lightning Protection:

The lightning protection function of controller is limited and it is recommended to install devices for lightning protection on the input side to increase system reliability.

5. Troubleshooting:

Error Code	Cause	Solution
E01	Battery Low-Voltage	Recharging the battery or change a new one.
E02	Load Over-Load	Check the loads connection or reduce the electric equipment.
E03	Load Short-Circuit	
E04	Load Over-Voltage	
E05	Solar Panel Over-Current	Check the power of solar panel or reduce the solar panel.

6. Technical Specification:

Max Current	10A20A	30A/40A	50A/60A	80A
Battery Voltage	12V/24V/36V/48V Auto			
Max PV Open Circuit Voltage	100V			
Self-consumption	≤30mA			
Loop Voltage Drop	≤0.3V			
USB Output	5V/2A *2			
Temperature Compensation	-4mV/℃/2V (25℃)			
Operating Temperature	-20℃~+50℃			
Protection Category	IP32			
Humidity	95%, no-condensing			
Terminals	8AWG/10mm²	6AWG/16mm²	4AWG/25mm²	
Mounting Hole Size	158*68mm-Φ6mm	190*69mm-Φ5mm	190*104mm-Φ5mm	
Dimension	168*88*36mm	200*106*47mm	200*131.6*61mm	200*131.6*72mm
Weight	0.22KG	0.4KG	0.73G	0.79KG

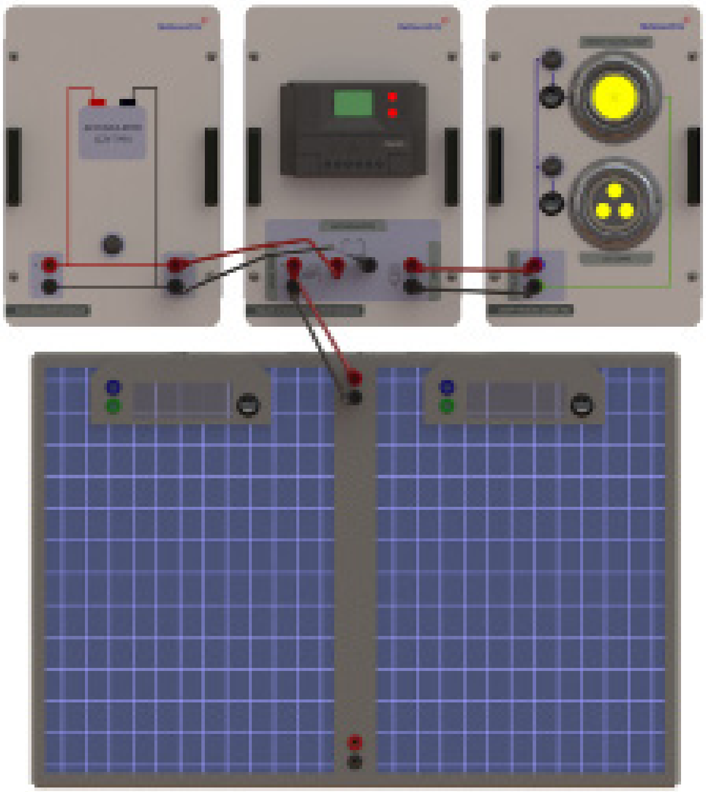


Figure-3

1.19. WIND TURBINE CHARGE CONTROL MODULE

Figure-1 Overall view of the Module

This is the module that charges the wind turbine and the accumulator. The charge control device shall charge the battery even if the wind turbine output produces 3 phase AC current or it is directly transferred to the output. The mine connection of the module can be seen in figure-2.

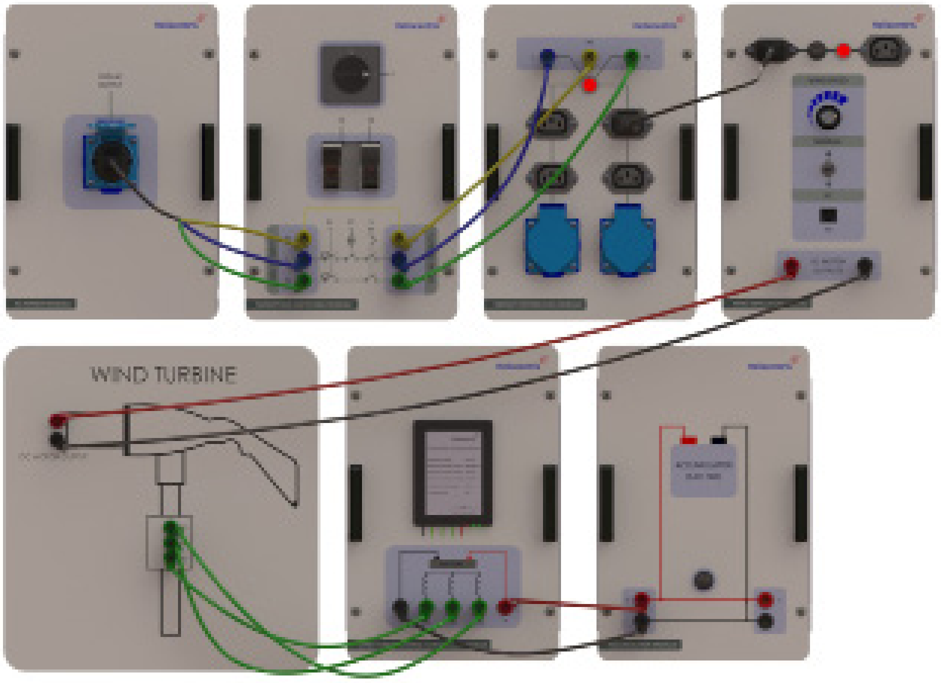


Figure-3

1.20. OFF GRID INVERTER MODULE

Figure-1 Overall view of the Module

This is the module that transforms the 12V DC accumulator voltage into 220V/50Hz sine signal. It does not have a network connection. Output is complete sine.

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1.21. ON GRID INVERTER MODULE

Figure-1 Overall view of the Module

This is the module that transforms 12V DC accumulator voltage into 220V/50Hz sine signal. It does not operate without a network connection.

1.22. ELECTRONIC POTENTIOMETER MODULE

Figure-1 Overall view of the Module

This is a load module with 1KΩ / 200W value whose intended resistance value is either manually set or is set via the computer. Necessary adjustments are easily made with the potentiometer that is on the module.

1.23. SOLAR PANEL SIMULATOR MODULE

Figure-1 Overall view of the Module

This is a module that is used for the independent operation of two solar panels and for the simulation of their serial or parallel connections.

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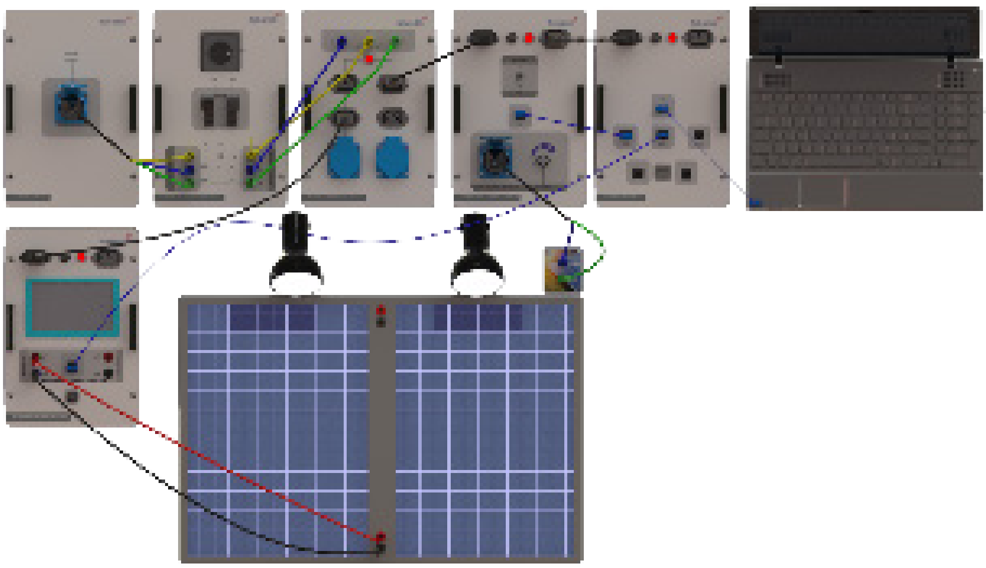
2. SOLAR ENERGY EXPERIMENTS

2.1. Photovoltaic Panel Experiments

2.1.1. Photovoltaic Panel Open Circuit Voltage Measurement



Figure–1

1) Photovoltaic Panel – The open circuit voltage values of the panels used in the light source module are given on a tag placed under the panel by the producer. These values have been measured under 1000W/m2 light power. The halogen lamp used in the training set allows only up to 100W/m2 light power. Record the open circuit voltage value (VOC) given on the tag in chart-1.

2) Connect as shown in figure-1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.

3) Photovoltaic Panel – On the Light Source Module, adjust the angle of incidence of light to 90° and position the panel's surface parallel to the ground (in summer). Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.

4) Place the digital luxmeter in the middle of the panel. Set the DIMMER potentiometer on the Light Source Control Module to a maximum and bring the brightness setting for sunlight to a maximum. Observe the values on the luxmeter under these circumstances, adjust the incidence of the light source to observe maximum values on the luxmeter, and record these values in chart-1. (Since the distance between the sun and the earth is much greater than the one between the panel and the training set, applying light to the panel with an incidence lower than 90° may cause a higher light intensity than that caused by an incidence of 90°). Remove the luxmeter from the panel and record the value given by the voltmeter on the AC/DC Measurement Module in chart-1. This value is the VOC value obtained after measurement.

VOC (volt) (Tag Value)	VOC (volt) (Measurement Value)	Işık Şiddeti (lux)

Chart-1

1) Explain the reasons for the difference between the VOC values obtained after measurement in a laboratory environment and the value given on the tag (or on the technical data page).

2) Explain the term ‘solar energy’.

3) Explain the greenhouse effect and the importance of photovoltaic panels.

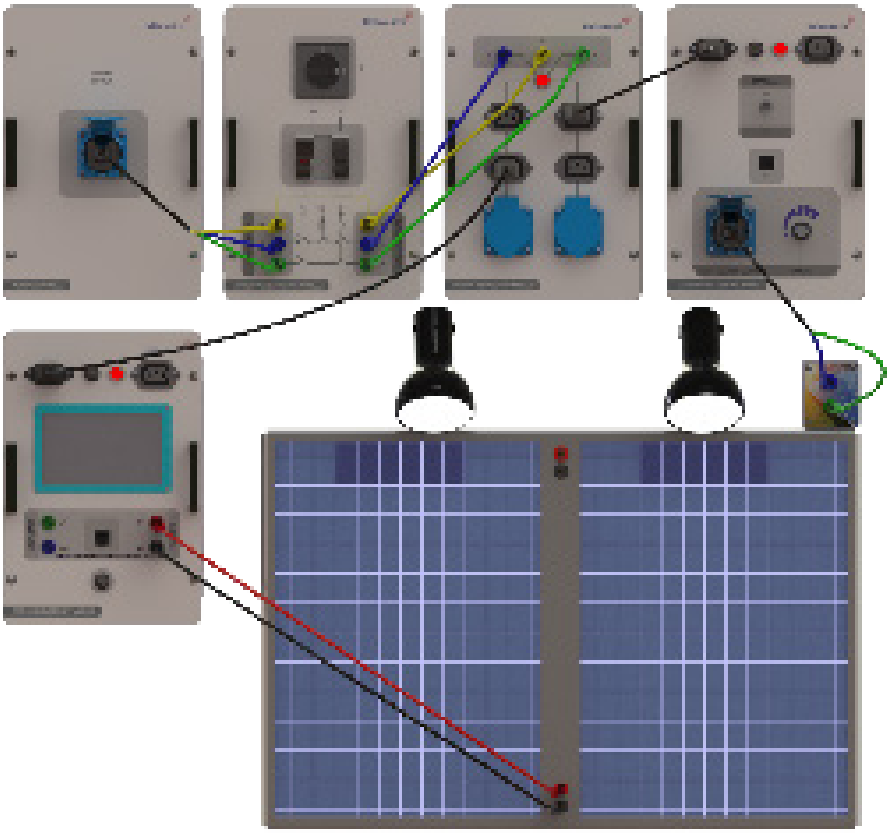
4) Explain the cellular structure of the solar panel by using sketches.

5) Explain the different varieties of panels and their specifications.

6) Explain the photovoltaic cell equivalent circuit by using sketches and a mathematical method.

7) Explain the effects of series and parallel connections on the VOC values.

2.1.2. Measuring the Photovoltaic Panel Short Circuit Current



Figure–1

1) Photovoltaic Panel – The short circuit current values of the panels used in the light source module are given on a tag placed under the panel by the producer. These values have been measured under 1000W/m2 light power. The halogen lamp used in the training set allows only up to 100W/m2 light power. Record the short circuit current value (ISC) given on the tag in chart-1.

2) Connect as shown in figure-1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
3) Photovoltaic Panel – On the Light Source Module, adjust the angle of incidence of light to 90° and position the panel's surface parallel to the ground (in summer). Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.

4) Place the digital luxmeter in the middle of the panel. Set the DIMMER potentiometer on the Light Source Control Module to a maximum and bring the brightness setting for sunlight to a maximum. Observe the values on the luxmeter under these circumstances, adjust the incidence of the light source to observe maximum values on the luxmeter, and record these values in chart-1. (Since the distance between the sun and the earth is much greater than the one between the panel and the training set, applying light to the panel with an inci

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Remove the luxmeter from the panel and record the value given by the voltmeter on the AC/DC Measurement Module in chart-1. This value is the ISC value obtained after measurement.

ISC(amper) (Tag Value)	ISC(amper) (Measurement Value)	Işık Şiddeti (lux)

Chart-1

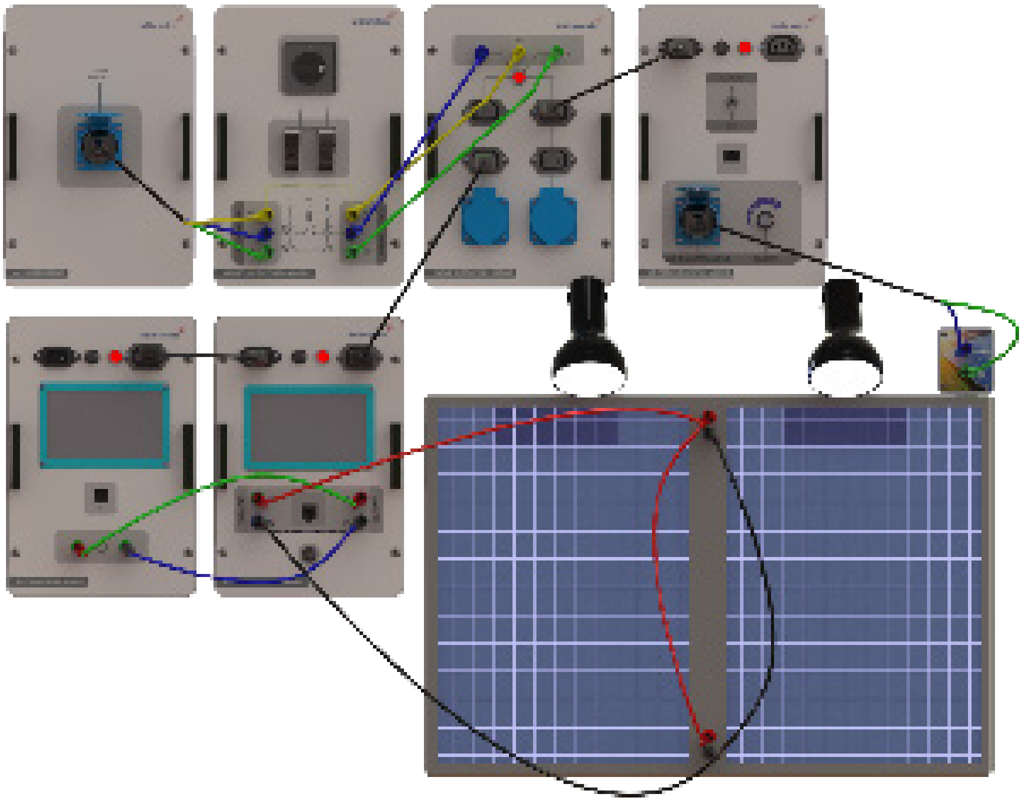
5) Explain the reasons for the difference between the ISC values obtained after measurement in a laboratory environment and the value given on the tag (or on the technical data page).

6) By drawing the electromagnetic spectrum, explain the change between the amount of energy and wavelength using a mathematical equation.

7) Explain how electric current occurs on the photovoltaic panel.

8) Explain the effects of series and parallel connections of panels on the ISC values.

2.1.3. Determining Photovoltaic Panel Current Voltage Characteristics



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.

2) Photovoltaic Panel – On the Light Source Module, adjust the angle of incidence of light to 90° and position the panel's surface parallel to the ground (in summer). Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.

3) Place the digital luxmeter in the middle of the panel. Set the DIMMER potentiometer on the Light Source Control Module to a maximum and bring the brightness setting for sunlight to a maximum. Observe the values on the luxmeter under these circumstances, adjust the incidence of the light source to observe maximum values on the luxmeter, and record these values in chart-1. (Since the distance between the sun and the earth is much greater than the one between the panel and the training set, applying light to the panel with an incidence lower than 90° may cause a higher light intensity than that caused by an incidence of 90°).

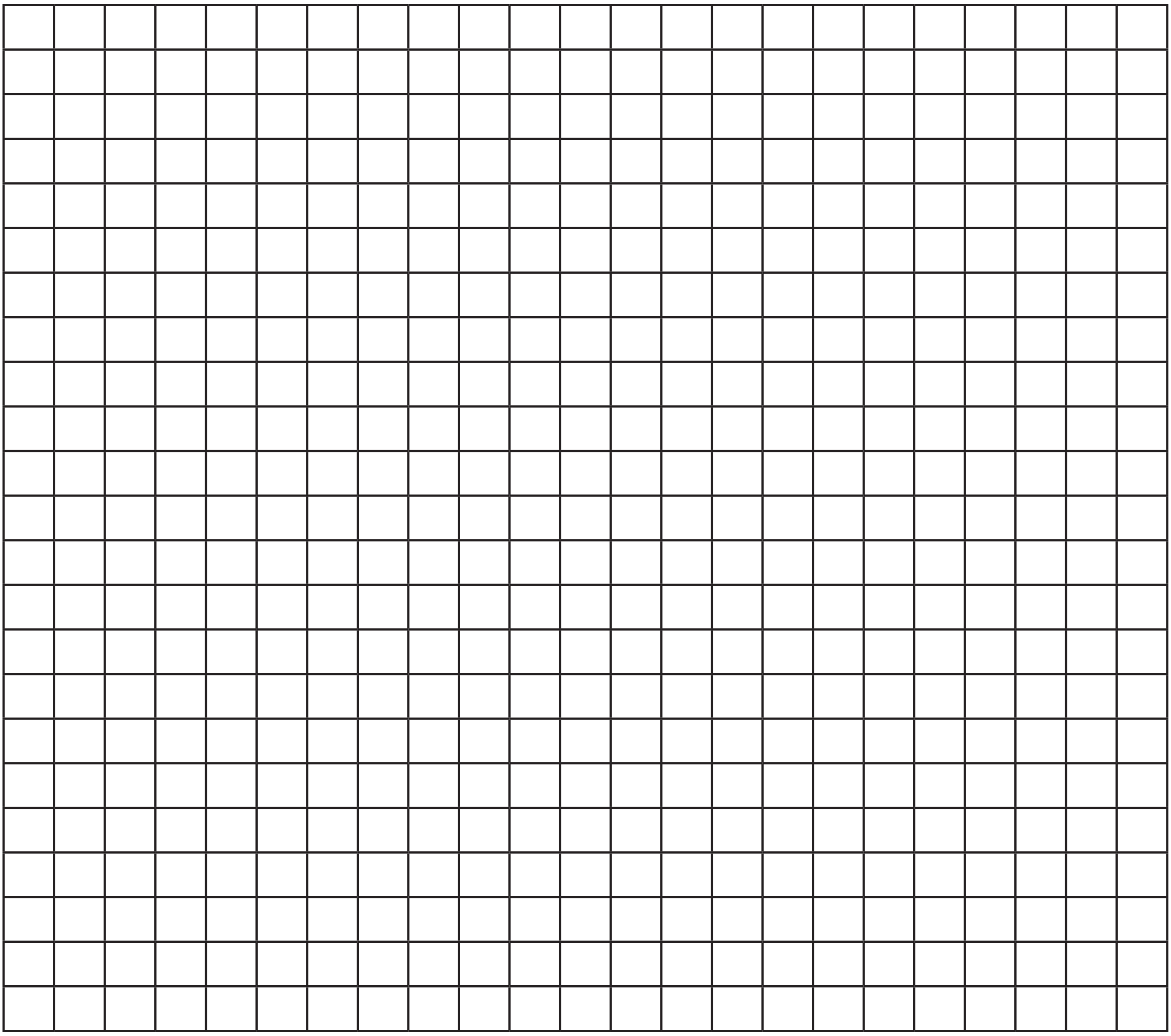
4) Set the Electronic Potentiometer Module to gradually decrease, starting from a load value of 500ohm, with a decrease of 100ohm.

5) Record the values given by the voltmeter and ammeter on the AC/DC Measurement Module in Table-1, resulting from every 100 ohm decrease in the potentiometer values on the Electronic Potentiometer Module, starting from 500 ohms.

R (Ω/ohm)	V (V/volt)	I (A/amper)
500		
400		
300		
200		
100		
0		

Chart-1

6) Using the current and voltage values given in chart-1, draw the current-voltage characteristics in the designated area in graphic-1.



Graphic-1

7) Setting the light power in an increasing order to 1000lux, 2000lux, 3000lux, 4000lux, and 5000lux, repeat the measurements for each one of these light power values.

8) Use the obtained results to draw IV characteristics in the designated area in graphic-2.

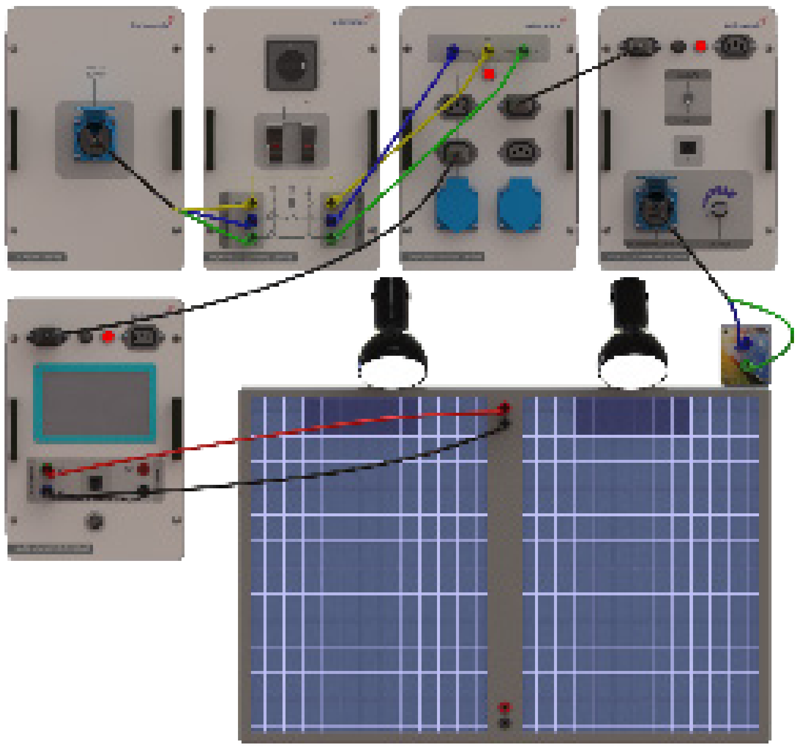
Graphic-2

9) Explain what kind information can be obtained from the Photovoltaic panel IV characteristics.

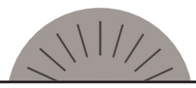
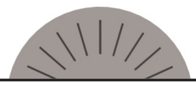
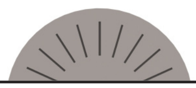
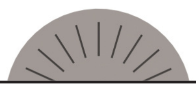
10) Explain which point in the graphic corresponds to the maximum power point.

11) Explain what MPPT (Maximum Power Point Tracking) is.

2.1.4. Examining the Non-Load Output Voltage of the Photovoltaic Panel Depending on Daily Solar Movement



Figure–1

Indence of light on panel	Light power (lux)	Panel Voltage (V)
0 		
30 		
60 		
90 		

Tablo-1

1) Prepare the experimental setup in fig.1.

2) Using the pins on the module, set the incidence between 0°-90° as shown in the chart. Use the DIMMER potentiometer on the Light Source Control Module to adjust the light power according to the incidence it corresponds to.

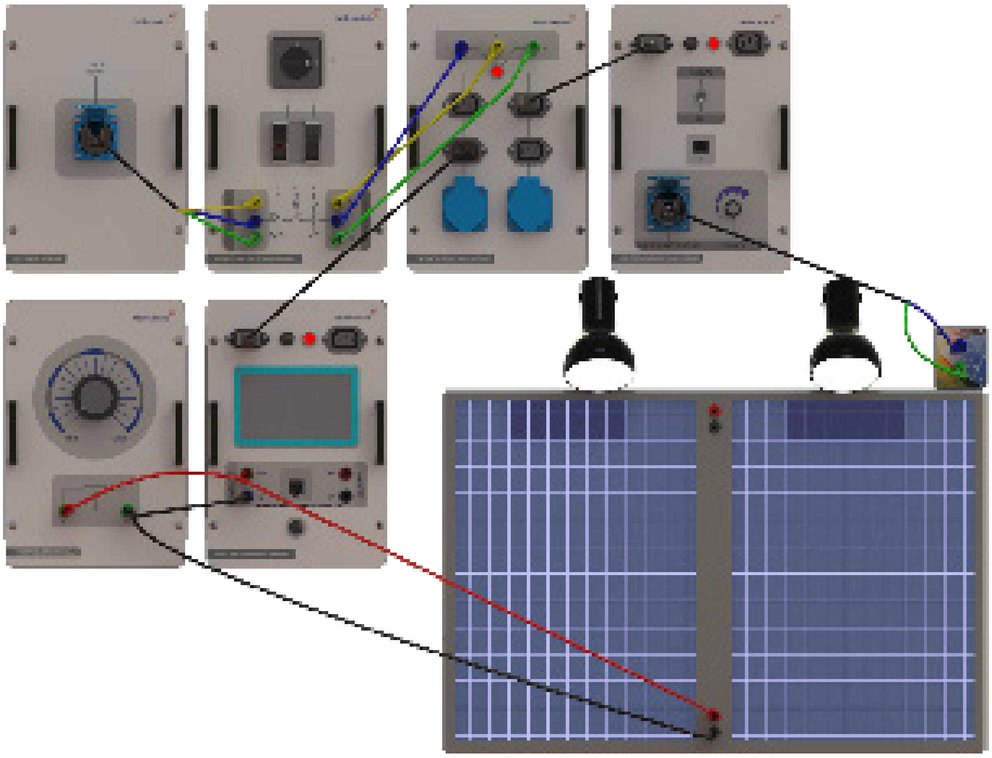
3) Record in chart-1 the voltage value corresponding to each incidence and light power value.

4) What can be done to allow maximum efficiency for the photovoltaic panel in the face of changes in light during the course of the day?

5) Use the solar cell equivalent circuit and a mathematical model to explain the effects of daily changes in light.

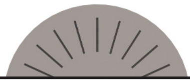
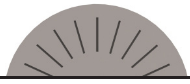
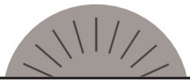
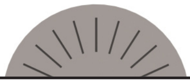
6) Draw a block diagram to explain the sun seeker system.

2.1.5. Examining the Loaded Output Voltage of the Photovoltaic Panel Depending on Daily Solar Movement



Şekil-1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.

Indence of light on panel	Light power (lux)	Panel Voltage (V)
0 		
30 		
60 		
90 		

Tablo-1

2) Set the Electronic Potentiometer Module to 200Ω resistance value.

3) Set the incidence of light between 0°-90° as shown in the chart. Use the DIMMER potentiometer on the Light Source Control Module to adjust the light power according to the incidence it corresponds to.

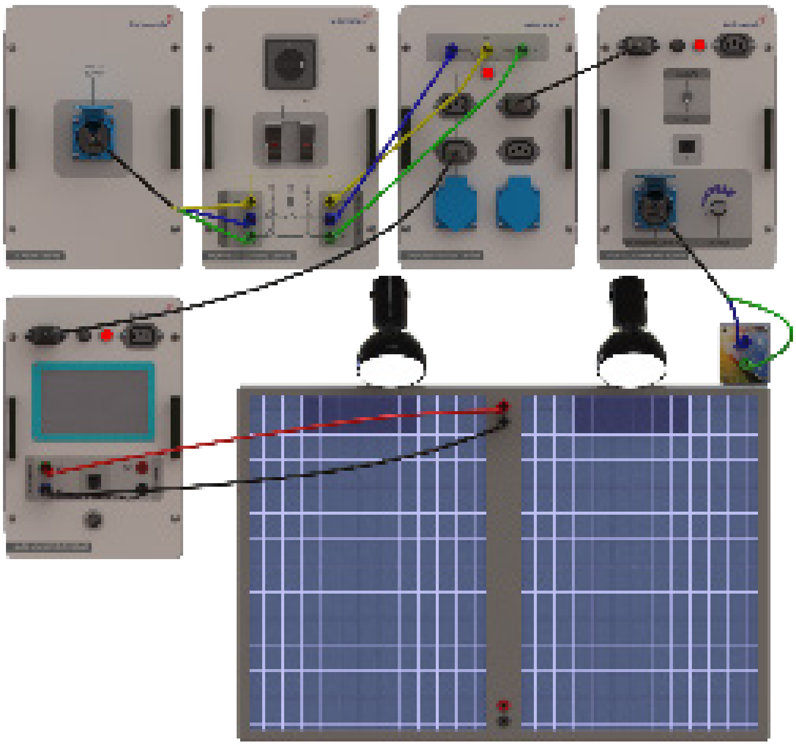
4) Record in chart-1 the voltage value corresponding to each incidence and light power value.

5) Explain how the panel output voltage, dependent on the intensity of light, changes according to the amount of load.

6) Use the cell equivalent circuit and a mathematical model to explain the effect of battery current, which is determined by the load.

2.1.6. Examining the Non-Load Output Voltage of the Photovoltaic

Panel Depending on Seasonal Changes



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. The angle of the panel in relation to the ground will simulate the incidence of sunlight according to seasonal changes. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Set the angle of the panel in relation to the ground according to the values given in chart-1. Use the DIMMER potentiometer on the Light Source Control Module to adjust the light power according to the season it corresponds to. Use the luxmeter to adjust the light power, and then remove the luxmeter.
4) Record in chart-1 the panel voltage value that corresponds to each step.

5) Determine the changes in the efficiency of the photovoltaic panel in relation to seasonal changes.

6) Determine the amount of daylight power in your region in different seasons, and draw out a daylight map.

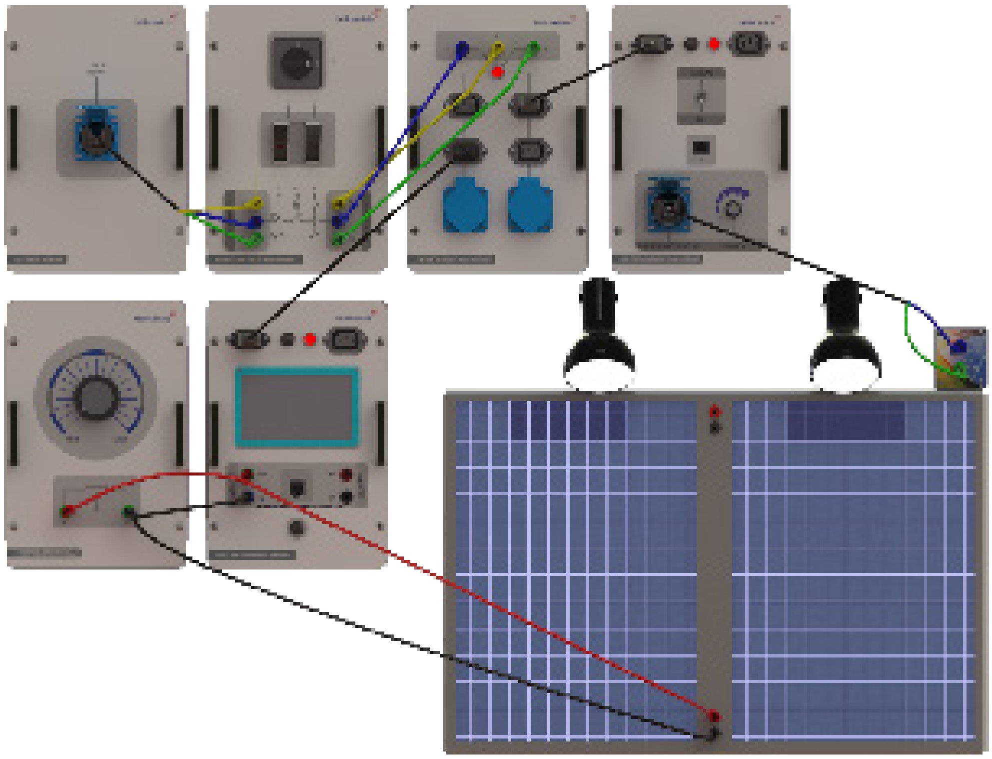
7) Find out which countries make most use of solar power, then determine and analyze the seasonal characteristics of this country, and compare them to the seasonal characteristics of your own country.

The angle of panel in relation to ground/Season	Light power (lux)	Panel Voltage (V)
0° (Yaz)		
30° (Bahar)		
60° (Kış)		

Chart-1

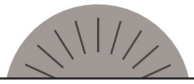
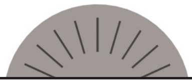
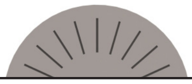
2.1.7. Examining the Loaded Output Voltage of the Photovoltaic

Panel Depending on Seasonal Changes



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. The angle of the panel in relation to the ground will simulate the incidence of sunlight according to seasonal changes. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3 Set the angle of the panel in relation to the ground according to the values given in chart-1. Use the DIMMER potentiometer on the Light Source Control Module to adjust the light power according to the season it corresponds to.
4) Set the Electronic Potentiometer Module to 200Ω voltage value.
5) Record in chart-1 the panel voltage value that corresponds to each angle and light intensity value.
6) Decrease load value from 200 ohm to 100 ohm. Repeat the same measurements and record your findings in chart-1.

The angle of panel in relation to ground/Season	Light power (lux)	Panel Voltage (V)	Panel Voltage (V) (Load 100Ω)
0° (summer) 			
30° (spring-fall) 			
60° (winter) 			

Tablo-1

7) Determine the effect of load change on output voltage.

8) Explain how heat change will affect panel output voltage. Base your explanations on a mathematical model.

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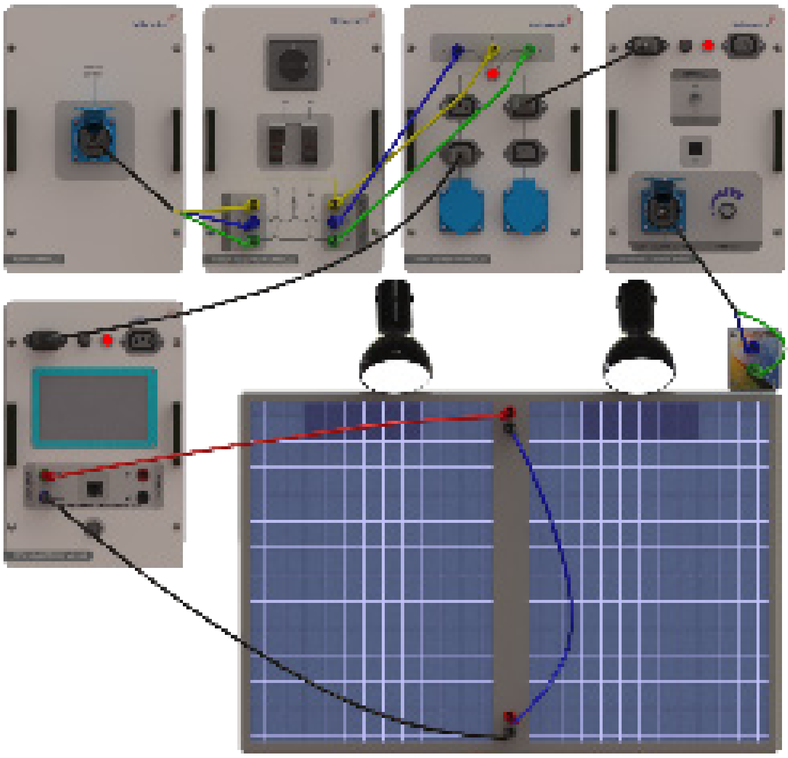
2.1.8. Examining the Series Connection in Photovoltaic Panels



Figure–1

1) Prepare the experimental setup in fig.1. . Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.

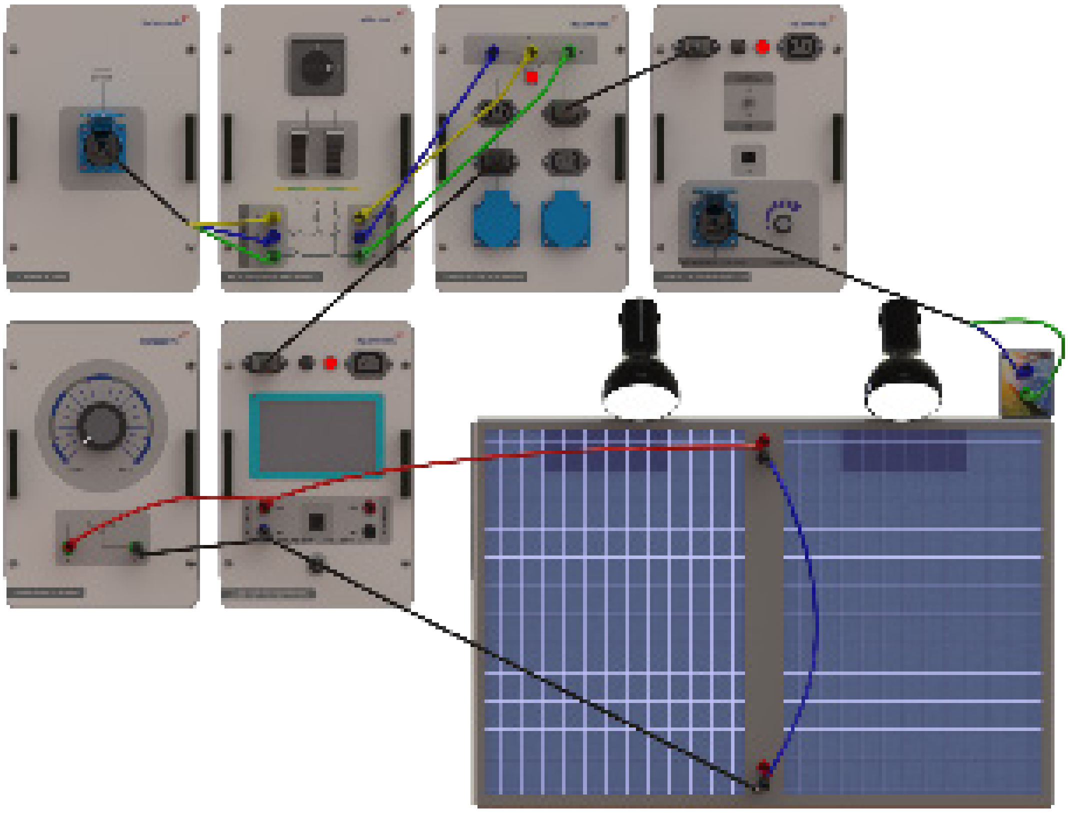
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module. Use the DIMMER potentiometer to set the light power to a maximum.

3) Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module.

4) Set the Electronic Potentiometer Module to 200Ω and connect it to the series panel discharge ends as shown in figure-2. Measure the loaded output voltage and record the value in chart-1.

Vseries (non-load)	Vseries (Loaded)

Chart-1

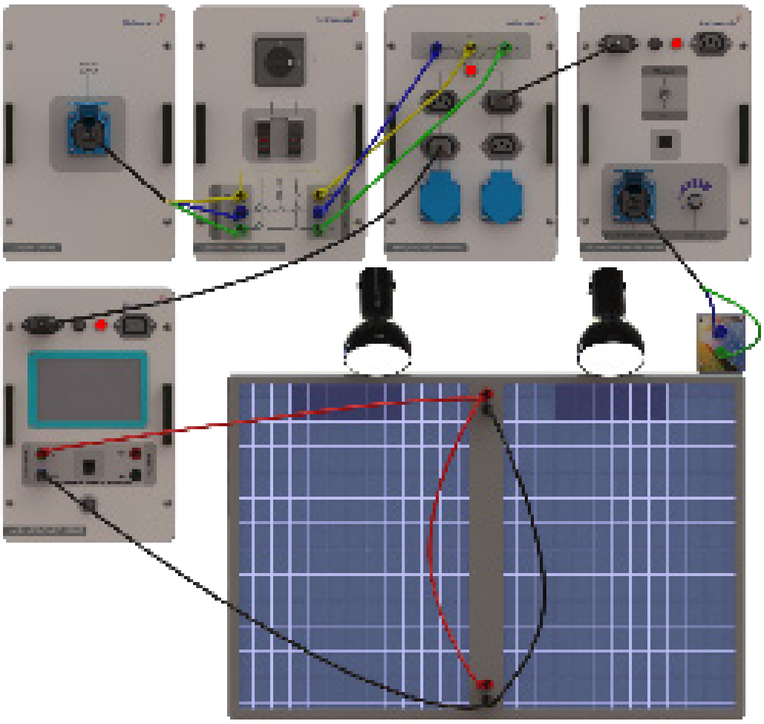


Figure–2

5) Explain the effect of connecting photovoltaic panels in series on the equivalent series resistance.

6) Explain the effect of connecting photovoltaic panels in series on the equivalent parallel resistance.

2.1.9. Examining the Parallel Connection in Photovoltaic Panels

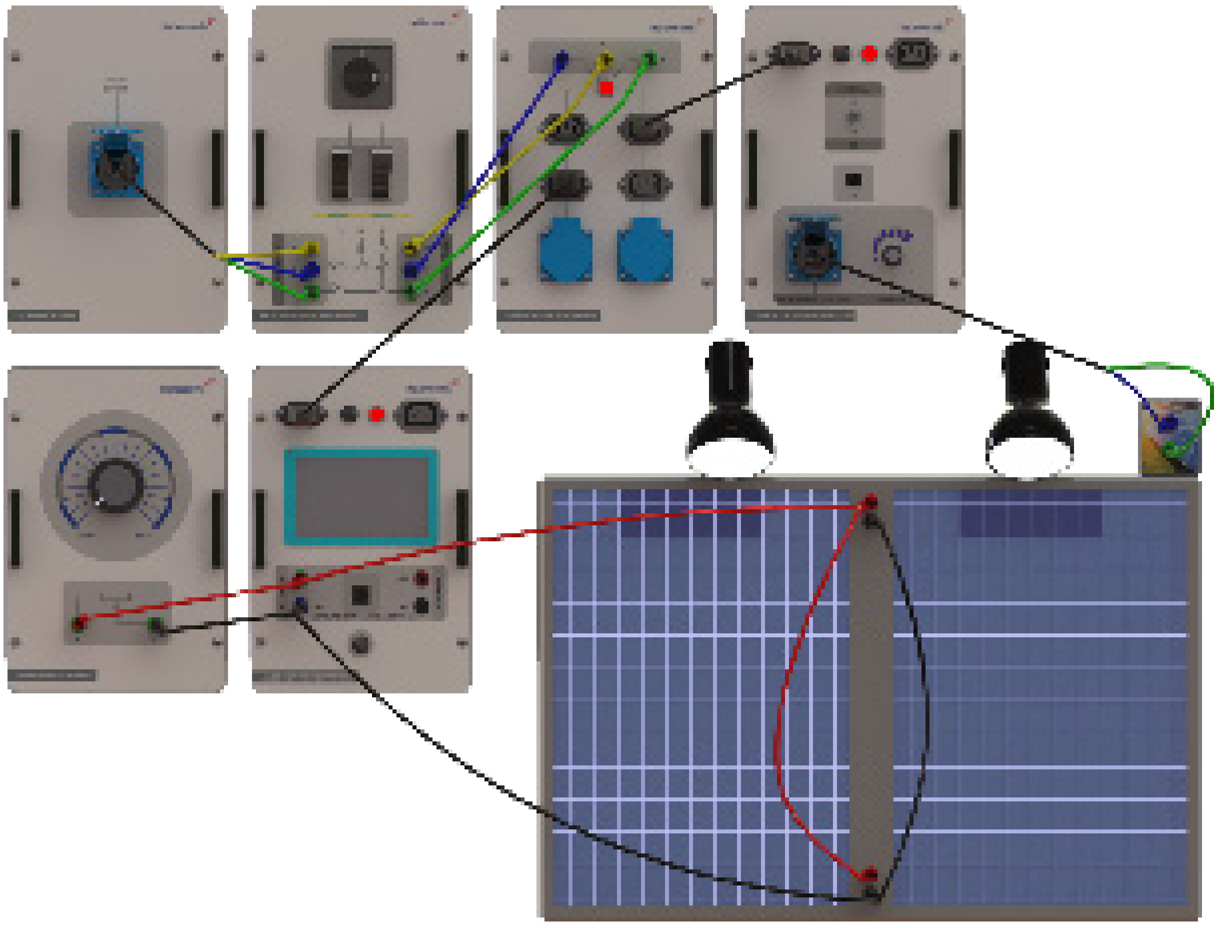


Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module.
4) Set the Electronic Potentiometer Module to 200Ω and connect it to the parallel-connected panel discharge ends as shown in figure-2. Measure the loaded output voltage and record the value in chart-1.

Vseries (non-load)	Vseries (Loaded)

Chart-1

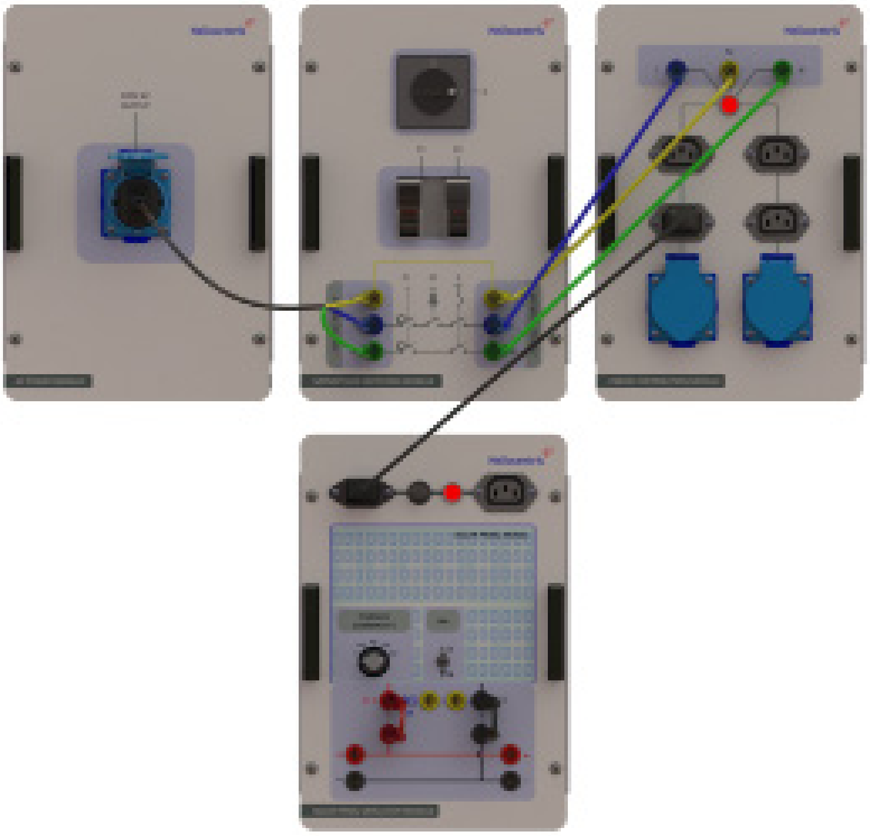


Figure–2

5) Explain the effect of connecting photovoltaic panels in parallel on the equivalent series resistance.

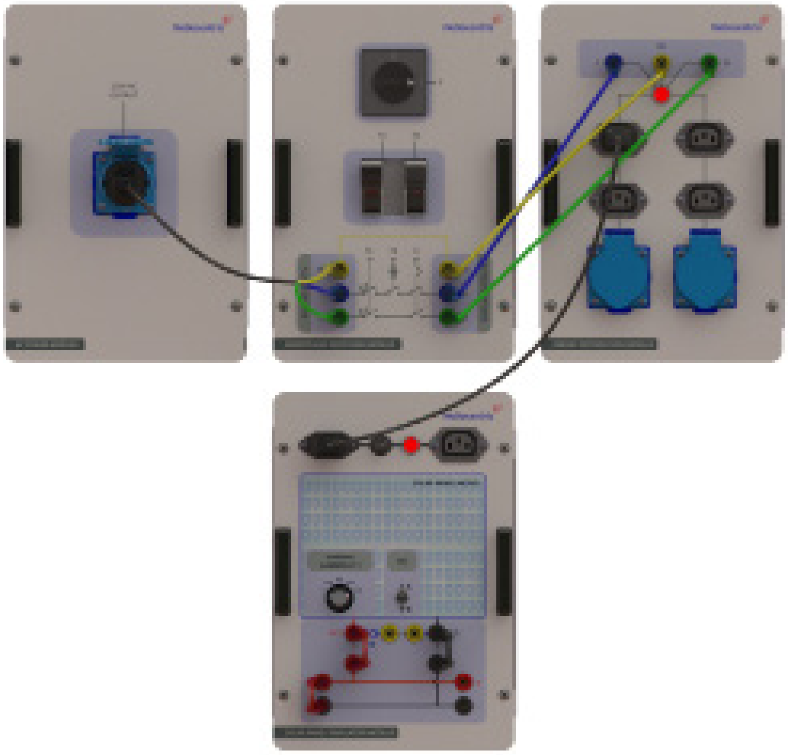
6) Explain the effect of connecting photovoltaic panels in parallel on the equivalent parallel resistance.

2.1.10. Examining the Photovoltaic Panel Simulator



Figure–1

1) The Solar Panel Simulator Module acts like a solar panel and is used indoors when it is not possible to work with solar energy.
2) Prepare the experimental setup in fig.1. Set the irradiance selector switch to 0,2.
3) Set the A-A selector switch to A. This selector switch determines the open-circuit voltage (VOC) value of the photovoltaic panel. This value is approximately 17V when set to A, and 13V when set to B.
4) Observe the photovoltaic panel open-circuit voltage on the voltmeter, and record it in chart-1.
5) Set the selector switch to B and repeat the same measurements. Record the measured voltage value in Chart-1.
6) Set the irradiance selector switch to 0,4; 0,6; 08 and 1 (in this order) and repeat the same measurements. Record the results in Chart-1.
7) Connect as shown in figure-2 to measure the photovoltaic panel short-circuit voltage.
8) The A-B selector switch does not affect the short-circuit current.



Figure–2

9) Set the irradiance selector switch to 0,2. Record in chart-1 the measured amount of short-circuit current.

10) Set the irradiance selector switch to 0,4; 0,6; 08 and 1 (in this order) and repeat the same measurements. Record the results in Chart-1.

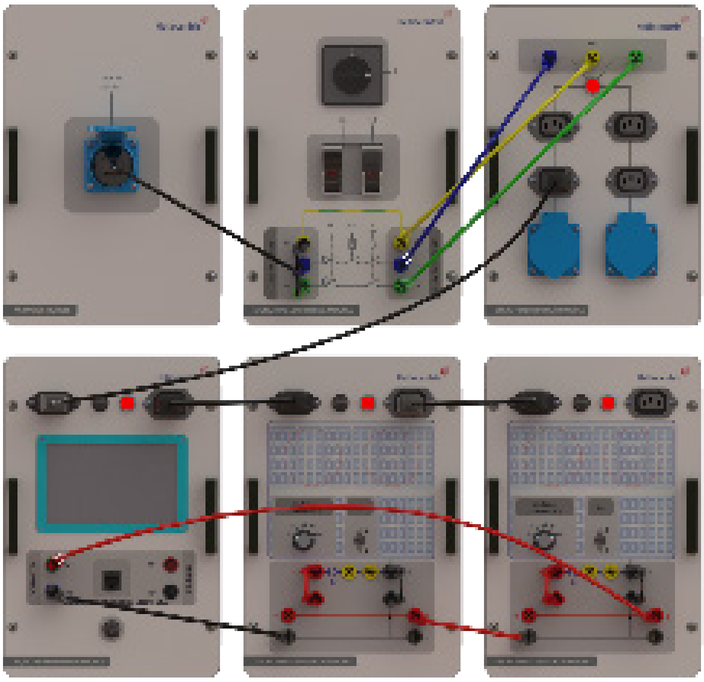
IRRADIANCE	VOC (VOLT) (Set to A)	VOC (VOLT) (Set to B)	ISC (mA)
0,2			
0,4			
0,6			
0,8			
1			

Chart-1

11) Connect as shown in figure-3 to examine the series connection of photovoltaic panels. Set the selector switches on both modules to A.

12) Set the irradiance selector switches to 0,2 (at the same time on both modules). Use the voltmeter on the AC/DC Measurement Module to measure the open-circuit voltage that corresponds to the series connection, and record your findings in chart-2.

13) Set the irradiance selector switch to 0,4; 0,6; 08 and 1 (in this order) and repeat the same measurements. Record the results in Chart-2.



Figure–3

IRRADIANCE	VOC (VOLT) (Set to A)	VOC (VOLT) (Set to B)
0,2		
0,4		
0,6		
0,8		
1		

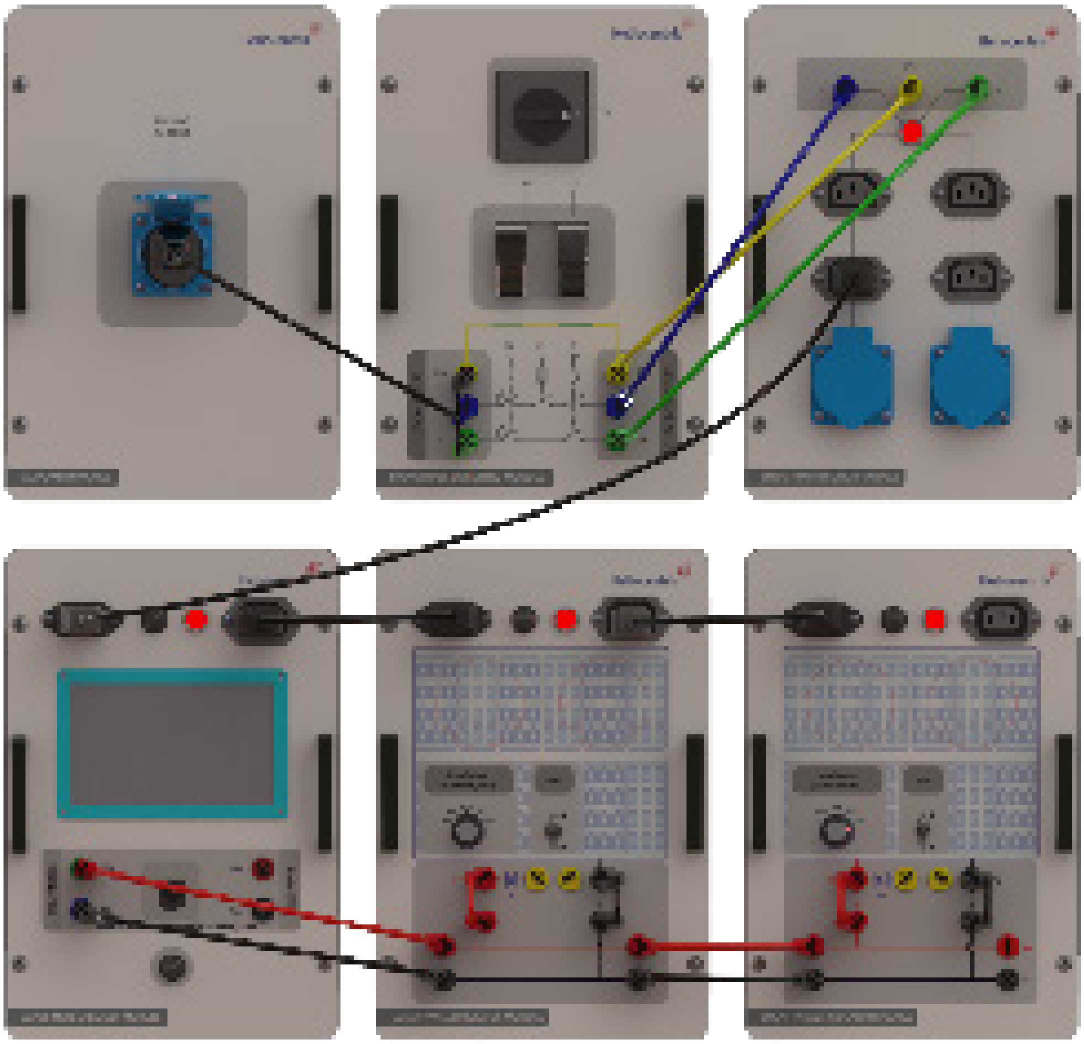
Chart-2

14) Set the selector switches on both modules to B. Repeat the same measurements. Record the results in Chart-2.

15) Connect as shown in figure-4 to examine the parallel connection of photovoltaic panels. Set the selector switches on both modules to A.

16) Set the irradiance selector switches to 0,2 (at the same time on both modules). Use the voltmeter on the AC/DC Measurement Module to measure the circuit voltage that corresponds to the series connection, and record your findings in chart-3.

17) Set the selector switch to 0,4; 0,6; 08 and 1 (in this order) and repeat the same measurements. Record the results in Chart-3.



Figure–4

IRRADIANCE	VOC (VOLT) (Set to A)	VOC (VOLT) (Set to B)
0,2		
0,4		
0,6		
0,8		
1		

Chart-3

18) Set the selector switches on both modules to B. Repeat the same measurements. Record the results in Chart-3.

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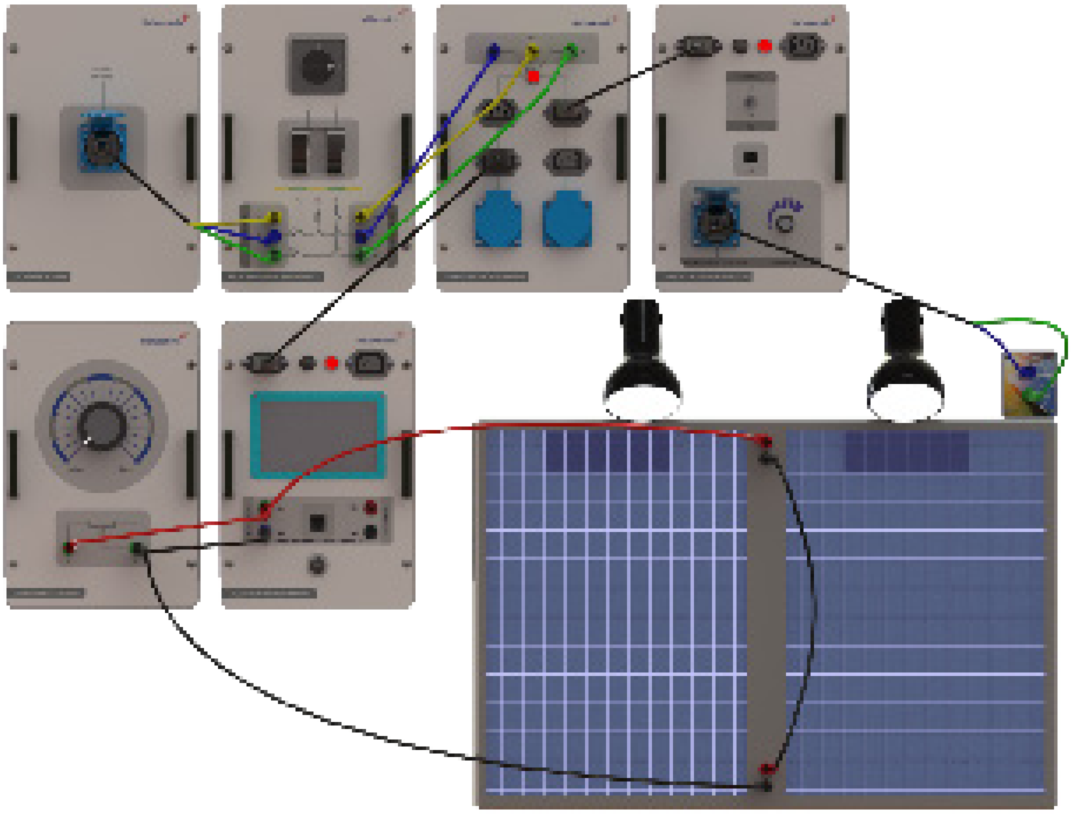
2.1.11. Examining the Effect of Shadow on Photovoltaic Panels



Figure–1

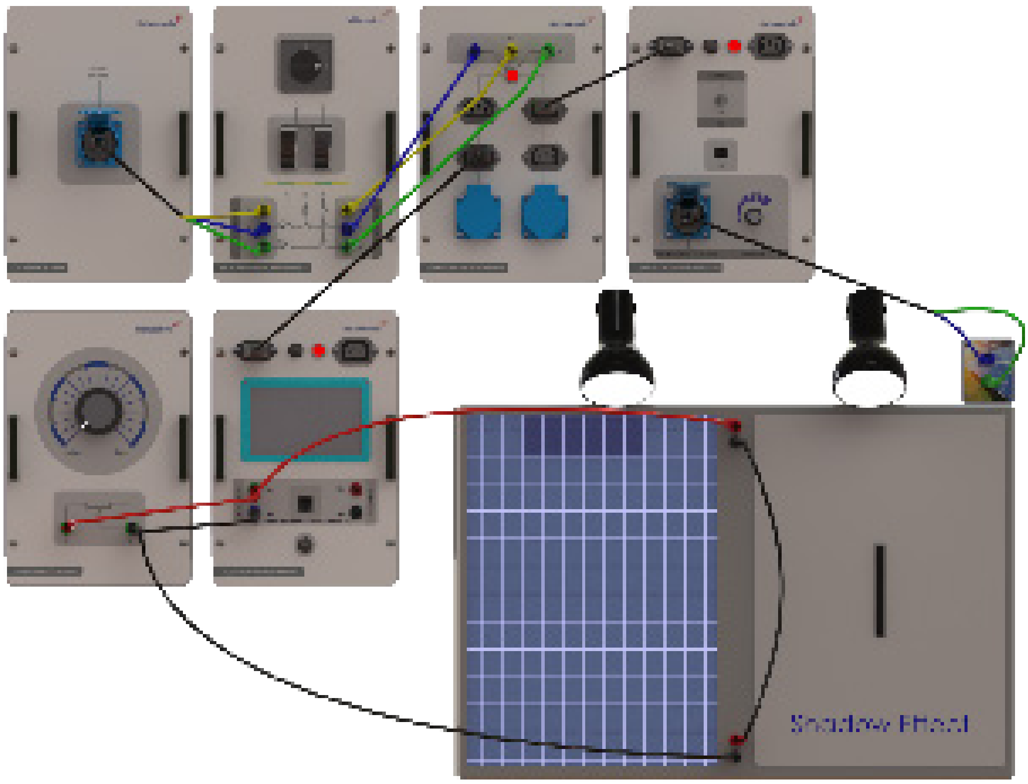
1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Set the Electronic Potentiometer Module to 500Ω.
4) Use the DIMMER potentiometer on the Light Source Control Module to set the light power to a maximum.

Vseries (no shadow)	Vseries (shadow on panel 1)	Vseries (shadow on panel 2)

Tablo-1

5) Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module.

6) Use the shadowing device to shadow panel-1 as shown in figure-1. Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module under this circumstance.



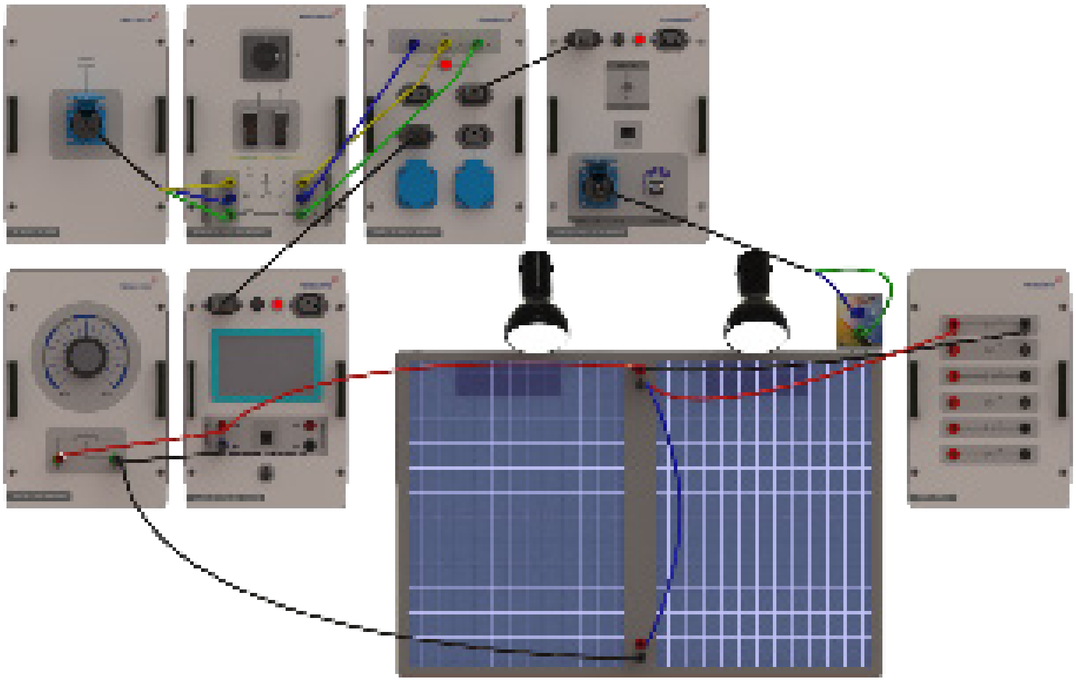
Figure–2

7) Use the shadowing device to shadow panel-2 as shown in figure-2. Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module under this circumstance.

8) Use IV characteristics to explain the effect of shadowing.

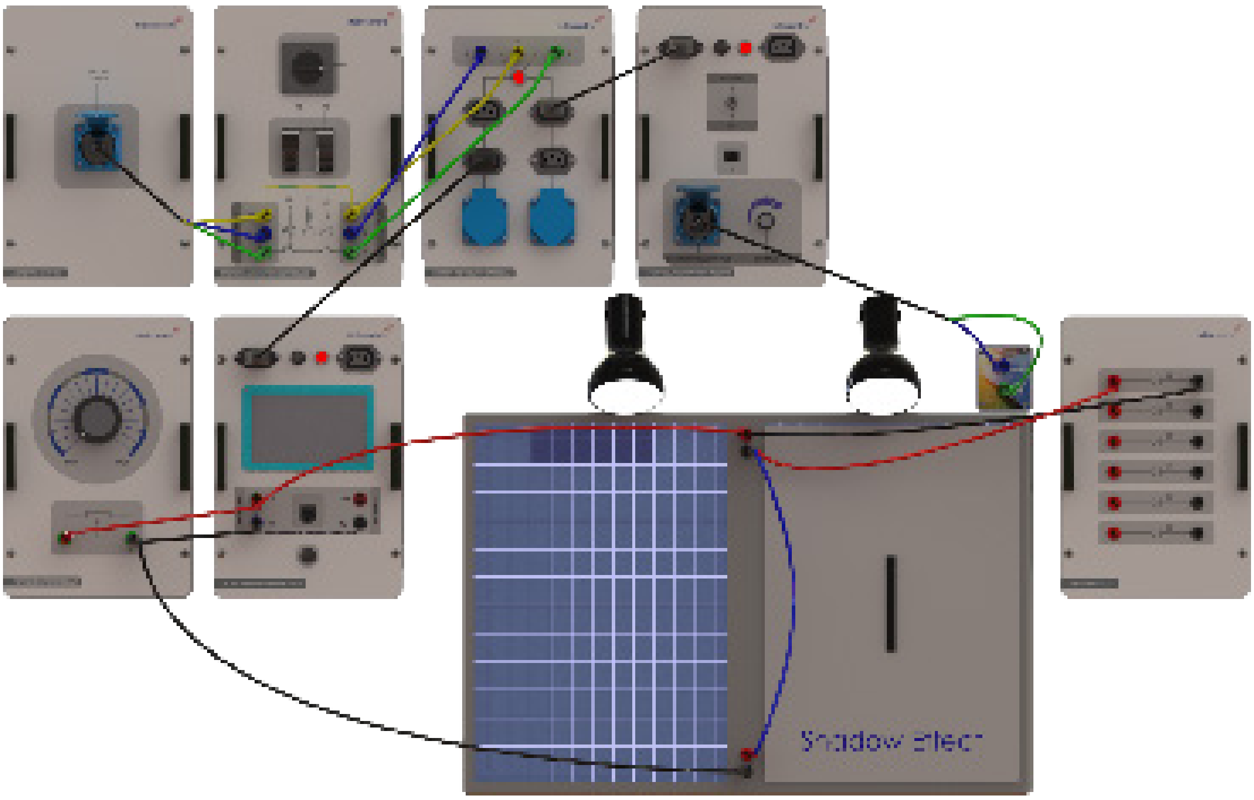
9) Explain what hot-spot is. Search for ways to avoid this effect.

2.1.12. Examining the Effect of Bypass Diodes on Photovoltaic Panels

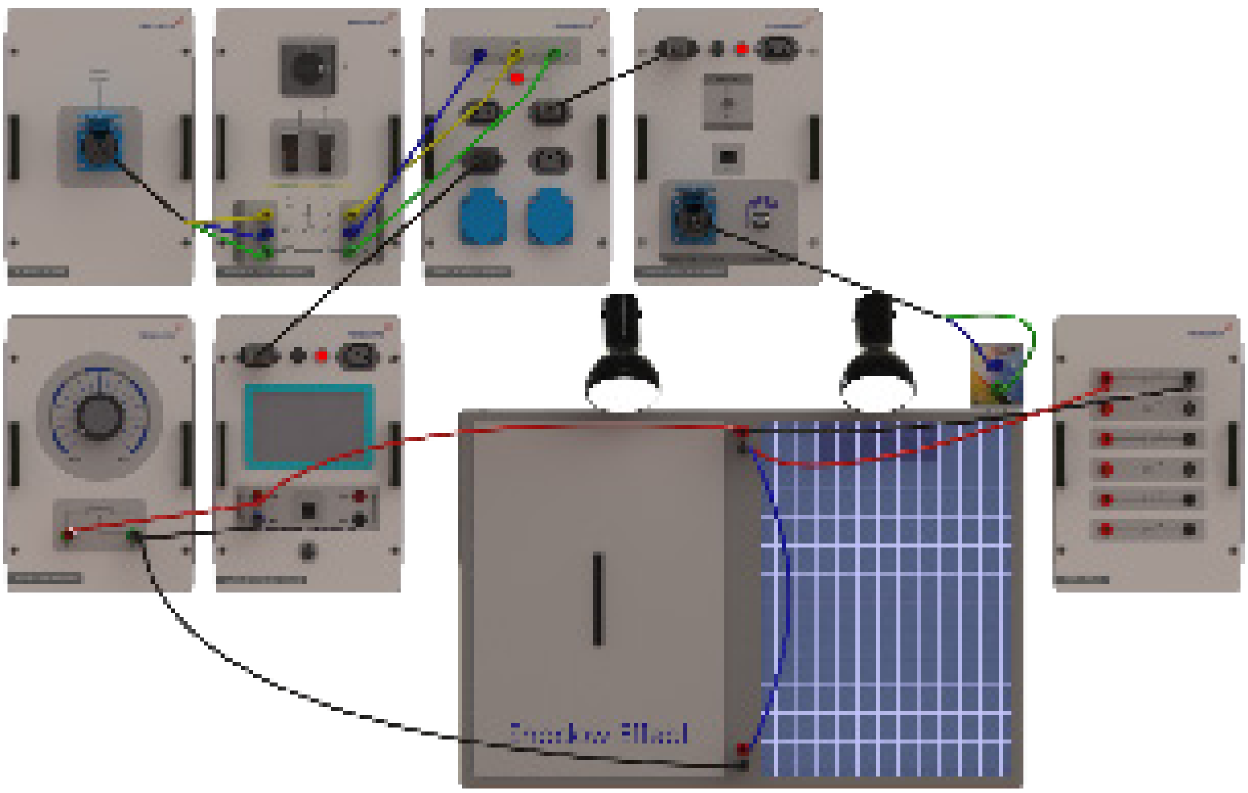


Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment. (Notice that the diode is cross connected.)
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Set the Electronic Potentiometer Module to 500Ω.
4) Use the DIMMER potentiometer on the Light Source Control Module to set the light power to a maximum.
5) Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module (without shadowing).
6) Use the shadowing device to shadow panel-1 as shown in figure-2. Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module under this circumstance.



Figure–2

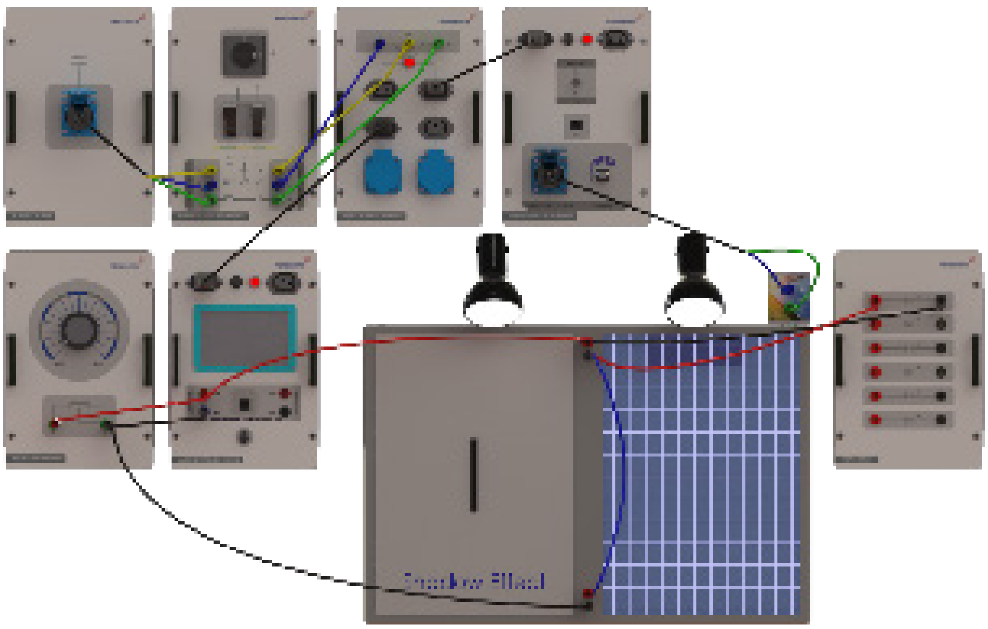


Figure–3

Vseries (no shadowing) (bypass diode connected to panel-1)	Vseries (shadowing on panel-1) (bypass diode connected to panel-1)	Vseries (shadowing on panel-2) (bypass diode connected to panel-2)	Vseries (shadowing on panel-1) (bypass diode connected to panel-2)	Vseries (shadowing on panel-1) (bypass diode connected to panel-2)

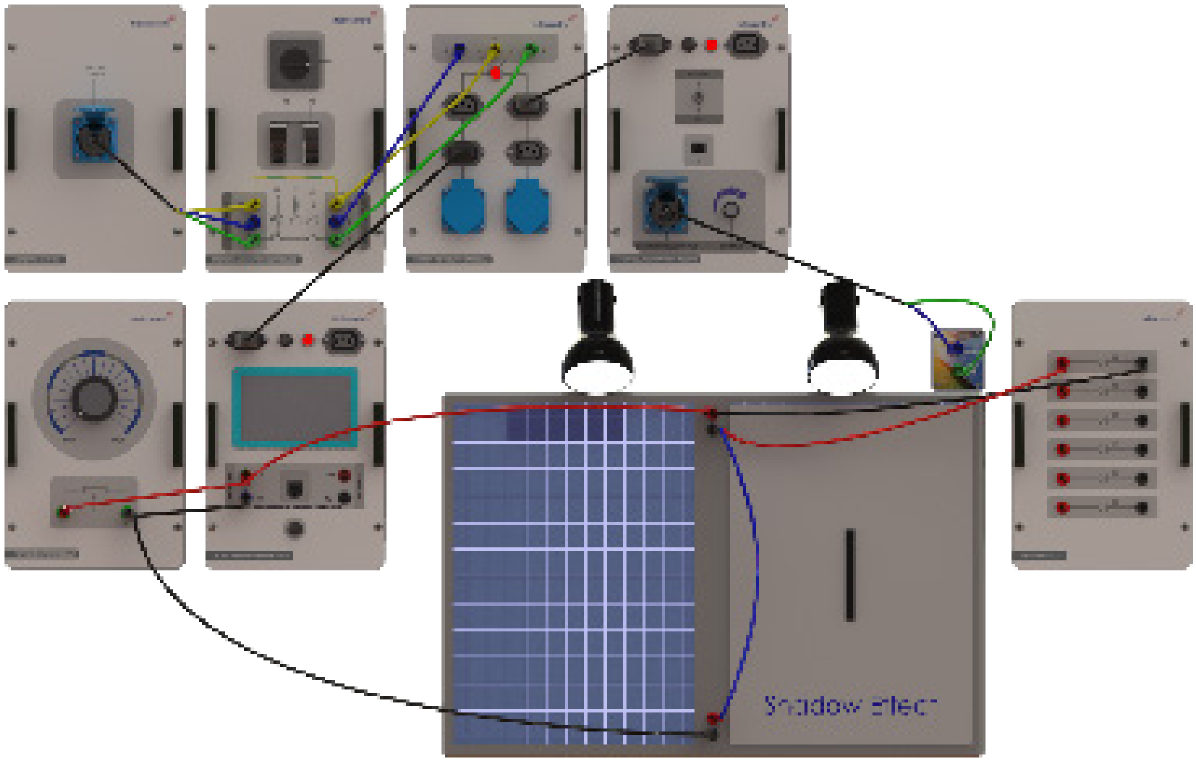
Chart-1

7) Use the shadowing device to shadow panel-2 as shown in figure-3. Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module under this circumstance.
8) Connect the bypass diode to panel-2. (Notice that the diode is cross connected.)

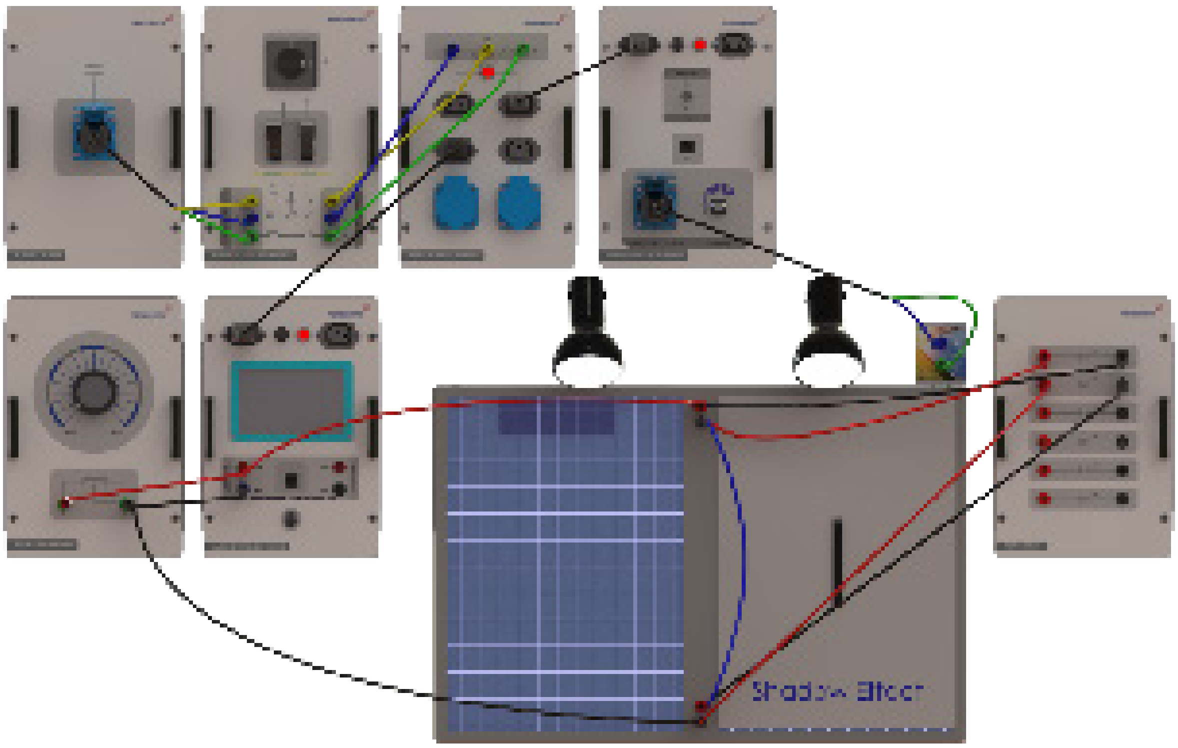


Figure–4

9) Use the shadowing device to shadow panel-1 as shown in figure-4. Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module under this circumstance.
10) Use the shadowing device to shadow panel-2 as shown in figure-5. Record in chart-1 the value observed on the voltmeter placed on the AC/DC Measurement Module under this circumstance.
11) Connect the bypass diodes to both panels as shown in figure-6 and use the shadowing device to shadow panel-1. (Notice that the diodes are cross connected.)



Figure–5

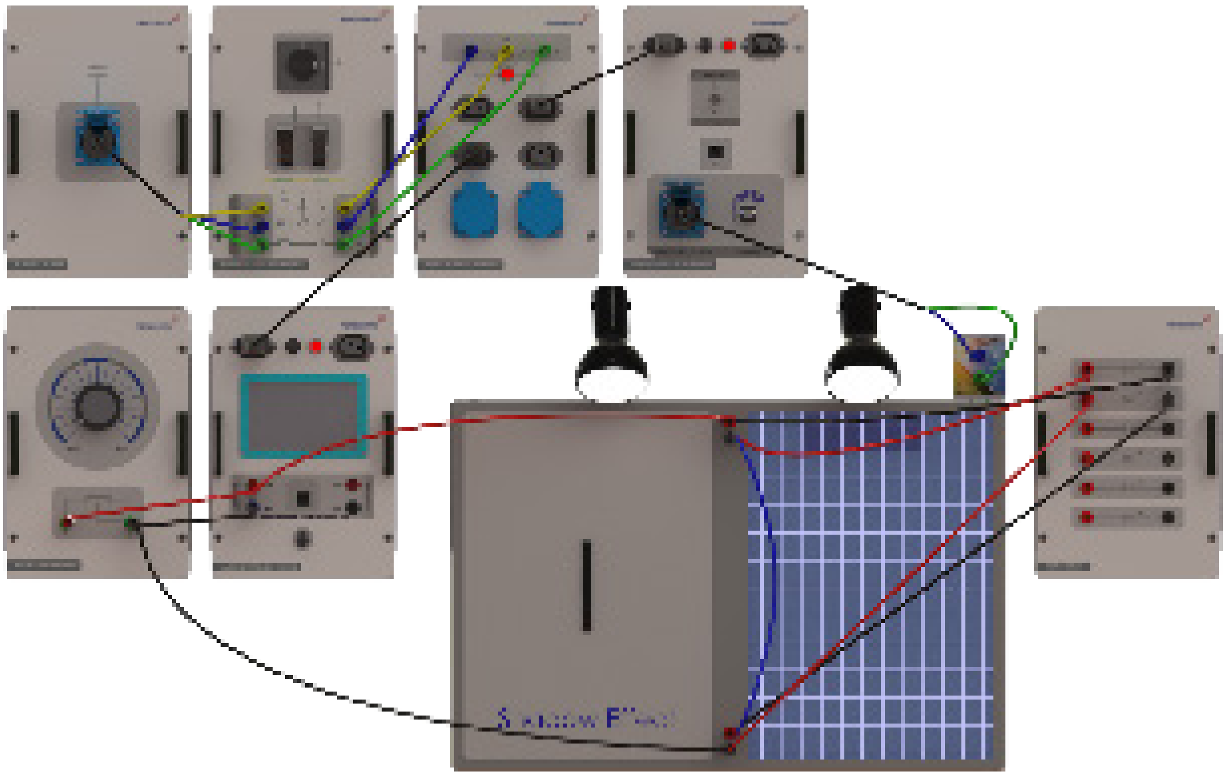


Figure–6

Vseries (shadowing on panel-1) (bypass diode connected to both panels)	Vseries (shadowing on panel-2) (bypass diode connected to both panels)

Chart-2

14) Use the shadowing device to shadow panel-2 as shown in Figure-7. Record in chart-2 the value observed on the voltmeter placed on the AC/DC Measurement Module under this circumstance.

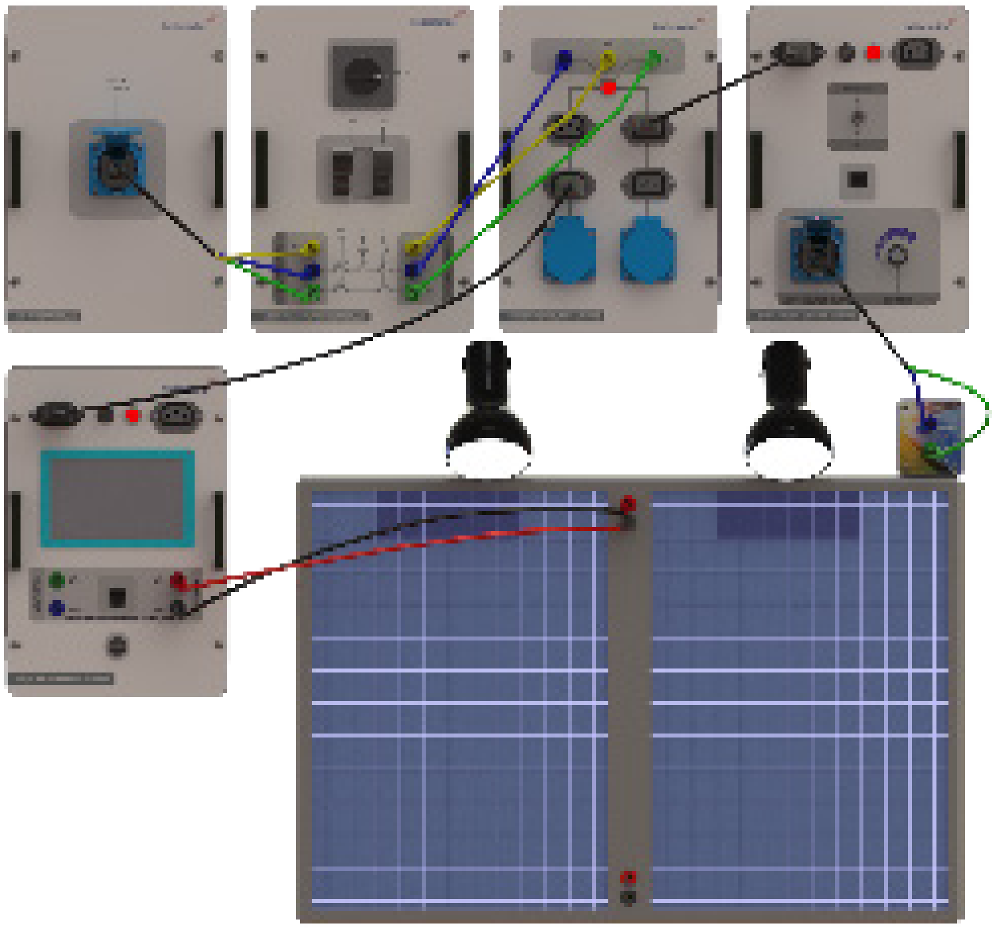


Figure–7

15) Explain the direction of bypass diode connection.

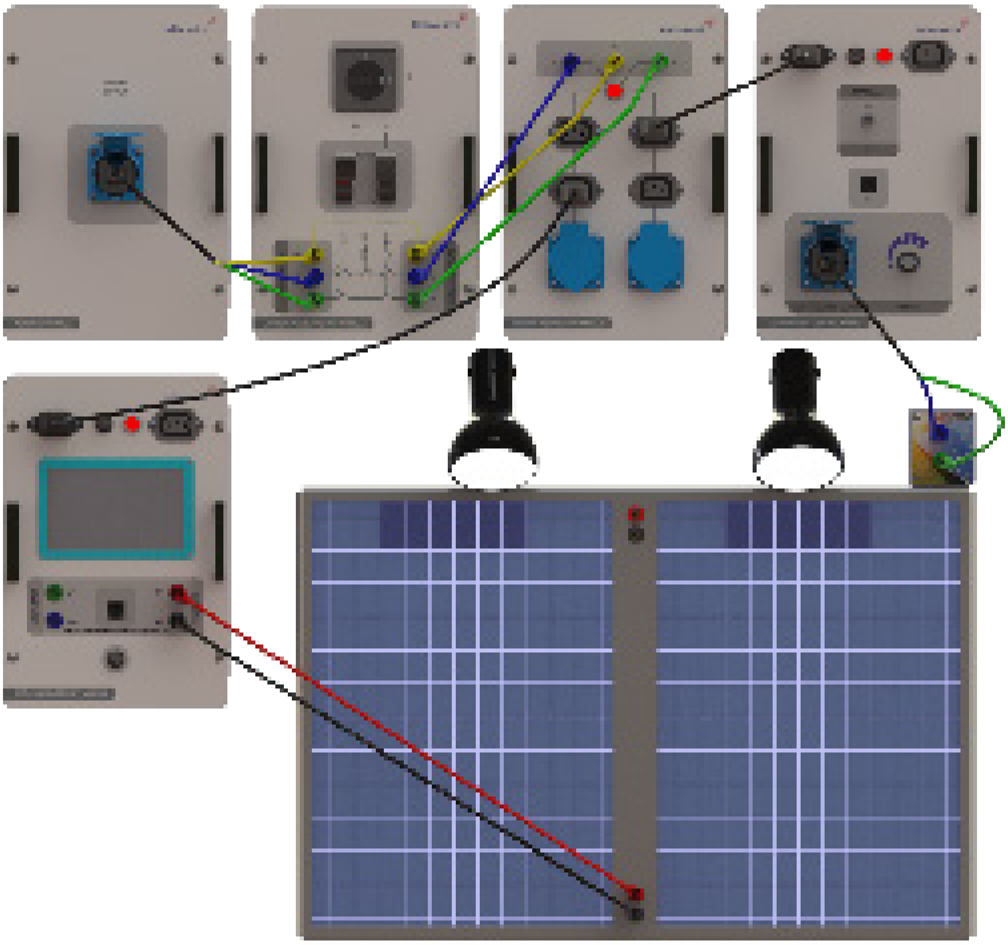
16) Draw an equivalent circuit to explain the bypass diode effect.

2.1.13. Examining the Effect of Mismatching on Photovoltaic Panels



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light power to a maximum.
4) Record in chart-2 the value observed on the ampermeter placed on the AC/DC Measurement Module. Notice that this is the short-circuit current (Isc1) value corresponding to panel-1.
5) Connect as shown in figure-2. Record in chart-1 the value observed on the ampermeter placed on the AC/DC Measurement Module. Notice that this is the short-circuit current (Isc2) value corresponding to panel-2.



Figure–2

Isc1	Isc2	Isc3

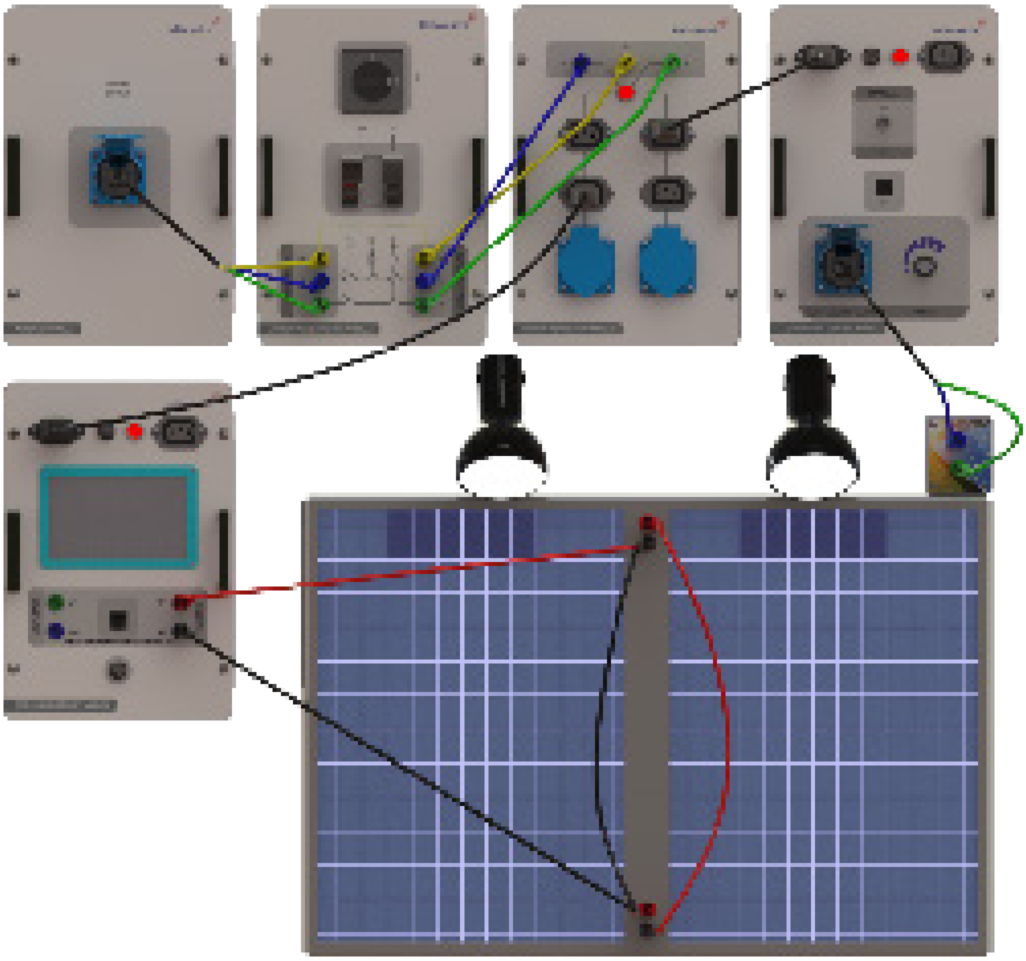
Chart-1

6) Connect as shown in figure-3. Notice that the panels are connected in series. Record in chart-1 the value observed on the ampermeter placed on the AC/DC Measurement Module. Notice that this is the shortcircuit current (Isc_series) value corresponding to the series connection.

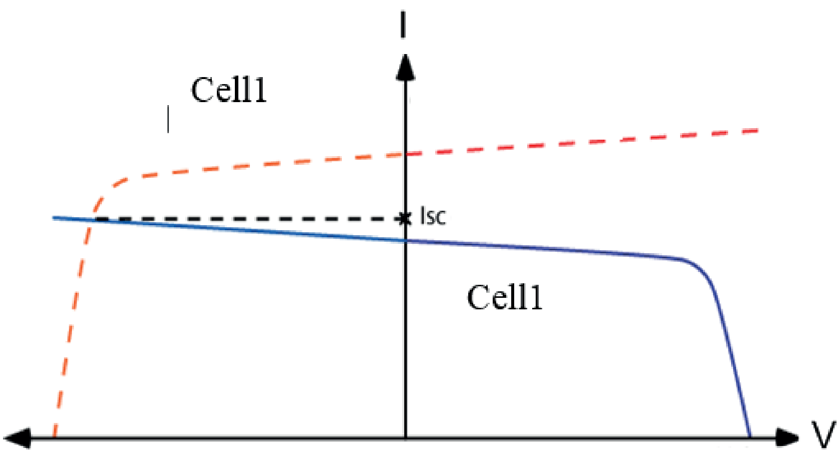
7) Note the current value (Isc_series) in panels connected in series. Notice that this value is between ISC1 and ISC2.

8) Draw out IV characteristics of each panel under the same light power and use the method explained in figure-4 to determine the Isc_series value.

9) Compare the values obtained after measurement and those obtained through the characteristic curve.

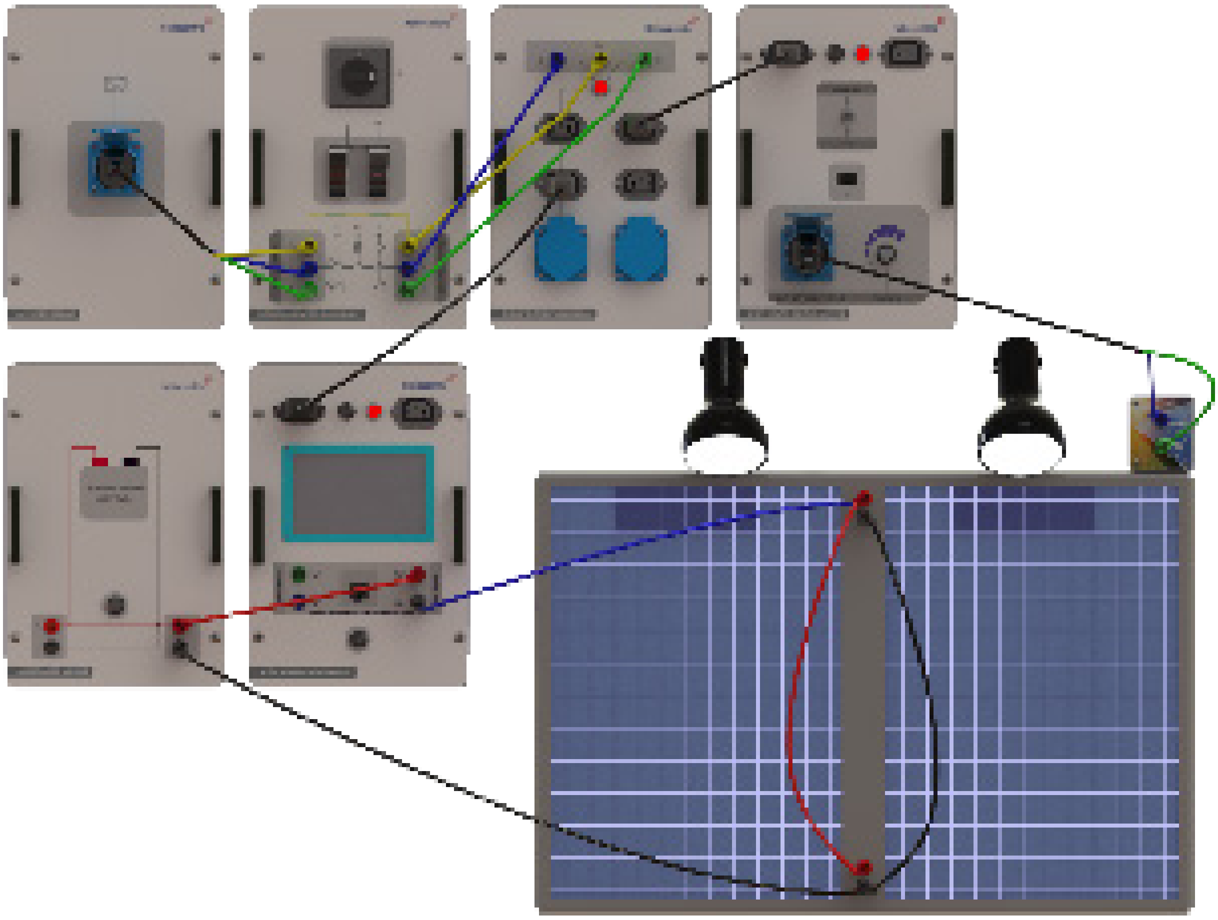


Figure–3



Figure–4

2.1.14. Examining the Effect of Blocking Diodes on Photovoltaic Panels



Figure–1

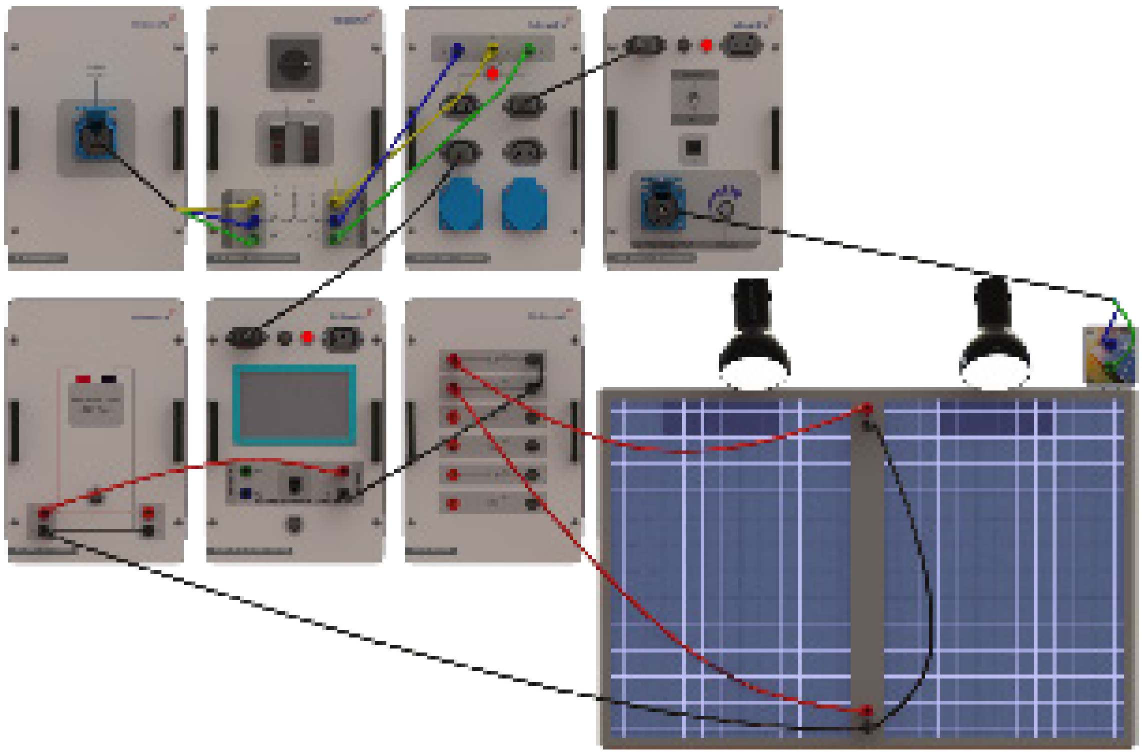
1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light power to a minimum.
4) Use the shadowing device to shadow one of the panels.
5) Record in chart-1 the value observed on the ampermeter (I1) and the direction of current flow.

I1	I2

Chart-1

6) Prepare the experimental setup in fig.1. Paying attention to the ampermeter, notice that there is no more current passage from the battery to the panels.

7) After removing the shadowing device, record in chart-1 the value observed on the ampermeter (I2) the direction of current flow.



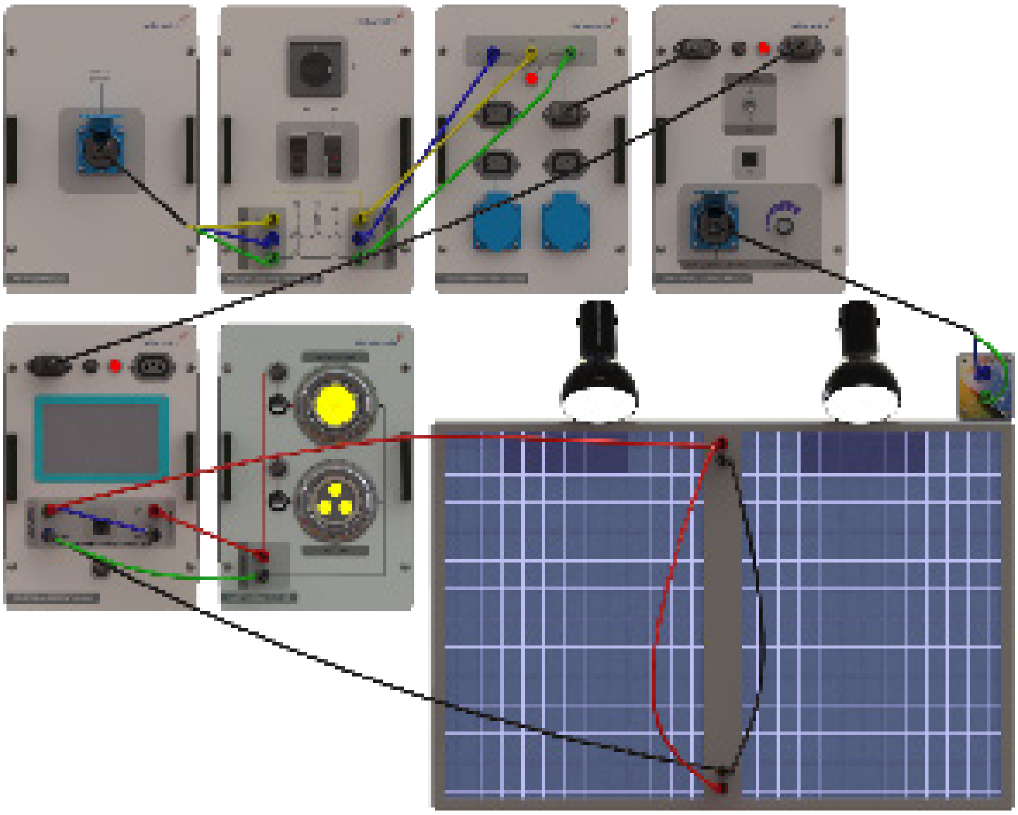
Figure–2

8) Draw a sketch to explain the blocking diode effect.

9) Specify the kinds of problems that may occur when a blocking diode is not used.

2.2. Photovoltaic System Experiments

2.2.1. Direct Loading of the Photovoltaic Panel



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light power to a minimum.
4) The ampermeter (I1) on the AC/DC Measurement Module is used to measure the current transferred from the panel to the load. Considering this, switch the Led Lamp Module switch to 1 when the light intensity of the lamp that is used to illuminate the panel is set to a minimum. (Halogen Lamp switch should remain set to 0.) In this case, depending on the level of light in the laboratory, the Leds will give out a faint light.
5) Record in chart-1 the values observed on the voltmeter (V1) and the ampermeter (I1) placed on the AC/DC Measurement Module.

Minimum light intensity (LED lamp)		Maximum light intensity (LED lamp)	
I1 (mA)	V1 (V)	I1 (mA)	V1 (V)

Chart-1

6) Use the DIMMER potentiometer on the Light Source Control Module to gradually increase light intensity until V1 voltage reaches 12 volt. Do not exceed 12 volt. (Exceeding this limit may damage the LEDs!)
7) Record in chart-1 the values observed on the voltmeter (V1) and the ampermeter (I1) placed on the AC/DC Measurement Module (light intensity set to a maximum).
8) Set the Halogen Lamp switch on the Lamp Module to 1, and engage the halogen lamp as the load. Record in chart-2 the values observed on the voltmeter (V1) and the ampermeter (I1) placed on the AC/DC Measurement Module (light intensity set to a maximum).

Maximum light intensity (Halogen lamp)		ISC (Short-circuit current value obtained through Experiment 2.1.2)
I1 (mA)	V1 (V)	I1 (mA)

Chart-2

9) Observe that the lamps cannot be lit in this case, but that they draw a current from the panel which is close to short-circuit current.
10) Analyze the effects of a big decrease in load resistance (an increase in the amount of load) on panel output voltage and panel output current.
11) Find out if directly connecting the panel output to the load is a suitable manner of operation.

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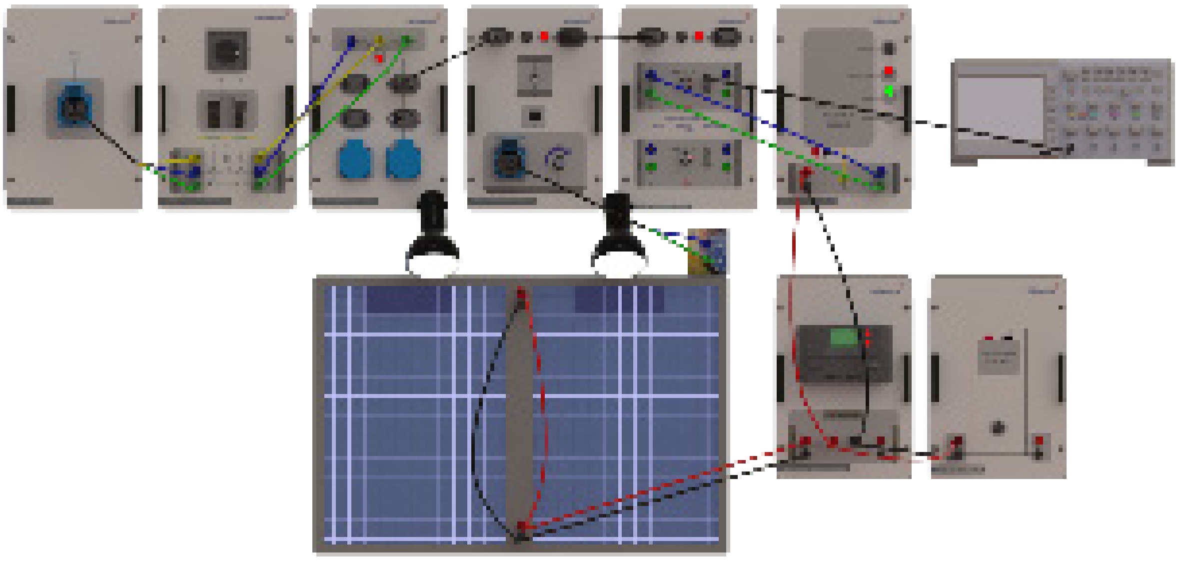
2.2.2. Engaging the Off-Grid Inverter (No-Load Operation)

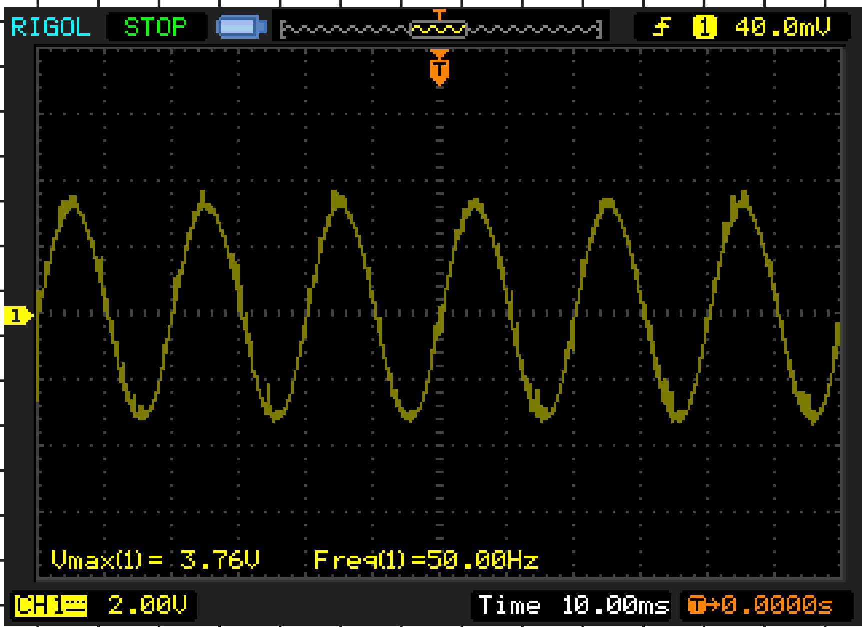


Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light power to a maximum.
4) Set the off-grid power switch to 1. Two LEDs, one red and one green, are placed next to the power switch. Along with an audible warning, the red LED indicates low battery voltage. The green one, on the other hand, indicated that the battery has been sufficiently charged, and that output voltage is being produced.
5) The green LED placed next to the POWER switch on the Off-Grid Inverter Module must be on. If the red one is on and there is an audible warning, this indicates that the battery has been insufficiently charged. In this case, it is necessary to turn off the inverter to charge the battery.

6)Set the commutator placed on the Isolated Measurement Module to X0,01. In this case, the inverter output signal will be isolated and weakened at a ratio of 1:100.

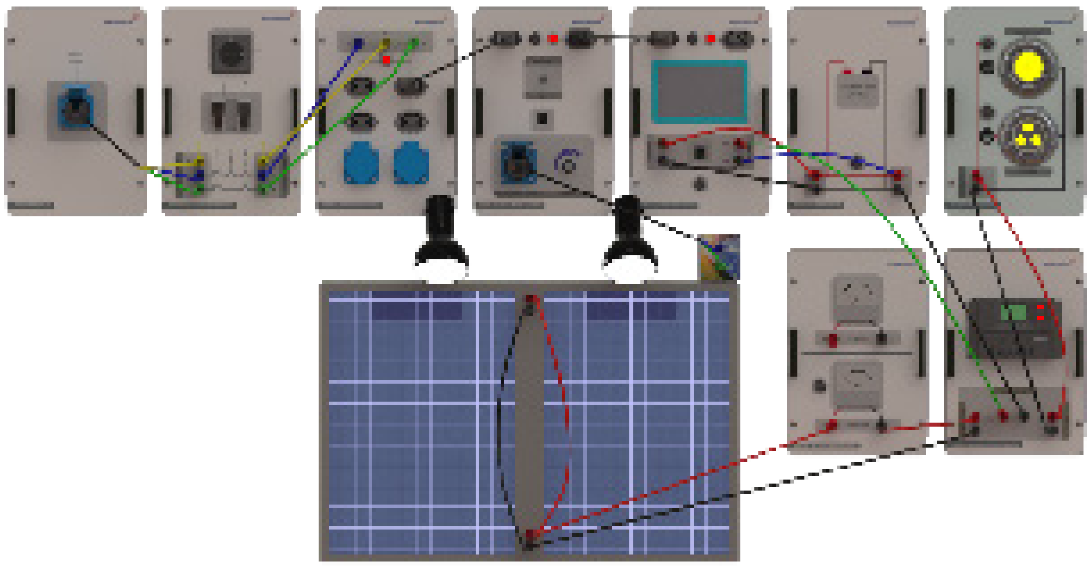
7) Use the Isolated Measurement Module to examine the form of signal that corresponds to the inverter output voltage. Draw the form in the area given below as graphic-1. Measure the peak-to-peak (Vpp) and effective values (Vrms) and frequencies of the inverter output voltage, then record these measurements in the area provided below the graphic. (Taking the 1:100 weakening into consideration, multiply the oscilloscopic measurements by 100. Make sure that prop weakening is set to X1).



Vpp(V): Vrms(V): f (Hz):

Chart-2

2.2.3. Setting up the Basic Photovoltaic System (DC Load)



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.

2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.

3) Use the DIMMER potentiometer on the Light Source Control Module to set the light power to a minimum.

4) Pay attention to the data on Solar Charge Regulator Module.

5) While the ampermeter (I1) on the AC/DC Measurement Module is used to measure the current supplied to or drawn from the battery, the external ampermeter (I2) is used to measure the current drawn from the photovoltaic panel. Considering this, record in chart-1 the values observed on the ampermeters when both switches on the Lamp Module are off (the loads are not engaged) and the light intensity of the lamp that is used to illuminate the panel is set to a minimum.

6) The voltmeter (V1) on the AC/DC Measurement Module is used to measure the battery voltage. Record this value in chart-1.

Minimum light intensity (no-load)			Maximum light intensity (LED lamp loaded)		
I1 (mA)	I2 (mA)	V1 (V)	I1 (mA)	I2 (mA)	V1 (V)

Chart-1

7) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a maximum. Record in chart-1 the value observed on the ampermeters and the voltmeter under this circumstance.
8) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a minimum.
9) Set the LED Lamp switch on the Lamp Module to 1 and engage the load.
10) Record in chart-2 I1, I2 and V1 values.
11) The voltmeter (V1) on the AC/DC Measurement Module is used to measure the battery voltage. Record this value in chart-2. (Minimum light intensity (loaded)).
12) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a maximum. Record in chart-2 the value observed on the ampermeters and the voltmeter under this circumstance. (Maximum light intensity (LED lamp loaded)).

Minimum light intensity (LED lamp loaded)			Maximum light intensity (loaded)		
I1 (mA)	I2 (mA)	V1 (V)	I1 (mA)	I2 (mA)	V1 (V)

Chart-1

Set the Halogen Lamp switch on the Lamp Module to 1, and engage the halogen lamp as the load. (Maximum light intensity).

14) Using the ampermeters and the voltmeter placed on the AC/DC Measurement Module, record in chart-3 I1, I2 and V1 values.

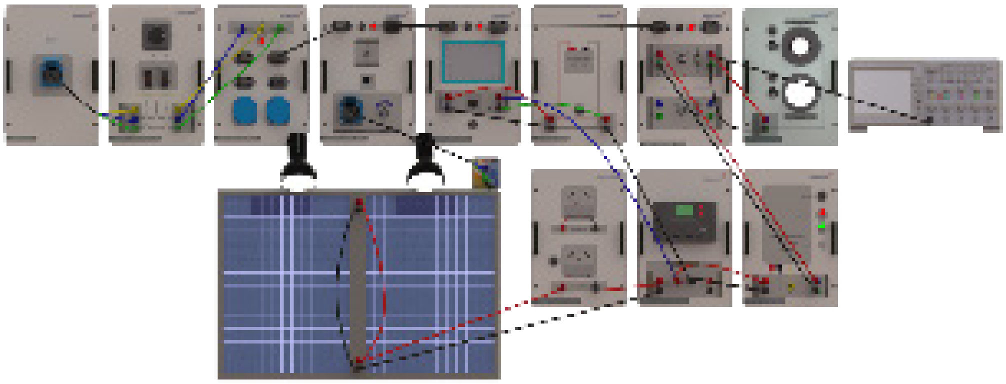
15) As the halogen lamp consumes a high amount of current, observe that a decrease occurs in the battery level indicators on the Solar Charge Regulator Module over time and that, after a certain point (this value is adjustable through the charge regulator), the load is disengaged and the battery is saved from being completely drained. (The battery symbol will start blinking.)

Maximum light intensity (Halogen lamp loaded)		
I1 (mA)	I2 (mA)	V1 (V)

Chart-1

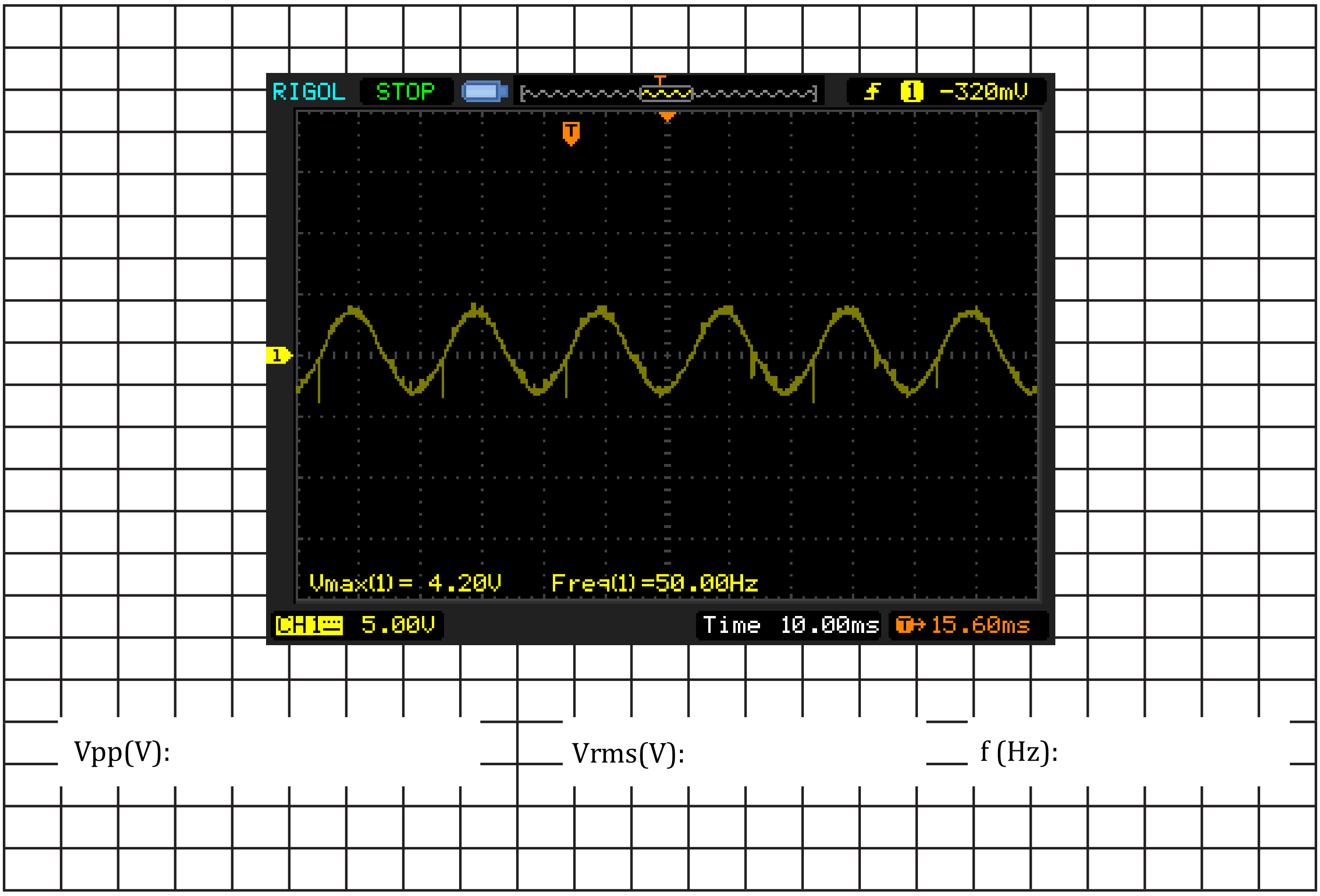
16) Keeping the light intensity at a maximum, wait until the accumulator is fully charged (this value is adjustable by the Solar Charge Regulator) and keep an eye on the values on the Solar Charge Regulator at the same time.

2.2.4. Setting up the Basic Photovoltaic System (AC Load)



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a maximum.
4) Set the power switch placed on the Off-grid Inverter Module to 0.
5) Keep an eye on the data observed on the Solar Charge Regulator Module.
6) If the battery has not been sufficiently charged, allow some time for it to charge. Once the battery has been sufficiently charged, set the power switch placed on the Off-grid Inverter Module to 1.
7) The green LED placed next to the POWER switch on the Off-Grid Inverter Module must be on. If the red one is on and there is an audible warning, this indicates that the battery has been insufficiently charged. In this case, it is necessary to turn off the inverter to charge the battery.
8) After the green LED placed next to the POWER switch on the Off-Grid Inverter Module has been switched on, draw the signal figures seen on the oscilloscope in Graphic-1. Measure the Vpp and Vrms and frequency values that correspond to the signal. (Because the Isolated Measurement Module CH1 selector switch is set to x0.01, multiply your findings by 100 to find the real value.)

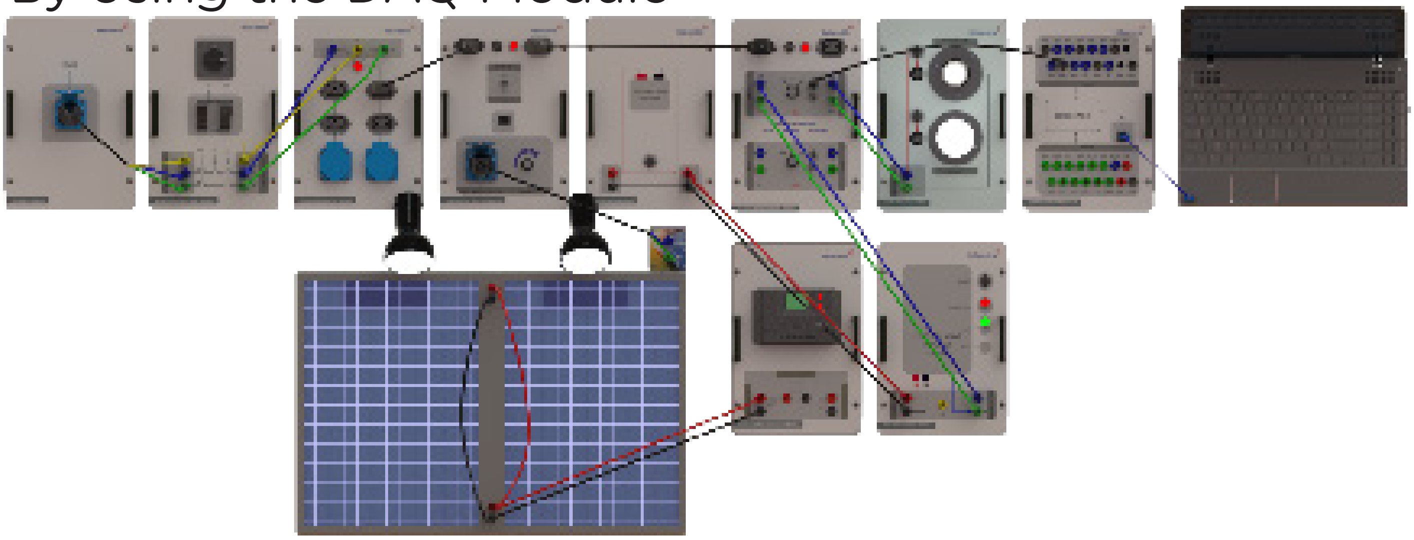


Graphic-1

9) Having set the LED Lamp switch on Lamp Module (220V AC) to 1, load the system. Observe the changes in the signal figure under this circumstance. (If the LED is on for a long time, depending on the battery, the inverter will cut the output power and give out an audible warning.)

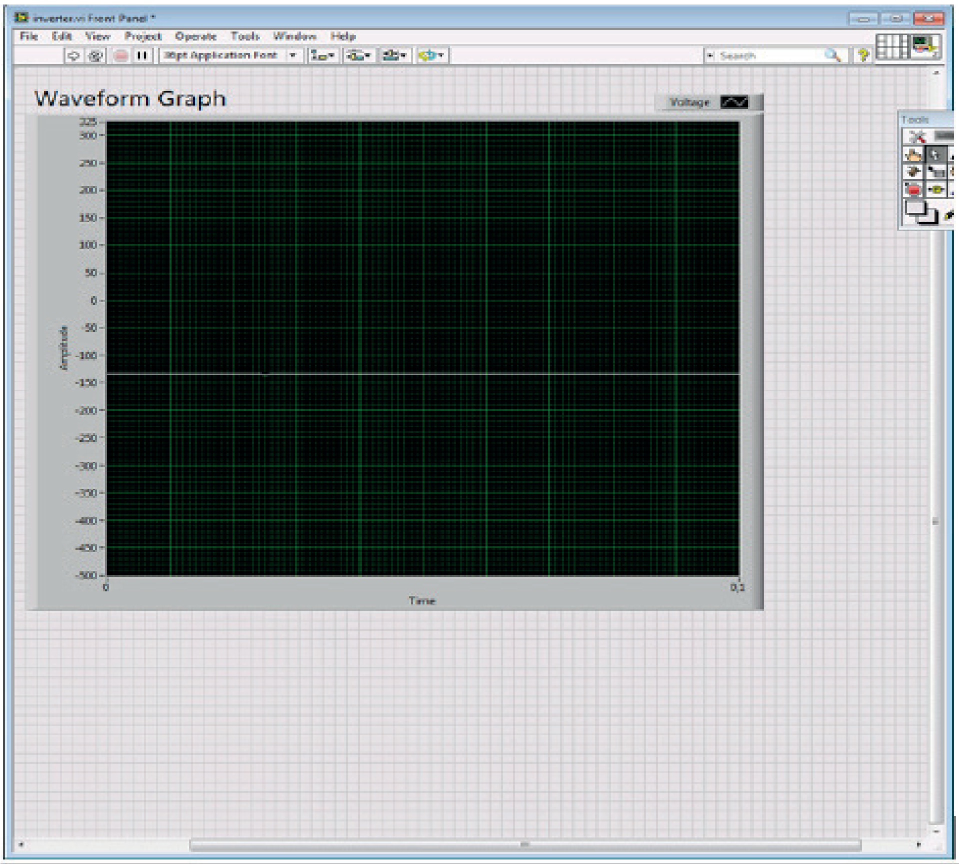
10) Having set the Halogen Lamp switch on Lamp Module (220V AC) to 1, load the system even more. Observe the Off-Grid Inverter Module. Depending on the battery, the inverter will cut the output power after a while, and give out an audible warning.

2.2.5. Examining the OFF_GRID Inverter Output Signal By Using the DAQ Module



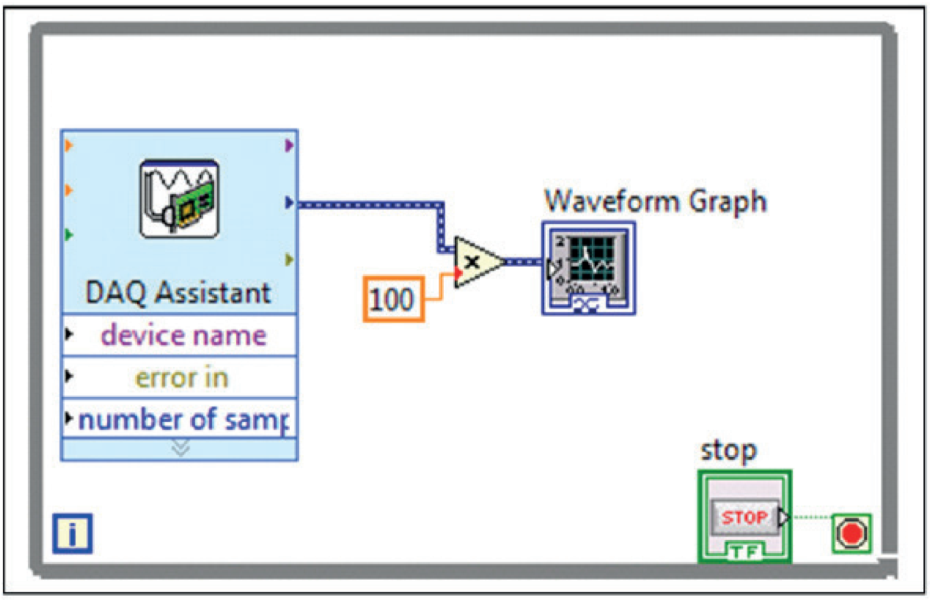
Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a maximum.
4) Set up a USB connection between the Data Acquisition Module and the computer.
5) Use the LabView software to add a waveform graph to the front panel as shown in figure-2. Set the timescale to 0.1 second.



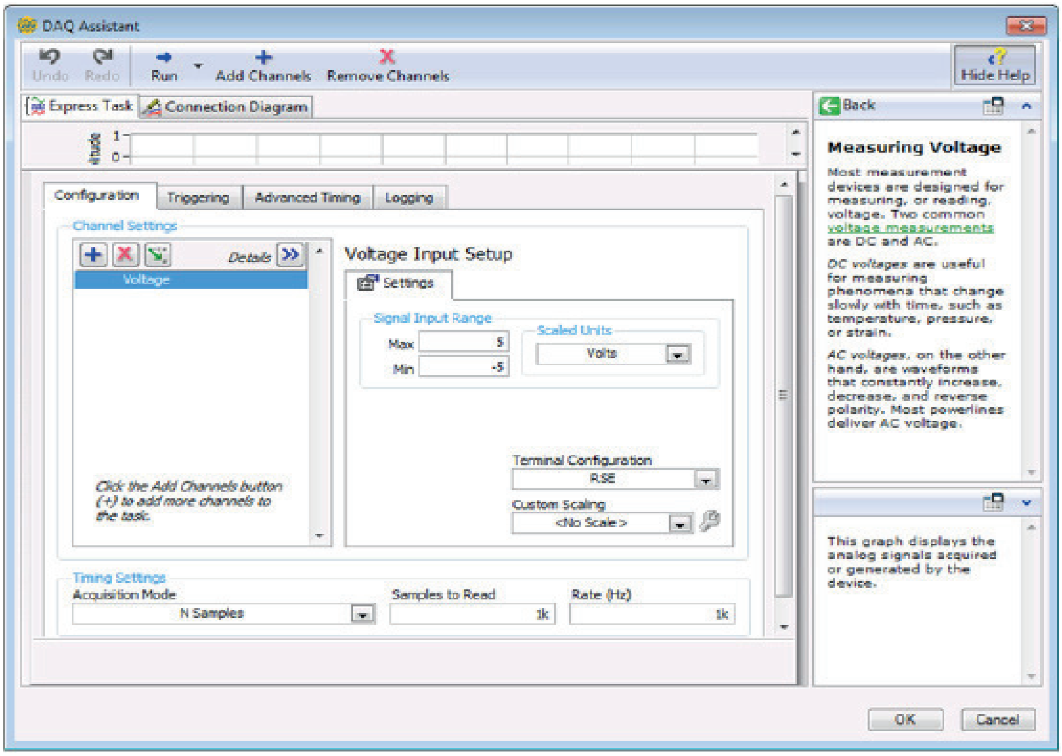
Figure–2

6) On the LabView Block Diagram screen, set up the exemplary circuit shown in figure-3.



Figure–3

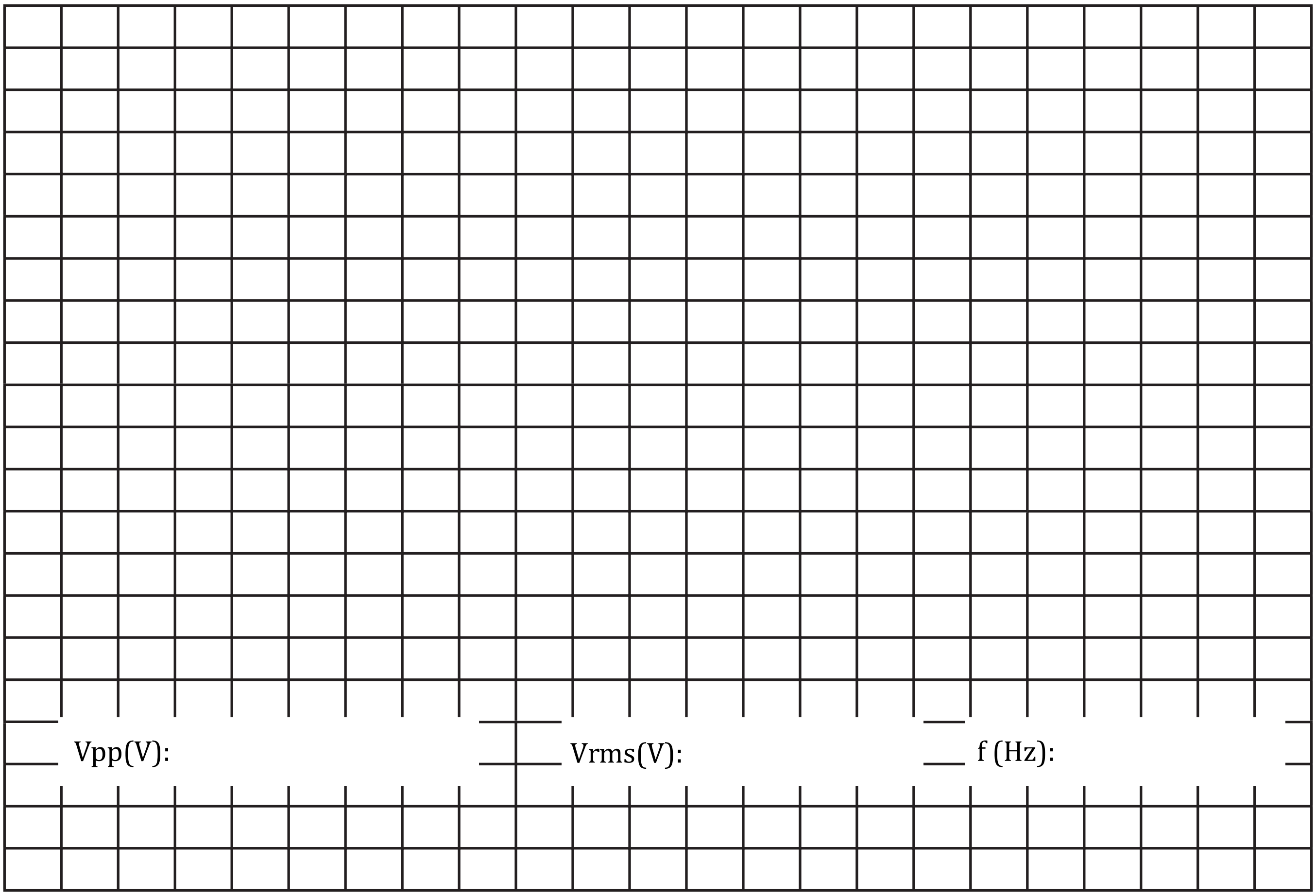
7) Double click the DAQ Assistant icon and apply the settings shown in figure-4 on the pop-up screen.



Figure–2

8) Set the power switch placed on the Off-grid Inverter Module to 1.

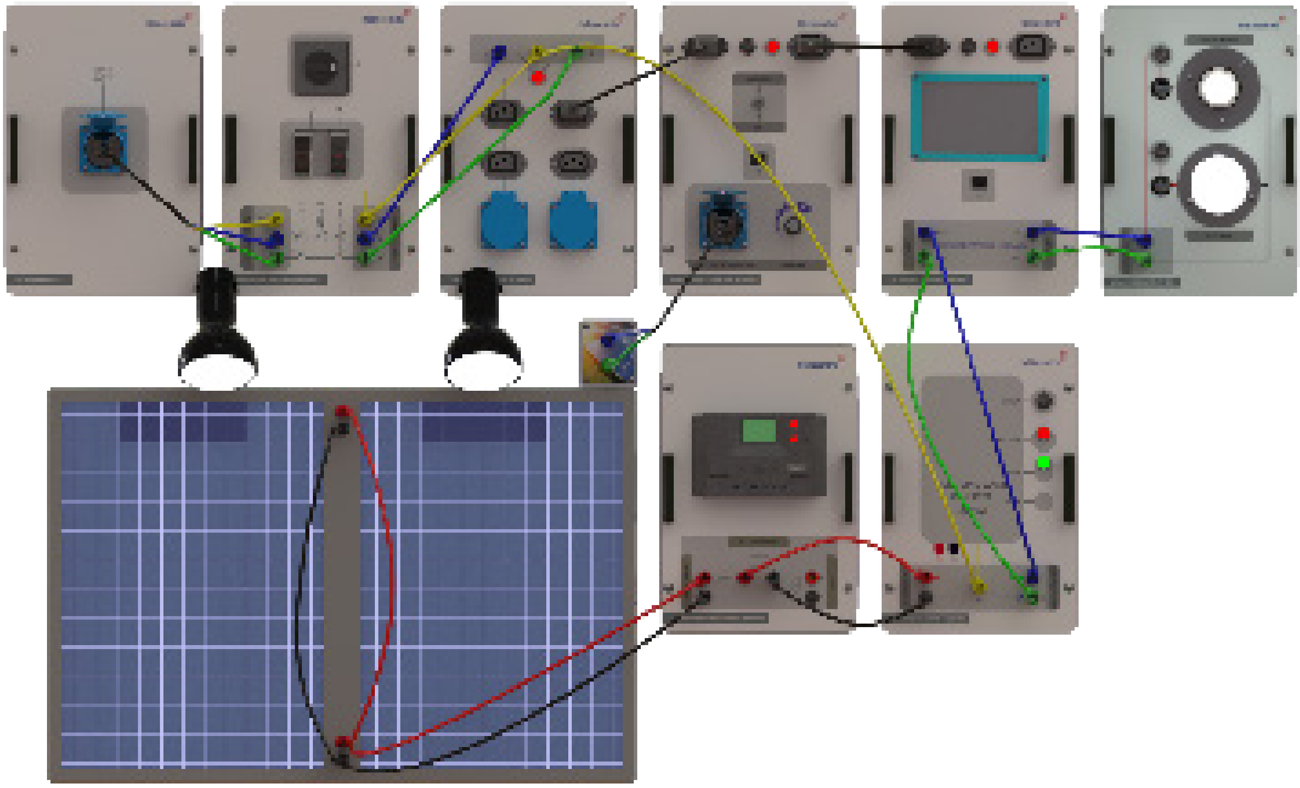
9) Keep an eye on the data observed on the Solar Charge Regulator Module.



Graphic-1

10) If the battery has not been sufficiently charged, allow some time for it to charge. Once the battery has been sufficiently charged, set the power switch placed on the Off-grid Inverter Module to 1.
11) The green LED placed next to the POWER switch on the Off-Grid Inverter Module must be on. If the red one is on and there is an audible warning, this indicates that the battery has been insufficiently charged. In this case, it is necessary to turn off the inverter to charge the battery.
12) Having clicked RUN on LabView, observe the Off-Grid inverter output signal. Draw the signal figures in Graphic-1. Measure and record the Vpp and Vrms and frequency values that correspond to the signal.

2.2.6. Measuring the OFF_GRID Inverter Output Signal By Using an Energy Analyzer



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a maximum.
4) Set the power switch placed on the Off-grid Inverter Module to 0. Keep an eye on the data observed on the Solar Charge Regulator Module.
5) If the battery has not been sufficiently charged, allow some time for it to charge. Once the battery has been sufficiently charged, set the power switch placed on the Off-grid Inverter Module to 1.
6) The green LED placed next to the POWER switch on the Off-Grid Inverter Module must be on. If the red one is on and there is an audible warning, this indicates that the battery has been insufficiently charged. In this case, it is necessary to turn off the inverter to charge the battery.

7) Having set the LED Lamp and Halogen Lamp switches on Lamp Module to 1, load the system.

8) Read the inverter output voltage (L1), frequency (f) and load current (I1) values on AC Energy Analyzer Module and record these in chart-1.

AC Energy Analyzer Data		
L1 (V)	I1 (A)	f (Hz)

Chart-1

9) Examine the other parameters measured by the energy analyzer.

10) Based on the measurement results, calculate the value of power obtained through the inverter output.

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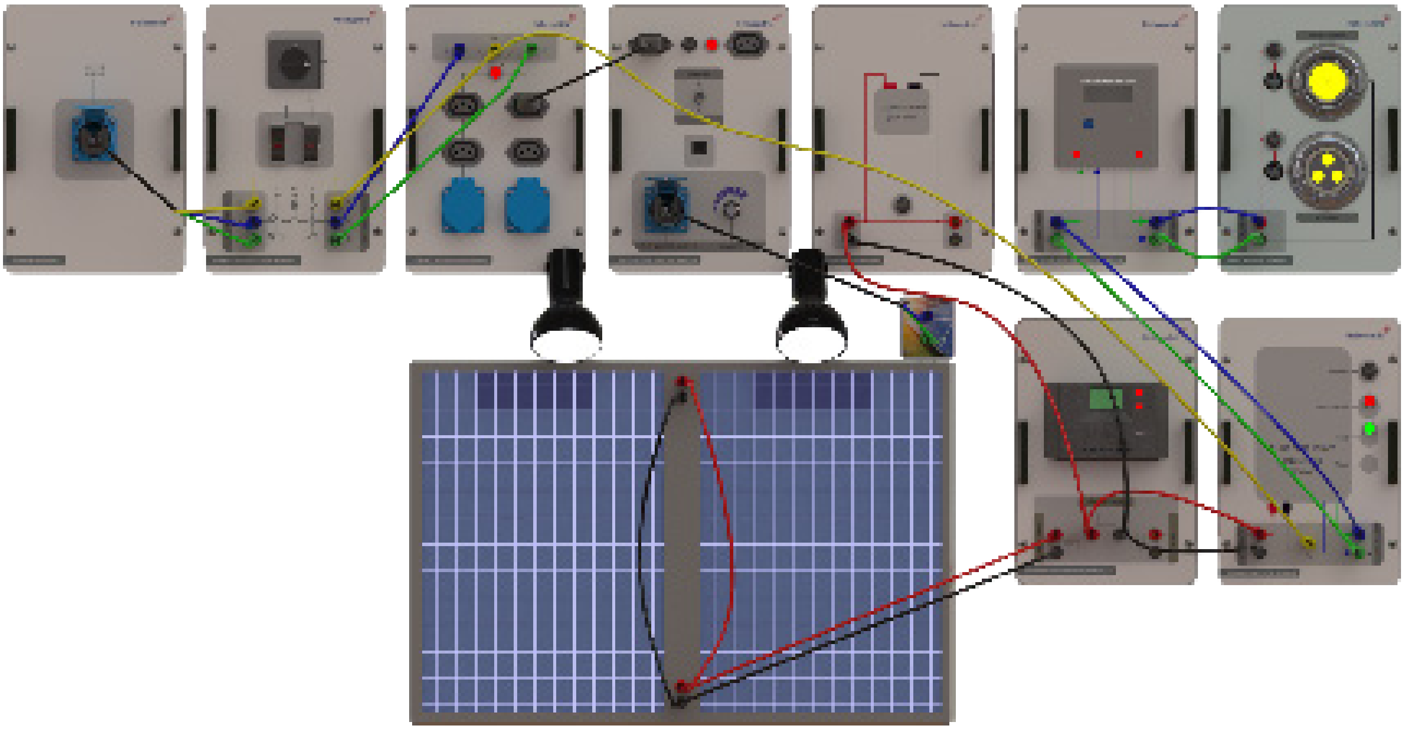
2.2.7. Measuring the Energy Received from the OFF_ GRID Inverter



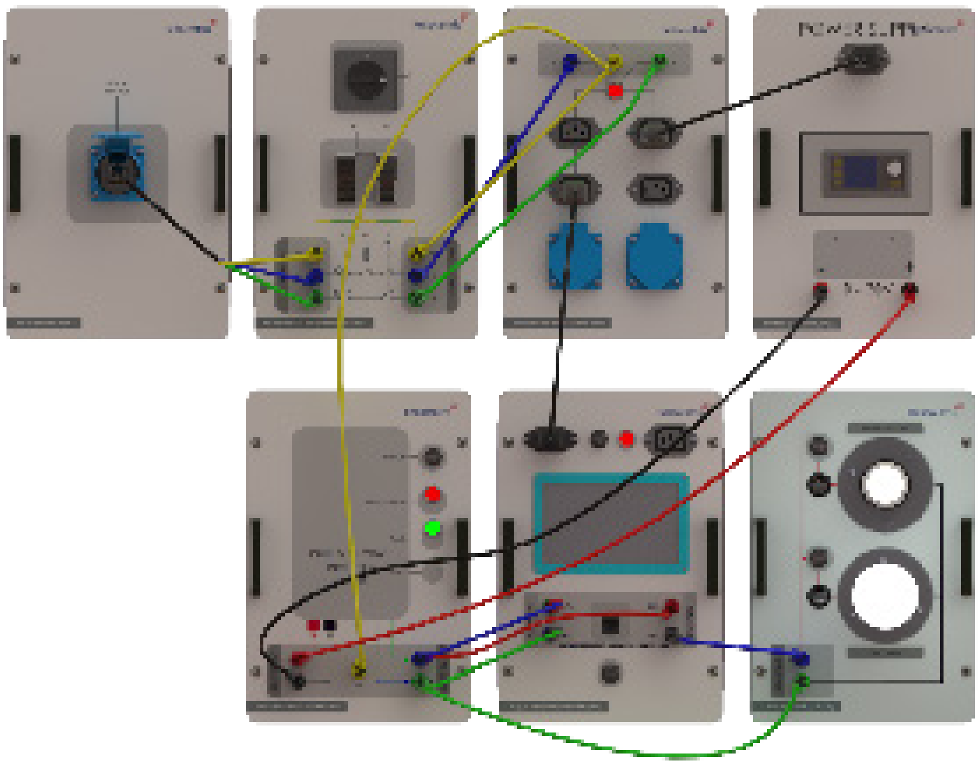
Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a maximum.
4) Set the power switch placed on the Off-grid Inverter Module to 0.
5) Keep an eye on the data observed on the Solar Charge Regulator Module.
6) If the battery has not been sufficiently charged, allow some time for it to charge. Once the battery has been sufficiently charged, set the power switch placed on the Off-grid Inverter Module to 1.
7) The green LED placed next to the POWER switch on the Off-Grid Inverter Module must be on. If the red one is on and there is an audible warning, this indicates that the battery has been insufficiently charged. In this case, it is necessary to turn off the inverter to charge the battery. If the battery has not been sufficiently charged, the inverter will cut the output without being able to make the energy measurement.
8) Having set both switches on Lamp Module (220V AC) to 1, load the system.

9) Use the Electronic Electricity Meter Module to observe the amount of energy used.

(NB: The aggregate power of these two lamps is 40W, which means that an hour-long energy consumption will be 40Wh. It is necessary to run the system for a long time to be able to observe the changes in the meter. This may not be possible in a laboratory setting, but energy measurement is a significant issue for industrial systems.)

2.2.8. Measuring the OFF_GRID Inverter Output Power and Efficiency



Figure–1

1) The inverter output power is 300W, which means that when there is maximum power the inverter output:

$I_O = \frac{P_O}{E_O} = \frac{300}{220} = 1{,}36\,A$ (the current to be drawn from the inverter output for maximum power)

The current to be drawn (assuming that there is 100% efficiency) from the battery output (on the inverter input will be

$I_i = \frac{E_O}{E_i} x I_O = \frac{220}{12} x1{,}36 = 24{,}93\,A$ Considering that there cannot be 100% efficiency, the amount of current will be even higher. Because there is no battery on the training set which can supply this amount of current, instead of a battery, a power-supply source that can supply 5A worth of output current will be used in the experiment and the output power, as well as the efficiency, will be measured according to this particular circumstance. (NB: If you have access to a battery or a power-supply source which can supply 50A worth of current, you can conduct the experiment with maximum power.

2) Connect as shown in figure-1. Set the switched on Lamp Module to 0. (No-load)

3) Set the inverter power switch to 0. In a no-load operation, measure the amount of current (Iioff) drawn by the inverter while the inverter output is not active (the current drawn from the power-supply source), and then record your findings in chart-1.

4) Set the inverter power switch to 1. In a no-load operation, measure the amount of current (Iioff) drawn by the inverter while the inverter output is active (the current drawn from the power-supply source), and then record your findings in chart-1.

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İnverter off	İnverter on
(Iioff)	(Iion)

Chart-1

5) Study the chart and observe that, even if it is off, the inverter draws current from the battery as long as it is connected to the system. The value of this current increases when the inverter is loaded.
6) Set the switches on Lamp Module to 1 while the inverter power switch is set to 1. (Load the system.)
7) Measure the amount of DC current drawn by the inverter input (IiDC) and the amount of AC current drawn by the inverter output (Io), and record your findings in Chart-2.

(IiDC)	(IoAC)

Chart-2

8) Use the values given in chart-2 to calculate the inverter input and output power. Record your calculations in chart-3.

$$P_{iDC} = I_{iDC} x V_{iDC} = 3{,}86x12 = 46{,}32 watt$$

$$P_{oAC} = I_{oAC} x V_{oAC} = 0{,}175x220 = 38{,}8 watt$$

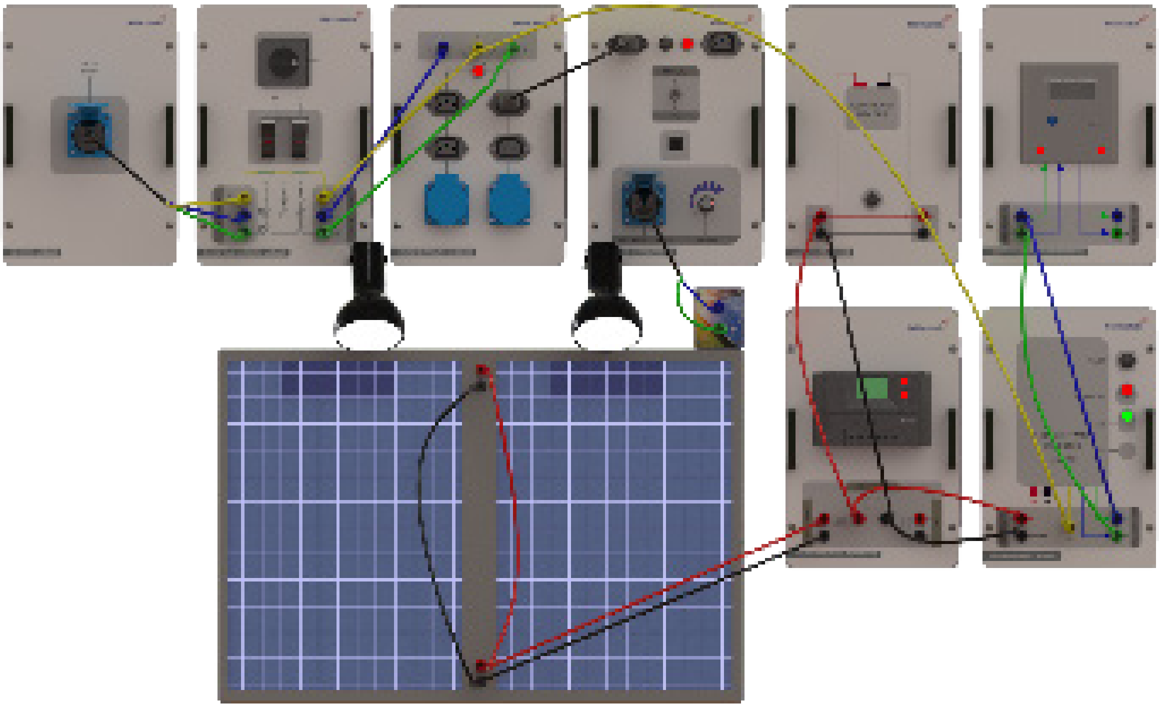
P_{iDC}	P_{oAC}	$verim = \frac{P_{oAC}}{P_{iDC}} x100$
46,32W	38,8W	%83,76

Chat-3

9) Use the values given in chart-3 to calculate the efficiency value. Record your calculations in chart-3.

$$verim = \frac{P_{oAC}}{P_{iDC}} x100 = \frac{38{,}8}{46{,}32} x100 = 83{,}76\%$$

2.2.9. OFF_GRID Inverter SCADA Application



Figure–1

1) Prepare the experimental setup in fig.1. SCADA, short for Supervisory Control And Data Acquisition, is a system which allows the central monitoring of large-scale facilities through a computer, mobile phone, or a tablet. In this experiment, the output voltage of the off-grid inverter will be monitored through RS485-Modbus port, using a remote computer connection.

2) Install the software “sayac_okuma_v5.4.exe” (“meter_reading_v5.4.exe”) on your computer to conduct the experiment.

3) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.

4) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a maximum.

5) Set the power switch placed on the Off-grid Inverter Module to 0.

6) Keep an eye on the data observed on the Solar Charge Regulator Module.

7) If the battery has not been sufficiently charged, allow some time for it to charge. Once the battery has been sufficiently charged, set the power switch placed on the Off-grid Inverter Module to 1.

8) The green LED placed next to the POWER switch on the Off-Grid Inverter Module must be on. If the red one is on and there is an audible warning, this indicates that the battery has been insufficiently charged. In this case, it is necessary to turn off the inverter to charge the battery. If the battery has not been sufficiently charged, the inverter will cut the output without being able to make the energy measurement.

9) Run the Elektromed meter reading software. Apply the necessary COMPORT settings on the “SETTINGS AND STORAGE” tab (Figure-2).

(NB: Use a suitable RS485/USB or RS485/RS232 convertor to set up a connection between your computer and the Electronic Electricity Module.)

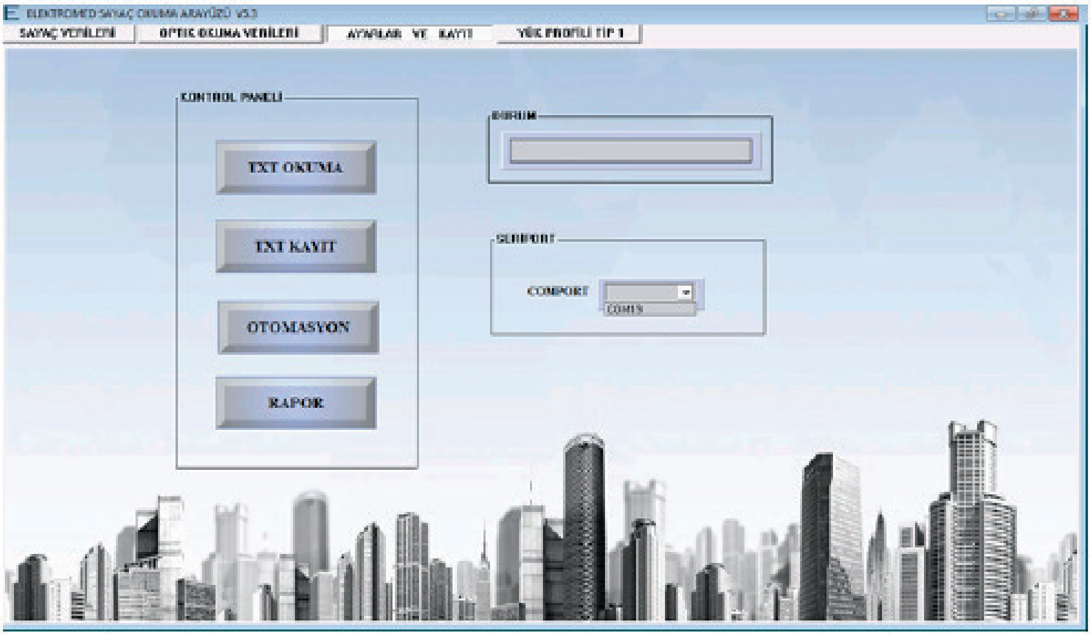


Figure-2

10) Having completed the COMPORT settings, go to the “METER DATA” and use the command READOUT to access the meter data. (Figure-3)

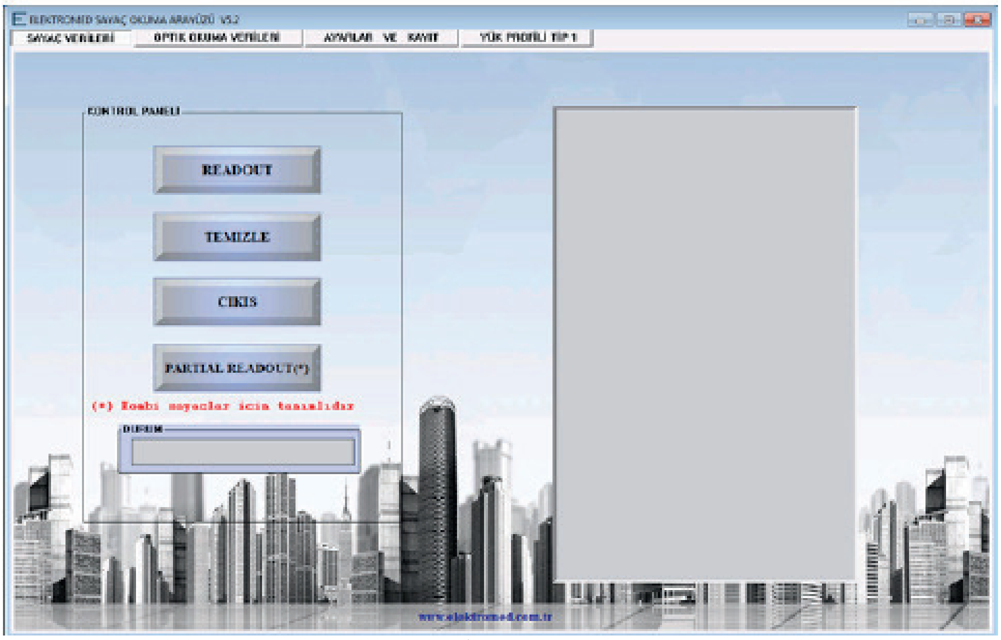


Figure-3

11) Remote access to all the data stored by the meter is made possible by the software. Use the relevant tab for remote access. (Figure-4)

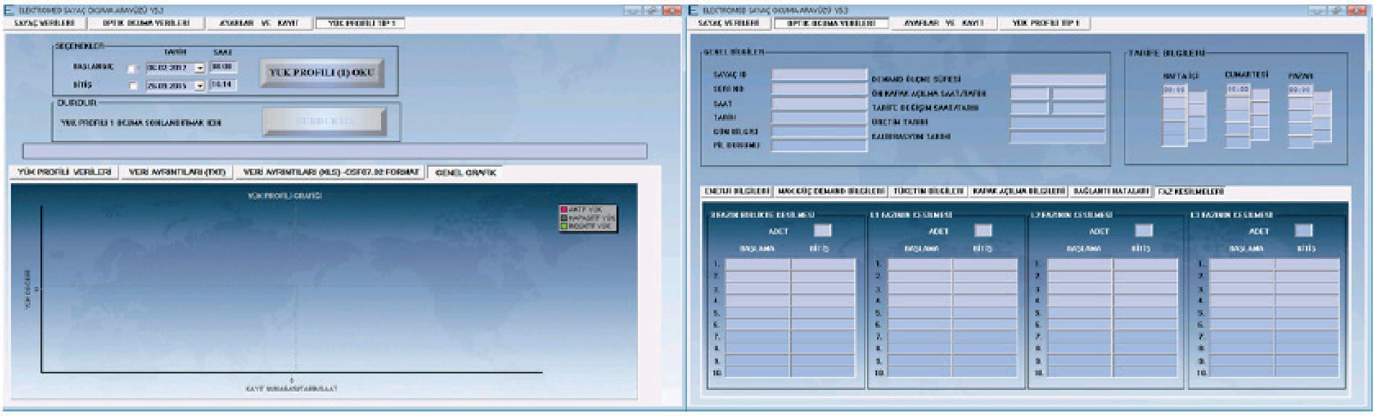
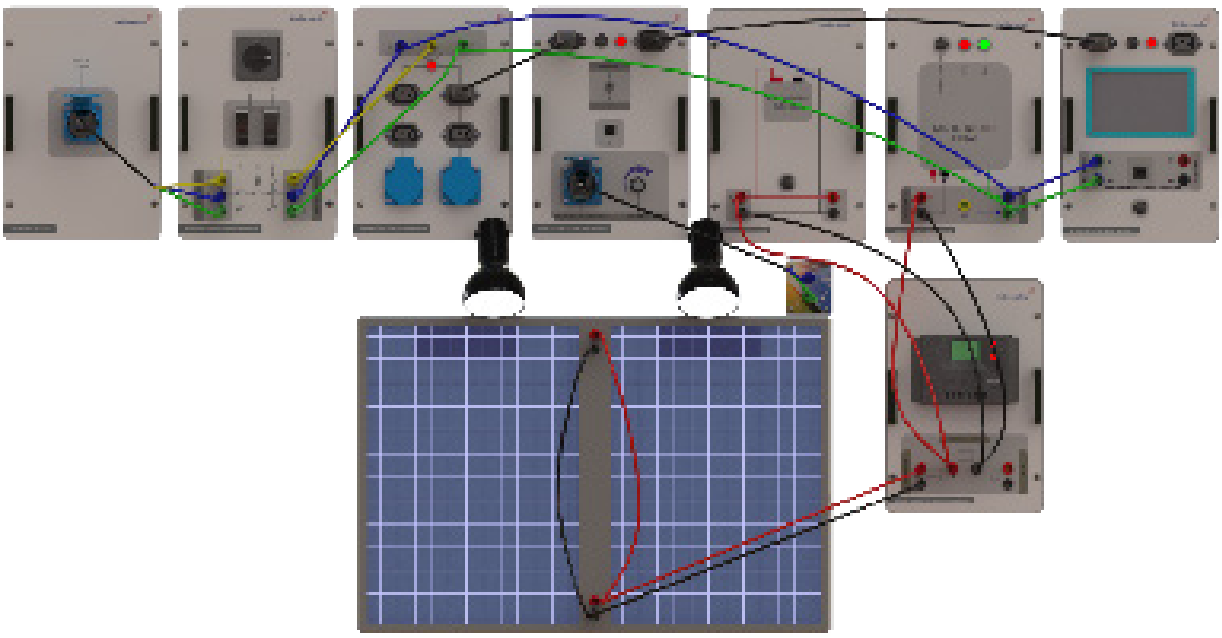


Figure-4

2.2.10. Examining the ON_GRID Inverter



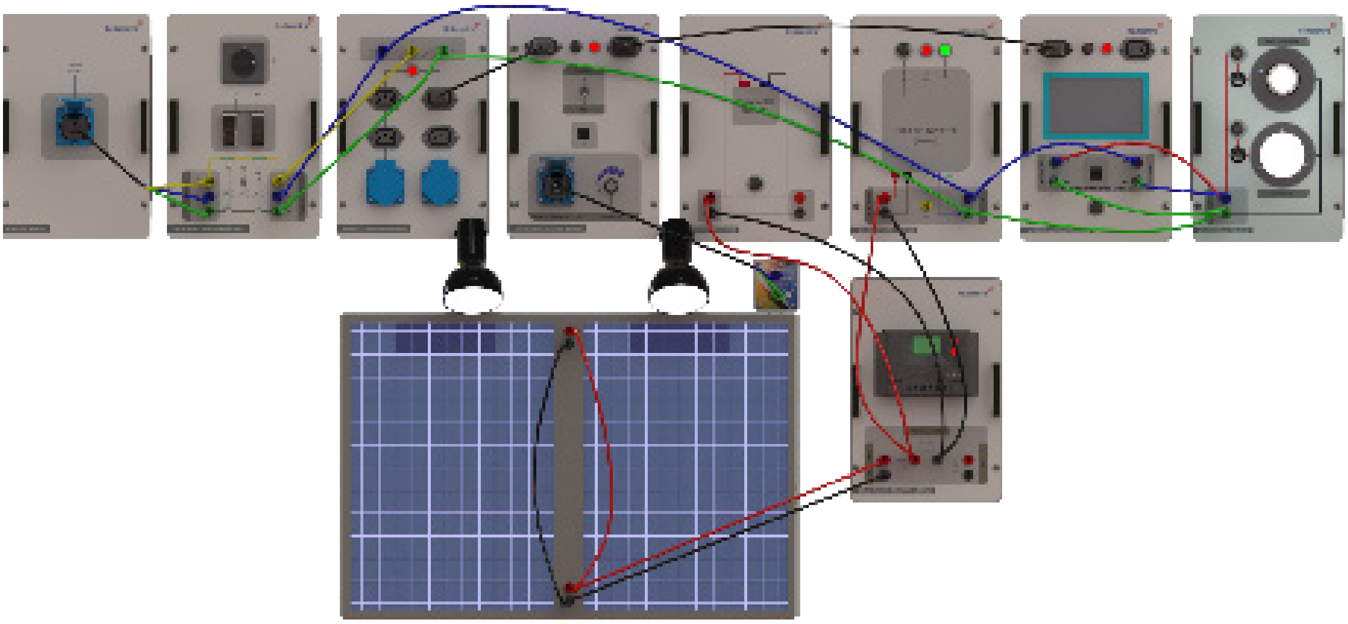
Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the quantity of light in the laboratory at a medium. Changing the position of the lamp or the curtains will affect the results of the experiment.
2) Photovoltaic Panel – Set the incidence of light to 90° on the Light Source Module. Pull the pins on the module to allow the necessary adjustments, and then put the pins back on the module.
3) Use the DIMMER potentiometer on the Light Source Control Module to set the light intensity to a maximum.
4) Record in chart-1 the value observed on the voltmeter AC/DC Measurement Module
5) Record in chart-1 the value (Vo1) observed on the voltmeter placed on the ON-GRID Inverter Module output. Notice that the mains voltage is not applied to the system.

Vo1 (Volt)	Vo2 (Volt)

Chart-1

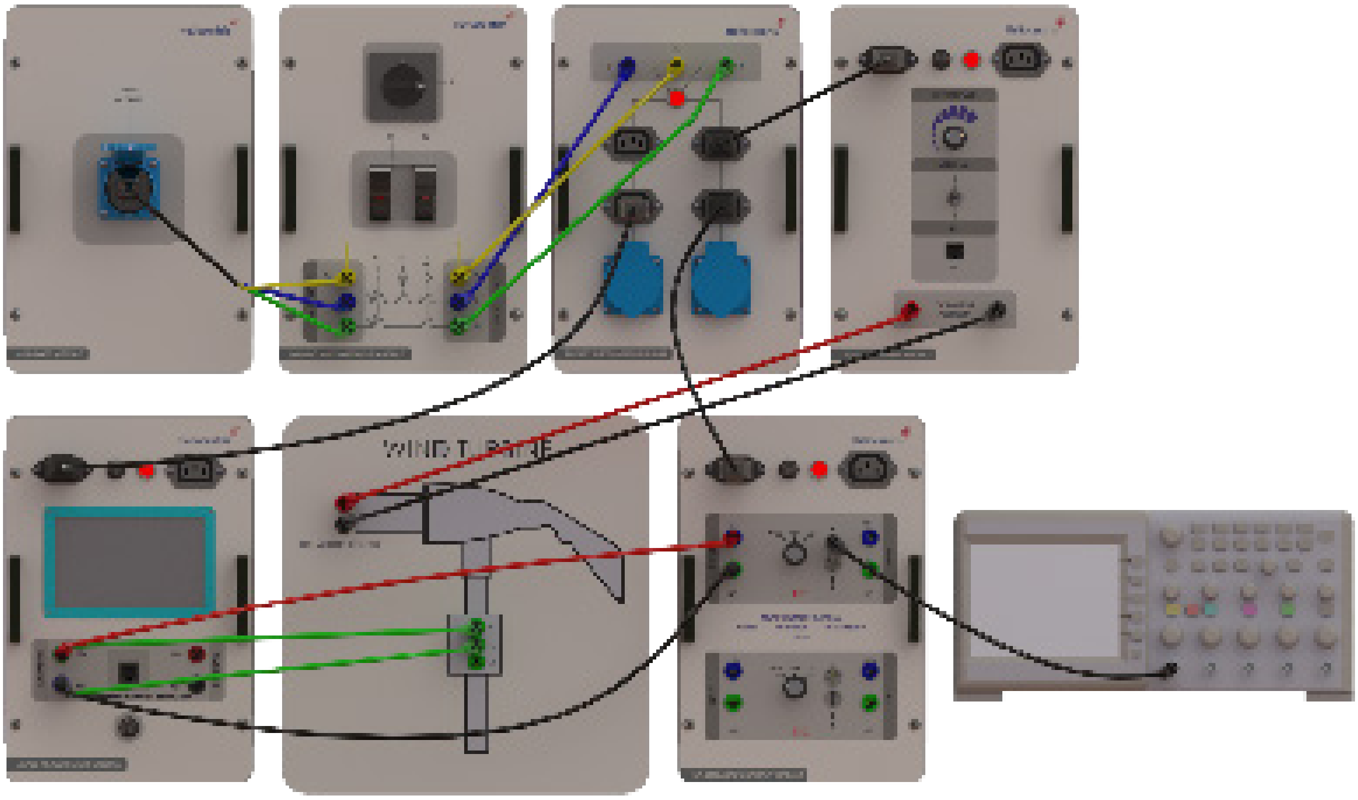
6) Connect as shown in figure-1. Notice that the mains voltage is applied to the system. (ON GRID)



Figure–2

3. WIND ENERGY EXPERIMENTS

3.1. Examining the Relation Between Turbine Speed and Turbine Output Voltage (No Load Operation)



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the wind turbine by locking its legs.

2) Set the key on Wind Simulator Module at MANUAL. Set the SPEED potentiometer at minimum (SPEED Minimum). The wind turbine is a 3 pahse (1 pole couple per phase) permanent magnet AC synchronised generator. It generates 60 V AC at maximum speed.(between to phase)

3) Record the value in chart-1 as seen in the voltmeter.

4) Gradually increase the wind speed with the SPEED potentiometer and set to level 1. Calculate the wind speed using this equation n= 60.f/2P

n= rotational speed (rpm)

f= frequency (Hz)

2P =Number of pole couple is 1

Record generator speed as rpm in chart-1. (SPEED 1)

5) Gradually increase the wind speed with the SPEED potentiometer and set to level 2. Record the wind speed in chart-1. (SPEED 2).

	SPEED MİN.	SPEED 1	SPEED 2	SPEED 3	SPEED 4	SPEED 5	SPEED 6	SPEED 7	SPEED 8	SPEED MAX.
Generator Output Voltage										
Generator speed(rpm)										

Chart-1

6) Gradually increase the wind speed with the SPEED potentiometer and set to level 3. Record the wind speed in chart-1. (SPEED 3).

7) Gradually increase the wind speed with the SPEED potentiometer and set to level 4. Record the wind speed in chart-1. (SPEED 4).

8) Gradually increase the wind speed with the SPEED potentiometer and set to level 5. Record the wind speed in chart-1. (SPEED 5).

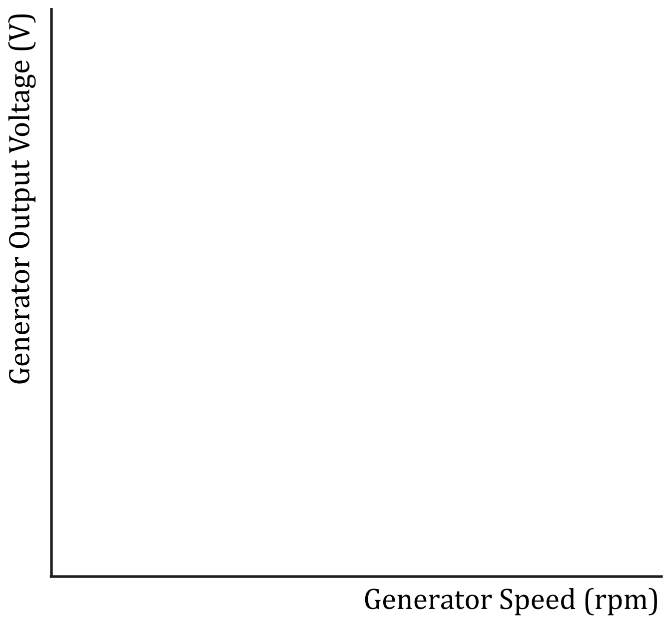
9) Gradually increase the wind speed with the SPEED potentiometer and set to level 6. Record the wind speed in chart-1. (SPEED 6).

10) Gradually increase the wind speed with the SPEED potentiometer and set to level 7. Record the wind speed in chart-1. (SPEED 7).

11) Gradually increase the wind speed with the SPEED potentiometer and set to level 8. Record the wind speed in chart-1. (SPEED 8).

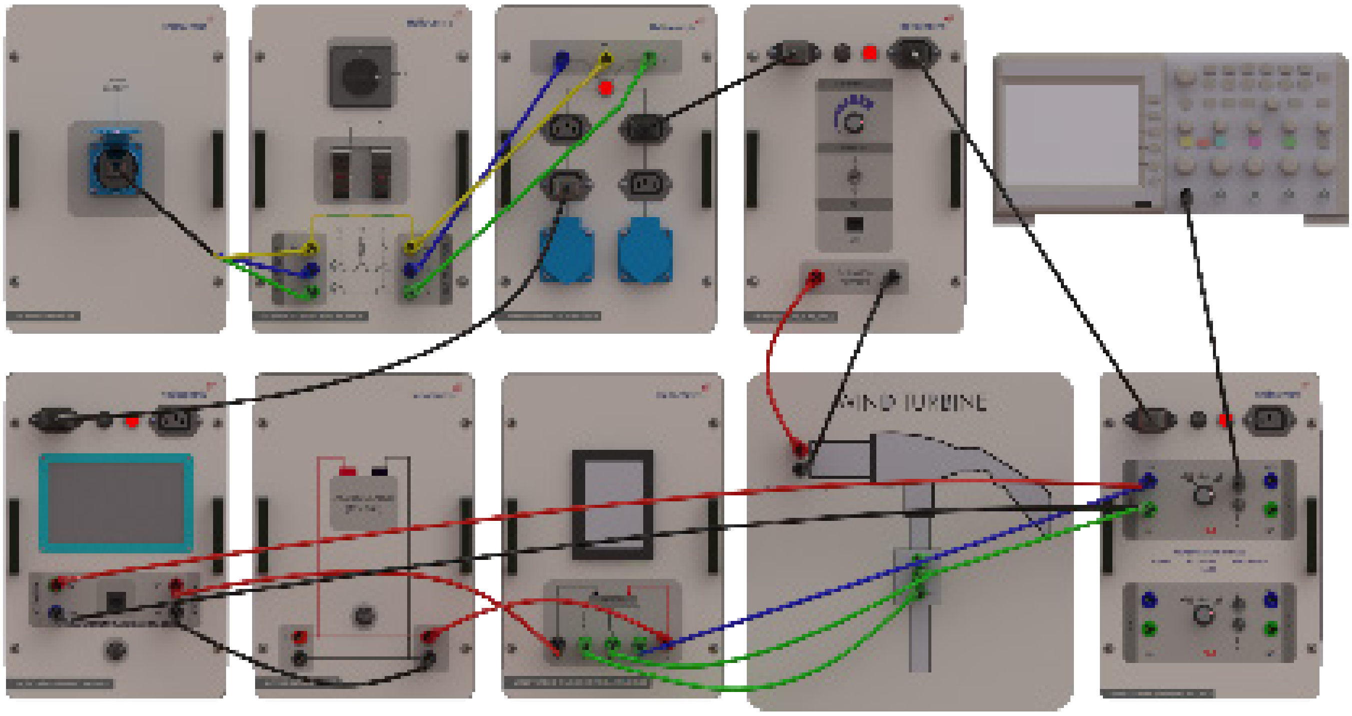
12) Set the SPEED potentiometer at maximum wind speed level and observe the output voltage.

13) Draw generator output voltage and generator speed graph. (Please note that: Wind turbine charge controller is for 2 voltage level (15 V and 30 V))



Graph 1

3.2. Examining Wind Turbine Controller Effect on the Relation Between Turbine Speed and Turbine Output Voltage (No Load Operation)



Figure–2

1) Prepare the experimental setup in fig.2. Stabilize the wind turbine by locking its legs.

2) Set the key on Wind Simulator Module at MANUAL. Set the SPEED potentiometer at minimum (SPEED Minimum). The wind turbine is a 3 pahse (1 pole couple per phase) permanent magnet AC synchronised generator. It generates 60 V AC at maximum speed.(between to phase)

3) Record the value in chart-1 as seen in the voltmeter.

4) Gradually increase the wind speed with the SPEED potentiometer and set to level 1. Calculate the wind speed using this equation n= 60.f

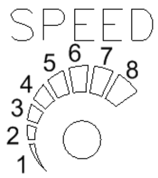
n= rotational speed (rpm)

f= frequency (Hz)

2P =Number of pole couple is 1

Record generator speed as rpm in chart-1. (SPEED 1)

5) Gradually increase the wind speed with the SPEED potentiometer and set to level 2. Record the wind speed in chart-1. (SPEED 2).



	SPEED MİN.	SPEED 1	SPEED 2	SPEED 3	SPEED 4	SPEED 5	SPEED 6	SPEED 7	SPEED 8	SPEED MAX.
Generator Output Voltage										
Generator speed(rpm)										

Chart-1

6) Gradually increase the wind speed with the SPEED potentiometer and set to level 3. Record the wind speed in chart-1. (SPEED 3).

7) Gradually increase the wind speed with the SPEED potentiometer and set to level 4. Record the wind speed in chart-1. (SPEED 4).

8) Gradually increase the wind speed with the SPEED potentiometer and set to level 5. Record the wind speed in chart-1. (SPEED 5).

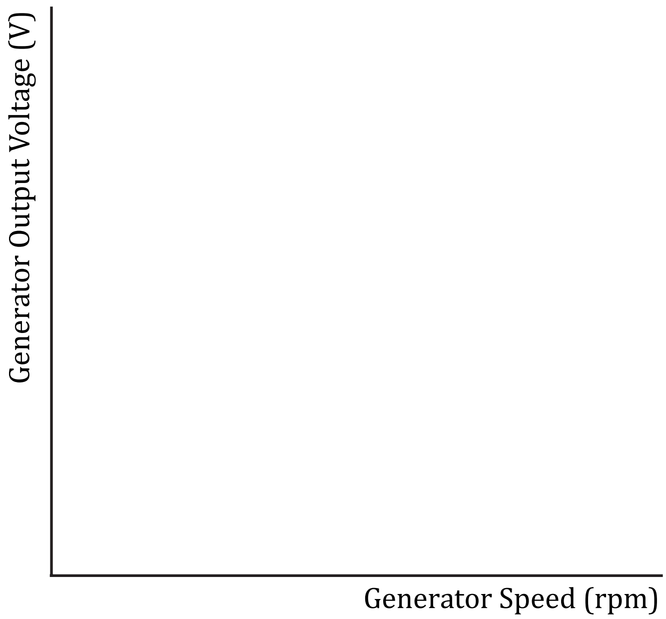
9) Gradually increase the wind speed with the SPEED potentiometer and set to level 6. Record the wind speed in chart-1. (SPEED 6).

10) Gradually increase the wind speed with the SPEED potentiometer and set to level 7. Record the wind speed in chart-1. (SPEED 7).

11) Gradually increase the wind speed with the SPEED potentiometer and set to level 8. Record the wind speed in chart-1. (SPEED 8).

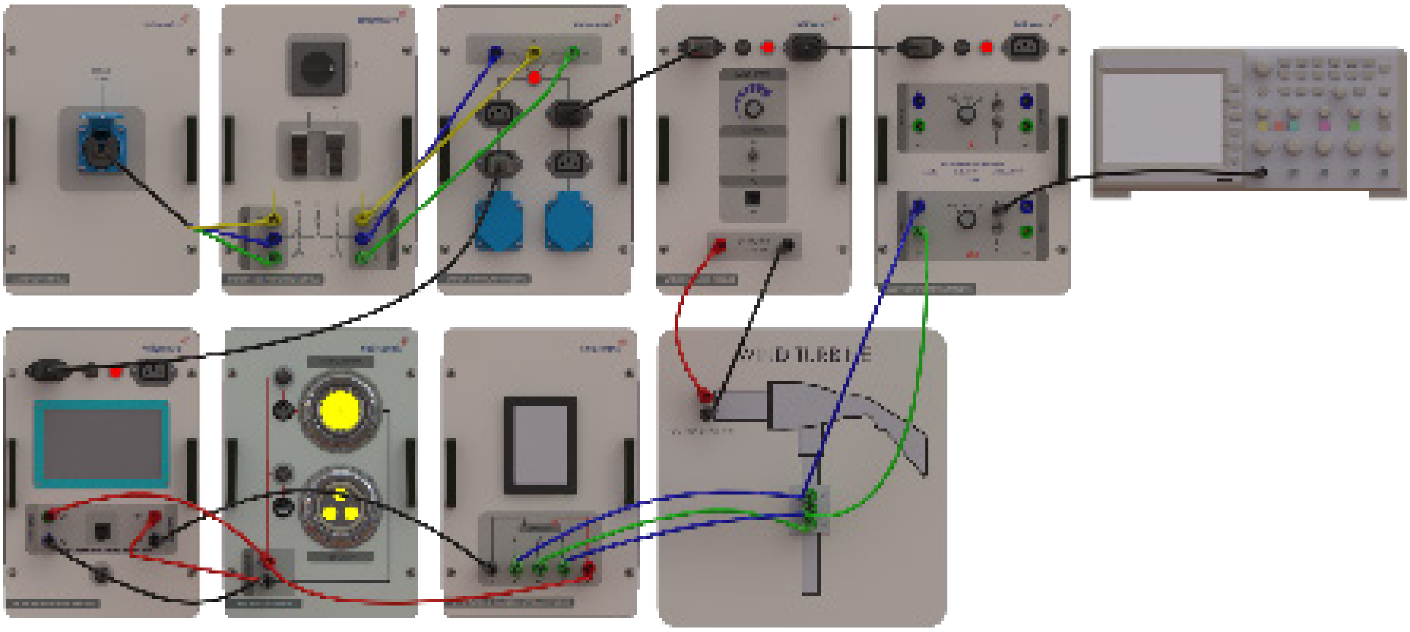
12) Set the SPEED potentiometer at maximum wind speed level and observe the output voltage.

13) Draw generator output voltage and generator speed graph.(Please note that: Wind turbine charge controller is for 2 voltage level (15 V and 30 V))



Graph 2

3.3. Examining the Relation Between Turbine Speed and Turbine



Figure–1

1) Prepare the experimental setup in fig.1. Stabilize the wind turbine by locking its legs.

2) Set the key on Wind Simulator Module at MANUAL. Set the SPEED potentiometer at minimum (SPEED Minimum). The wind turbine is a 3 pahse (1 pole couple per phase) permanent magnet AC synchronised generator. It generates 60 V AC at maximum speed.(between to phase)

3) Record the value in chart-1 as seen in the voltmeter.

4) Gradually increase the wind speed with the SPEED potentiometer and set to level 1. Calculate the wind speed using this equation n= 60.f

n= rotational speed (rpm)

f= frequency (Hz)

2P =Number of pole couple is 1

Record generator speed as rpm in chart-1. (SPEED 1)

5) Gradually increase the wind speed with the SPEED potentiometer and set to level 2. Record the wind speed in chart-1. (SPEED 2).

6) Gradually increase the wind speed with the SPEED potentiometer and set to level 2. Record the wind speed in chart-1. (SPEED 2).

7) Gradually increase the wind speed with the SPEED potentiometer and set to level 3. Record the wind speed in chart-1. (SPEED 3).

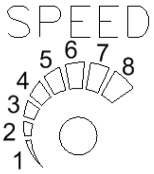
	SPEED MİN.	SPEED 1	SPEED 2	SPEED 3	SPEED 4	SPEED 5	SPEED 6	SPEED 7	SPEED 8	SPEED MAX.
Generator Output Voltage										
Generator speed(rpm)										

Chart-1

8) Gradually increase the wind speed with the SPEED potentiometer and set to level 4. Record the wind speed in chart-1. (SPEED 4).

9) Gradually increase the wind speed with the SPEED potentiometer and set to level 5. Record the wind speed in chart-1. (SPEED 5).

10) Gradually increase the wind speed with the SPEED potentiometer and set to level 6. Record the wind speed in chart-1. (SPEED 6).

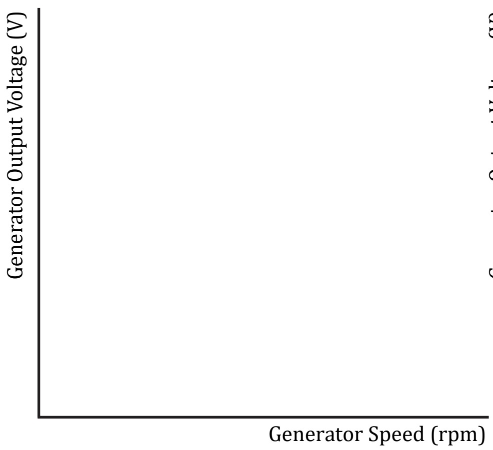
11) Gradually increase the wind speed with the SPEED potentiometer and set to level 7. Record the wind speed in chart-1. (SPEED 7).

12) Gradually increase the wind speed with the SPEED potentiometer and set to level 8. Record the wind speed in chart-1. (SPEED 8).

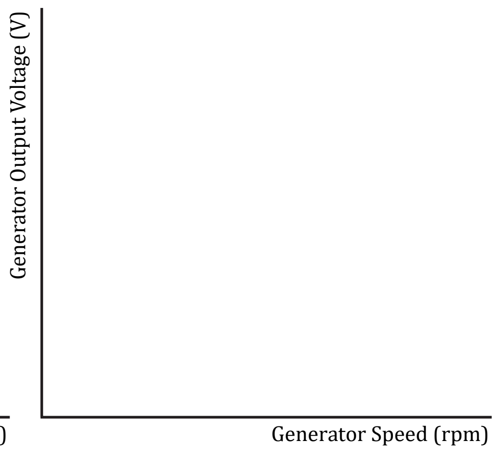
13) Set the SPEED potentiometer at maximum wind speed level and observe the output voltage. (Once the output exceeds 12V, cease operation quickly. Otherwise the led might be damaged!)

14) Compare the output parameters of both loaded and unloaded operations.

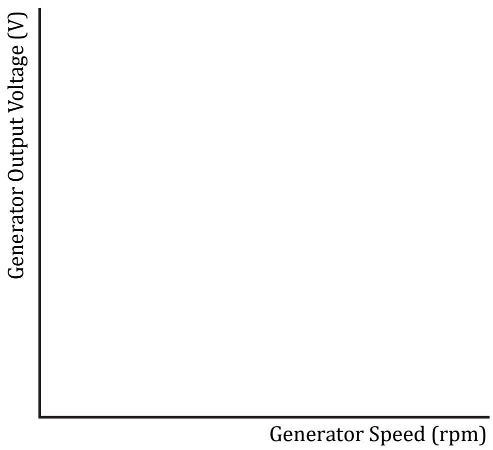
15) Draw generator output voltage , generator speed , current and power graph. (Power should be calculated from chart - 1.)



Graph-1

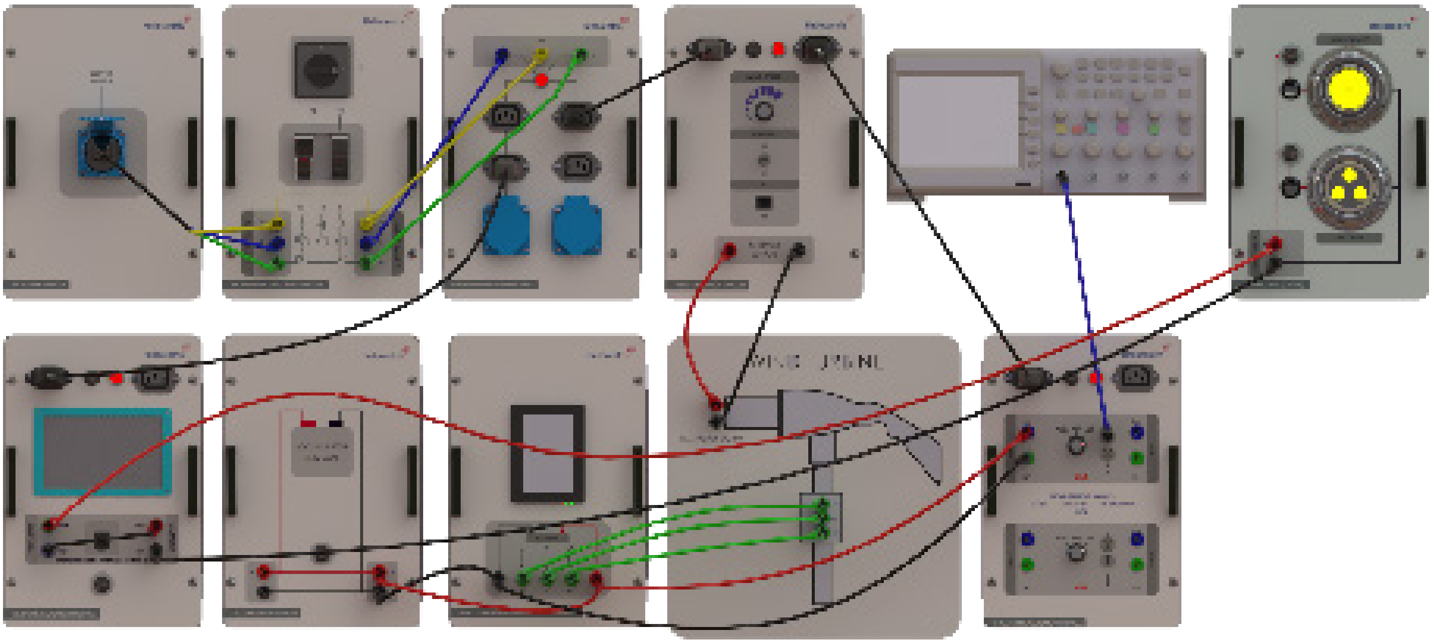


Graph-2



Graph-3

3.4. Examining Wind Turbine Controller Effect on the Relation Between Turbine Speed and Turbine Output Voltage (Loaded Operation)



Figure–2

1) Prepare the experimental setup in fig.2. Stabilize the wind turbine by locking its legs.

2) Set the key on Wind Simulator Module at MANUAL. Set the SPEED potentiometer at minimum (SPEED Minimum). The wind turbine is a 3 pahse (1 pole couple per phase) permanent magnet AC synchronised generator. It generates 60 V AC at maximum speed.(between to phase)

3) Record the value in chart-1 as seen in the voltmeter.

4) Gradually increase the wind speed with the SPEED potentiometer and set to level 1. Calculate the wind speed using this equation n= 60.f

n= rotational speed (rpm)

f= frequency (Hz)

2P =Number of pole couple is 1

Record generator speed as rpm in chart-1. (SPEED 1)

5) Gradually increase the wind speed with the SPEED potentiometer and set to level 2. Record the wind speed in chart-1. (SPEED 2).

6) Gradually increase the wind speed with the SPEED potentiometer and set to level 2. Record the wind speed in chart-1. (SPEED 2).

7) Gradually increase the wind speed with the SPEED potentiometer and set to level 3. Record the wind speed in chart-1. (SPEED 3).

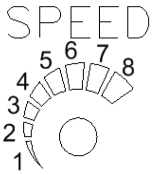
	SPEED MİN.	SPEED 1	SPEED 2	SPEED 3	SPEED 4	SPEED 5	SPEED 6	SPEED 7	SPEED 8	SPEED MAX.
Generator Output Voltage										
Generator speed(rpm)										

Chart-1

8) Gradually increase the wind speed with the SPEED potentiometer and set to level 4. Record the wind speed in chart-1. (SPEED 4).

9) Gradually increase the wind speed with the SPEED potentiometer and set to level 5. Record the wind speed in chart-1. (SPEED 5).

10) Gradually increase the wind speed with the SPEED potentiometer and set to level 6. Record the wind speed in chart-1. (SPEED 6).

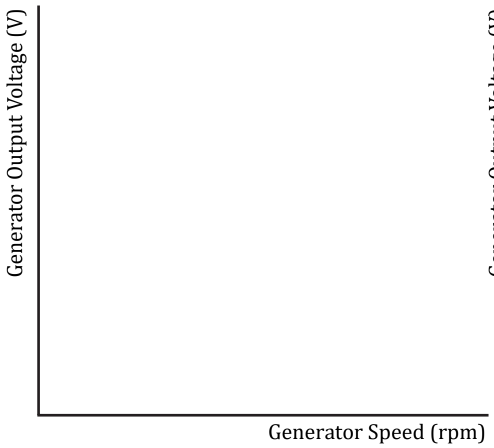
11) Gradually increase the wind speed with the SPEED potentiometer and set to level 7. Record the wind speed in chart-1. (SPEED 7).

12) Gradually increase the wind speed with the SPEED potentiometer and set to level 8. Record the wind speed in chart-1. (SPEED 8).

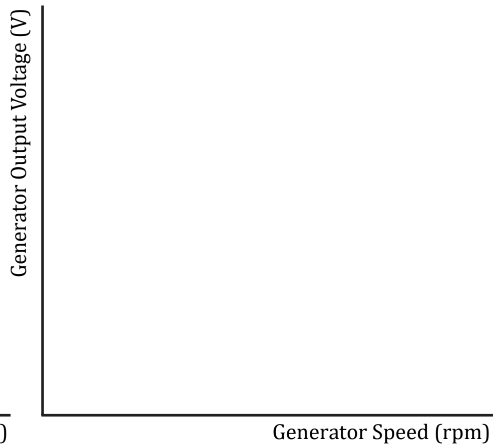
13) Set the SPEED potentiometer at maximum wind speed level and observe the output voltage. (Once the output exceeds 12V, cease operation quickly. Otherwise the led might be damaged!)

14) Compare the output parameters of both loaded and unloaded operations.

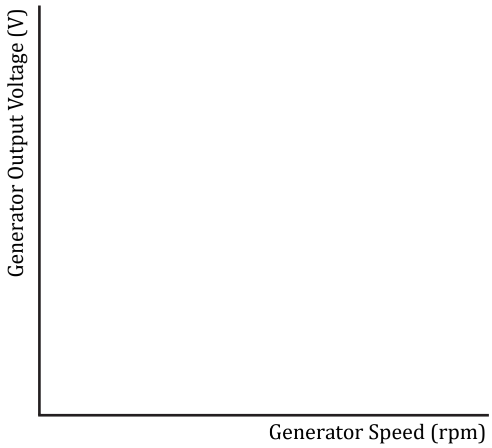
15) Draw generator output voltage , generator speed , current and power graph. (Power should be calculated from chart - 1.)



Graph-1



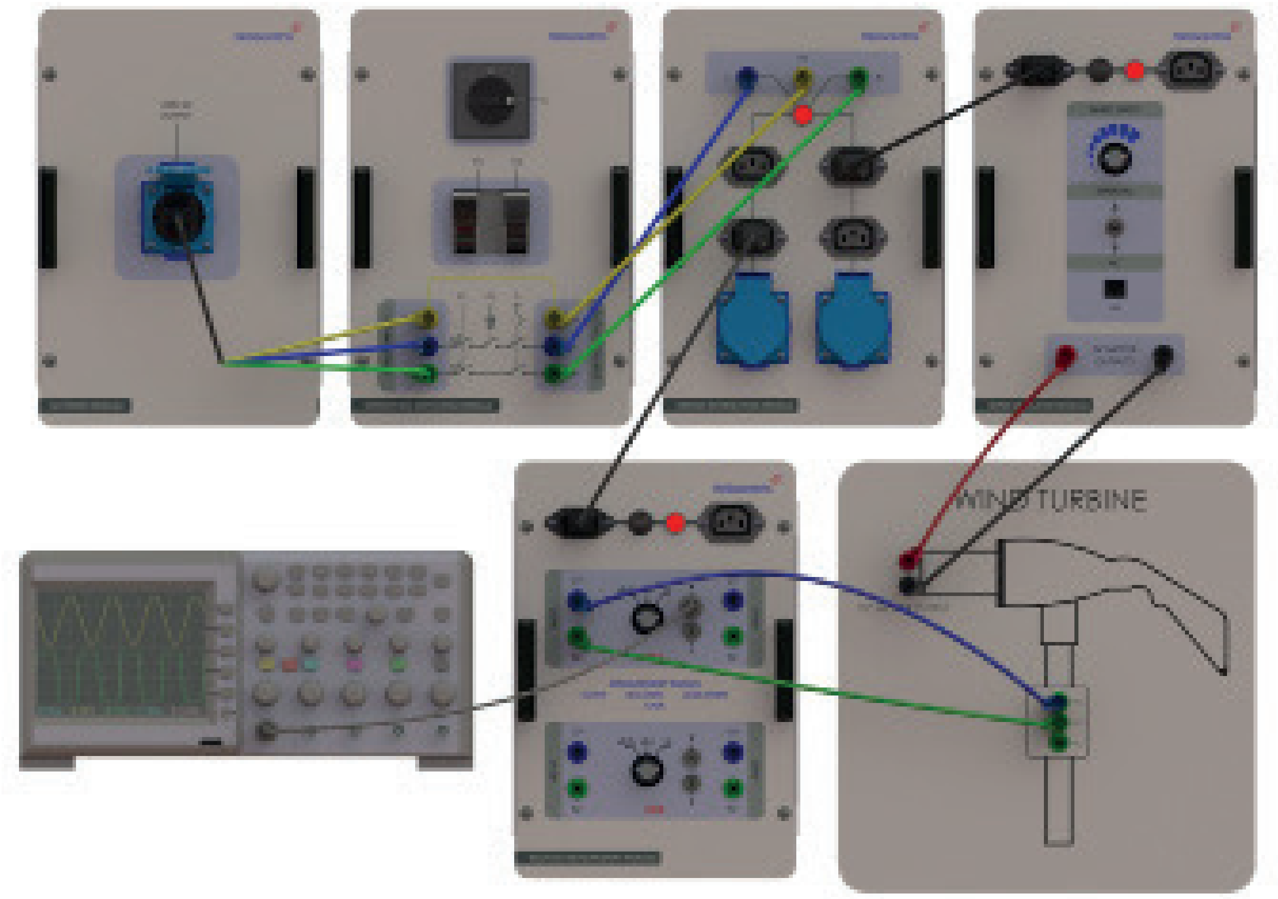
Graph-2



Graph-3

Heliocentris

3.5. Examining the Wind Turbine Output Voltage



Figure–1

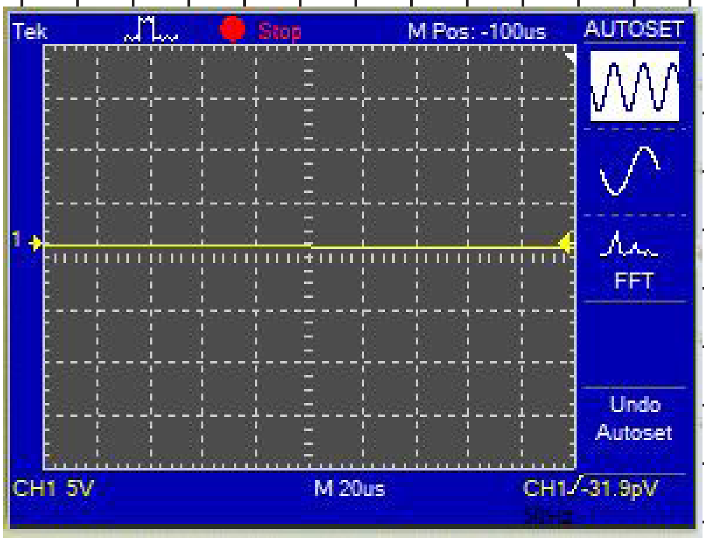
1) Prepare the experimental setup in fig.1. Stabilize the wind turbine by locking its legs.

2) Set the key on Wind Simulator Module at MANUAL. Set the SPEED potentiometer at minimum (SPEED Minimum). The wind turbine is designed to produce 12V for 12m/s wind speed.

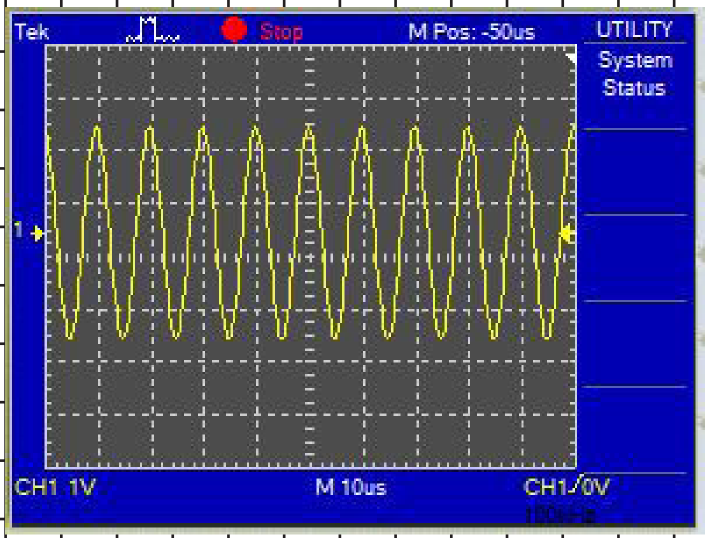
3) Set the commutator of CH1 channel that is on the Isolated Measurement Module at X1. Make the necessary settings for the oscilloscope.

4) Gradually increase the SPEED potentiometer and observe the change in the output signal figures.

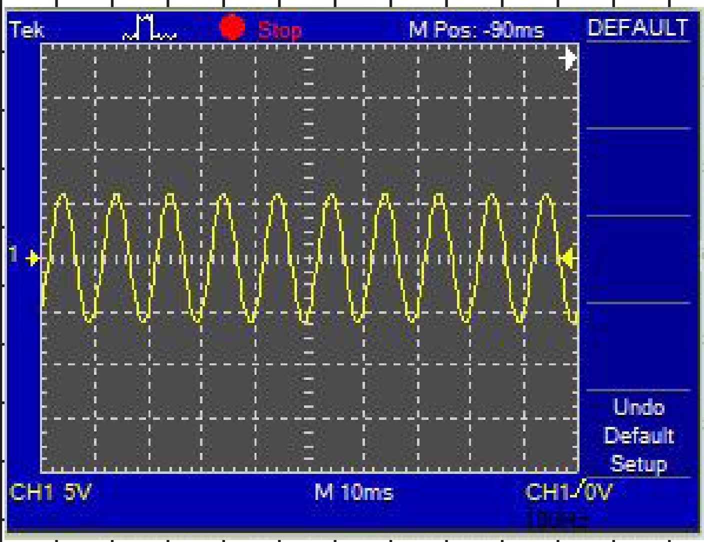
5) Set the SPEED potentiometer at level 6. Draw the signal figures seen on the oscilloscope in Graphic-1.



Signal output with potentiometer at minimum position



Signal output at potentiometer level-6



Signal output at 12 V

Chart-1

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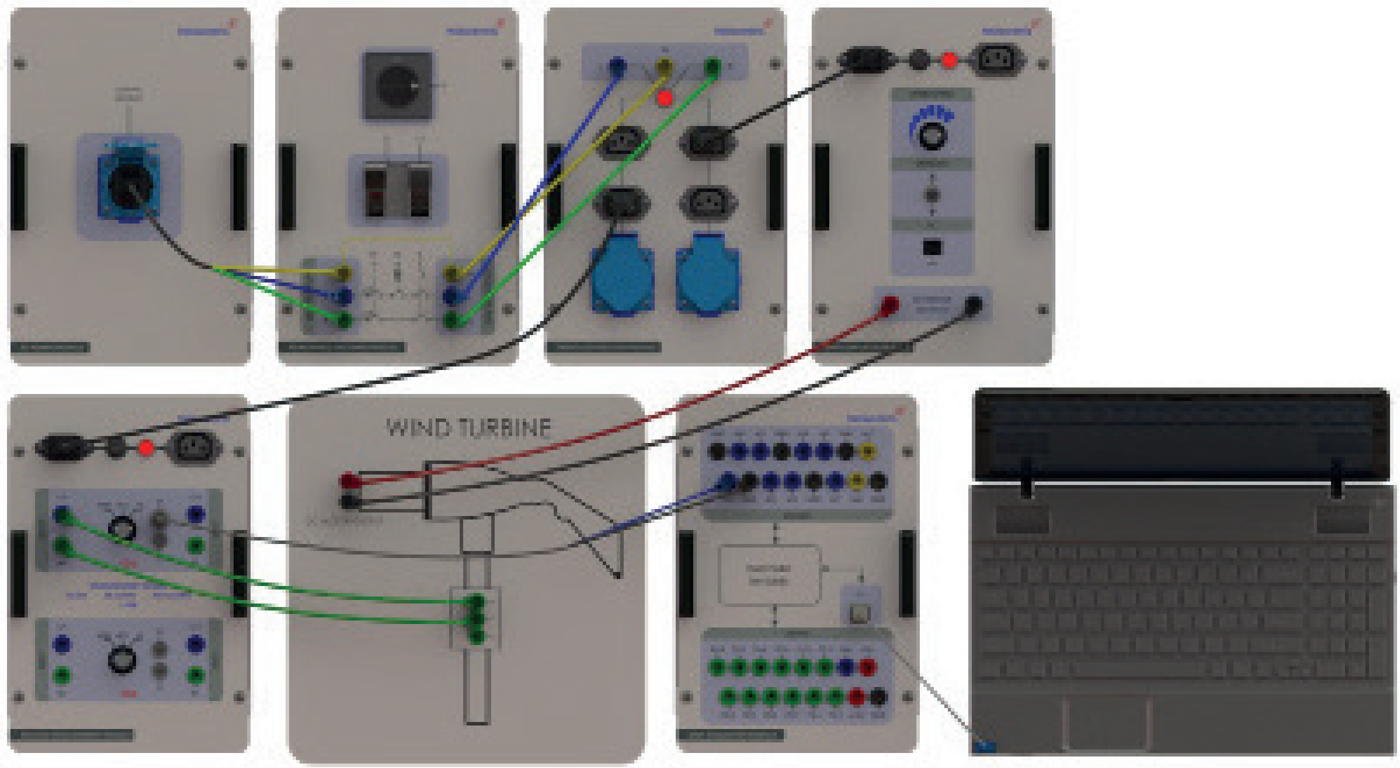
3.6. Examining the Wind Turbine Output Voltage by Using a DAQ Module



Figure–1

1) Connect as shown in figure-1. Stabilize the wind turbine by locking its legs.

2) Set the key on Wind Simulator Module at MANUAL. Set the SPEED potentiometer at minimum (SPEED Minimum). The wind turbine is designed to produce 12V for 12m/s wind speed.

3) Set the commutator of CH1 channel that is on the Isolated Measurement Module at X0.1. Make the necessary settings for the oscilloscope.

4) Make the USB connection between the Data Acquisition Module and the computer.

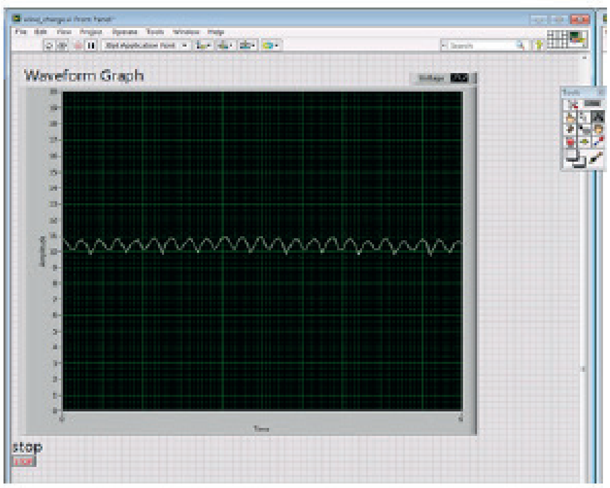


Figure-2

5) By using the LabView software, add a waveform graph to the front panel as shown in Figure-2. Set the time Time-scale at 0.1 seconds.

6) Set the sample circuit on the LabView Block Diagram window as seen in Figure-3.

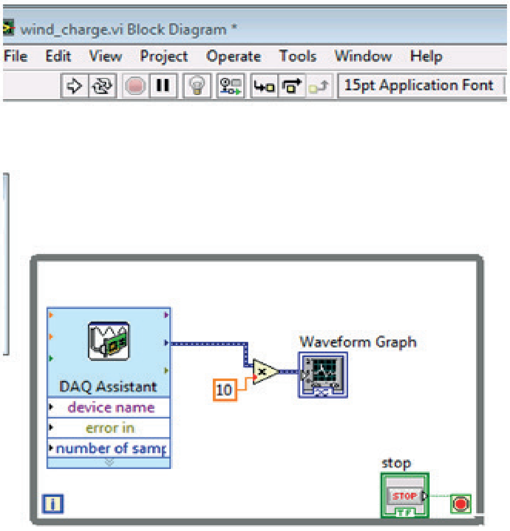


Figure-3

7) Double click on DAQ Assistant icon and make the relevant settings on the window as shown in Figure-4.

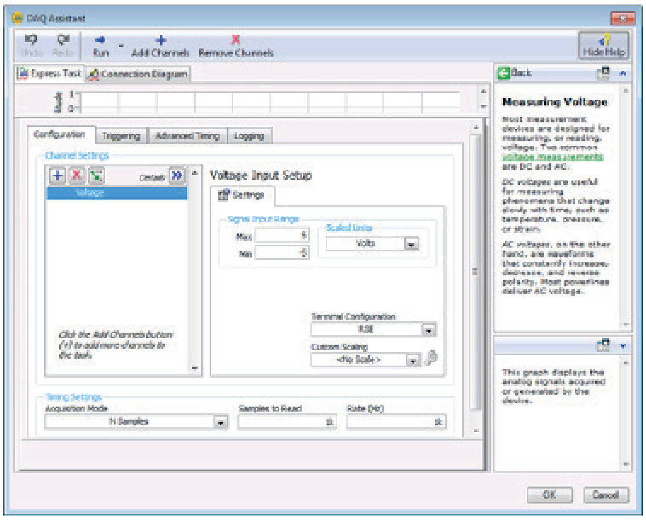


Figure-4

8) Gradually increase the SPEED potentiometer and observe the change in the output signal figures.

9) Set the SPEED potentiometer at level 6. Draw the signal figures as seen on the computer in Graphic-1.

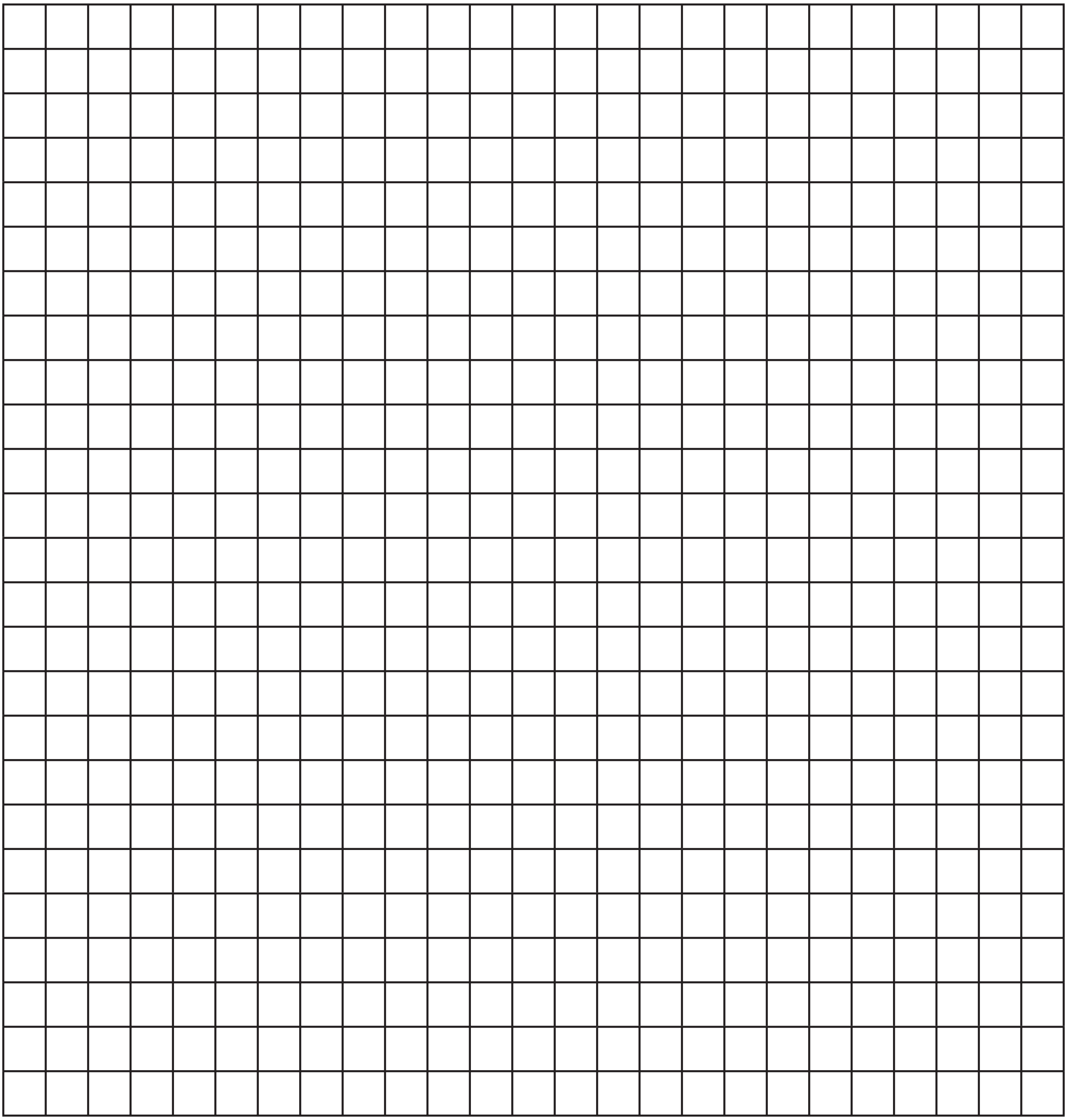
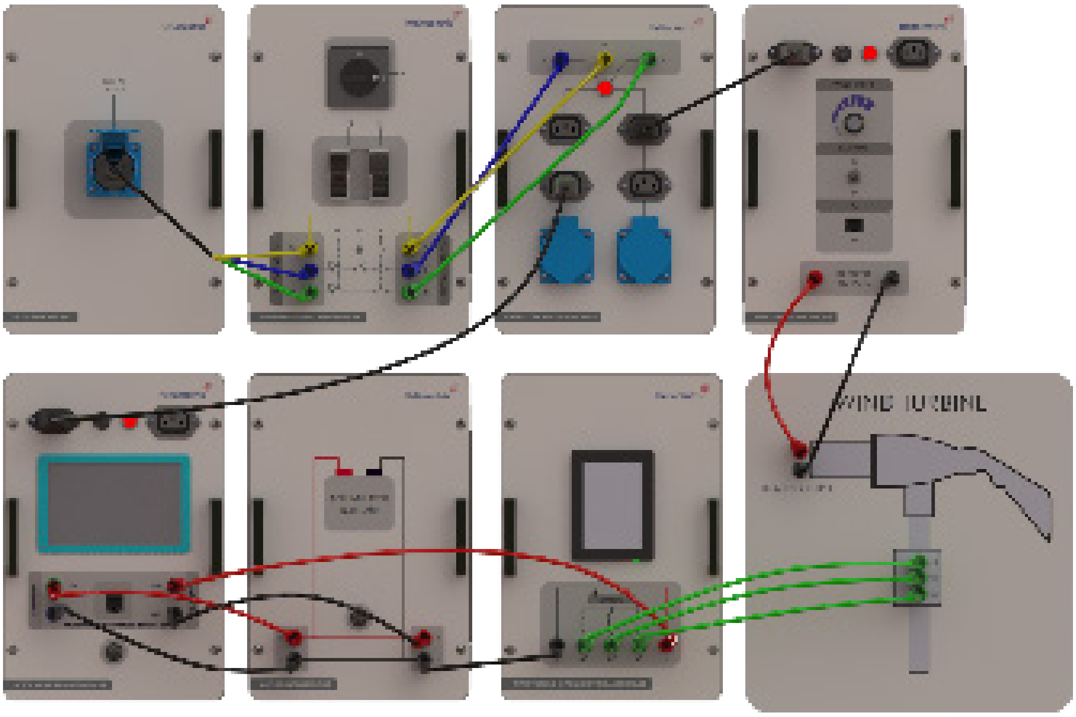


Chart-1

Heliocentris

3.7. Examining the Wind Energy System

1) Prepare the experimental setup in fig.1. Stabilize the wind turbine by locking its legs.



Figure–1

2) Set the key on Wind Simulator Module at MANUAL. Set the SPEED potentiometer at minimum (SPEED Minimum). The wind turbine is designed to produce 12V for 12m/s wind speed.

3) The voltmeter on the AC/DC Measurement Module shows the battery charge voltage and the ampermeter battery charge. Record the battery charge voltage and the battery charge current in the table by setting the SPEED potentiometer at minimum level.

4) Gradually increase the wind speed with the SPEED potentiometer and set to level 1. Record the charge voltage and charge current in chart-1.

5) Gradually increase the wind speed with the SPEED potentiometer and set to level 2. Record the charge voltage and charge current in chart-1.

6) Gradually increase the wind speed with the SPEED potentiometer and set to level 3. Record the charge voltage and charge current in chart-1.

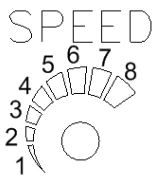
	SPEED MİN.	SPEED 1	SPEED 2	SPEED 3	SPEED 4	SPEED 5	SPEED 6	SPEED 7	SPEED 8	SPEED MAX.
Generator Output Voltage										
Generator speed(rpm)										

Chart-1

7) Gradually increase the wind speed with the SPEED potentiometer and set to level 4. Record the charge voltage and charge current in chart-1.

8) Gradually increase the wind speed with the SPEED potentiometer and set to level 5. Record the charge voltage and charge current in chart-1.

9) Gradually increase the wind speed with the SPEED potentiometer and set to level 6. Record the charge voltage and charge current in chart-1.

10) Gradually increase the wind speed with the SPEED potentiometer and set to level 7. Record the charge voltage and charge current in chart-1.

11) Gradually increase the wind speed with the SPEED potentiometer and set to level 8. Record the charge voltage and charge current in chart-1.

12) Gradually increase the wind speed with the SPEED potentiometer and set to maximum level. Record the charge voltage and charge current in chart-1. The system shall brake once the output voltage exceeds 15 V. If this is the case, be cautious. In order to examine this situation, remove the accumulator from the charge control device by engaging in unloaded operation and slowly set the SPEED potentiometer at maximum level. Once the system is stopped, turn down the SPEED potentiometer and switch off braking.

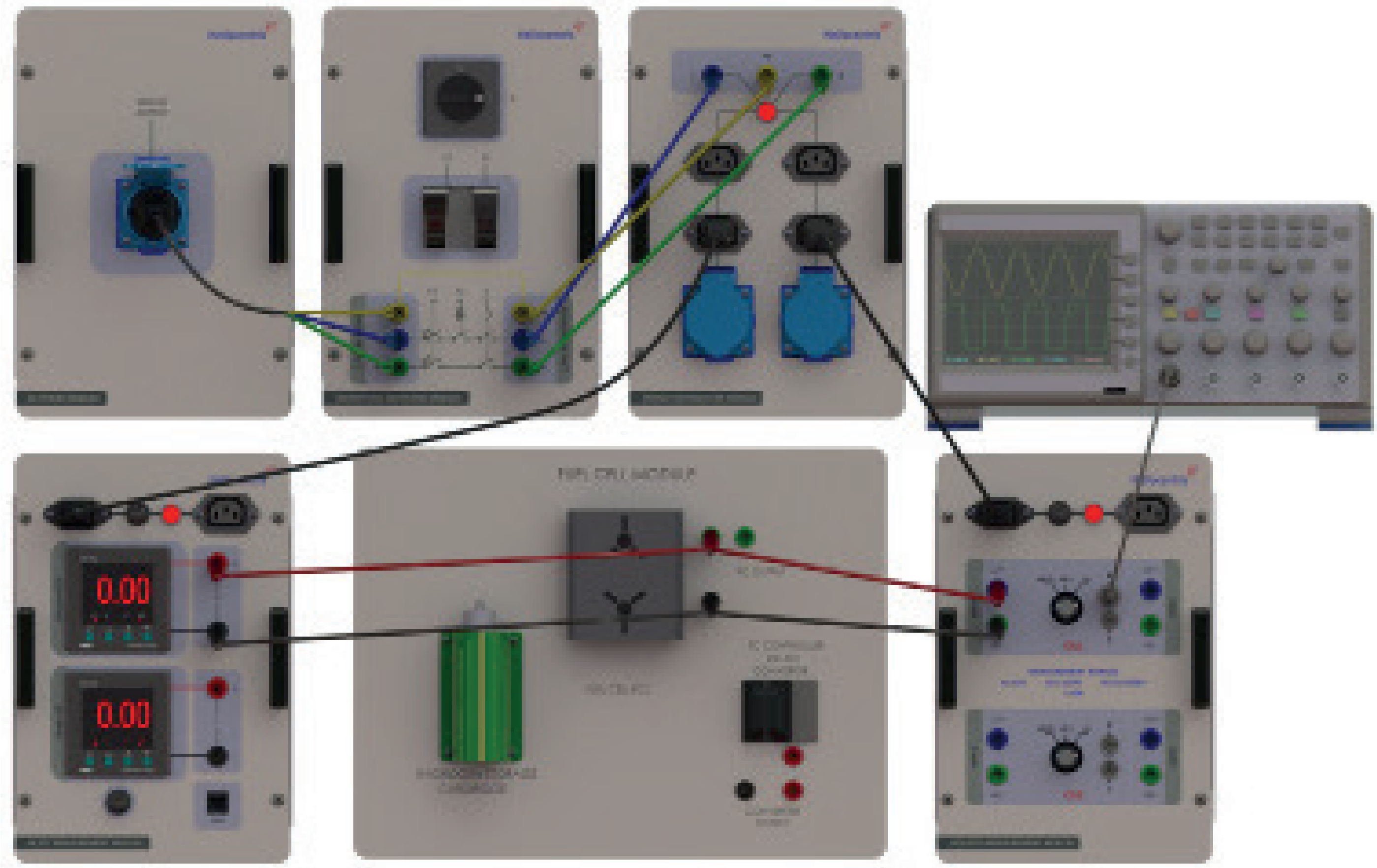
4. HYDROGEN FUEL CELL EXPERIMENTS

4.1. Examining the Hydrogen Fuel Cell Output Current with Oscilloscope

1) Fill the hydrogen tube and insert it in the hydrogen tube housing which is in the experiment set. Conduct all necessary preparations that are listed in other points before connection.

2) Connect as shown in Figure-1.

3) Set the commutator of CH1 channel that is on the Isolated Measurement Module at X0.1



Figure–1

4) Connect the hydrogen tube. Safety is of paramount importance while making the connection.

5) Measure the output signal figures by making the necessary settings for oscilloscope. Draw the signal figures in graphic-1. Note that the signal is weakened by a ratio of 1:10 while measuring and draing.

6) Record the value (Vo) shown in the voltmeter of AC/DC Measurement Module.

Vo=... ...volt

7) Explain the reason why there is a decrease at certain intervals in the signal figures.

8) Explain the operating principle of hydrogen fuel cell.

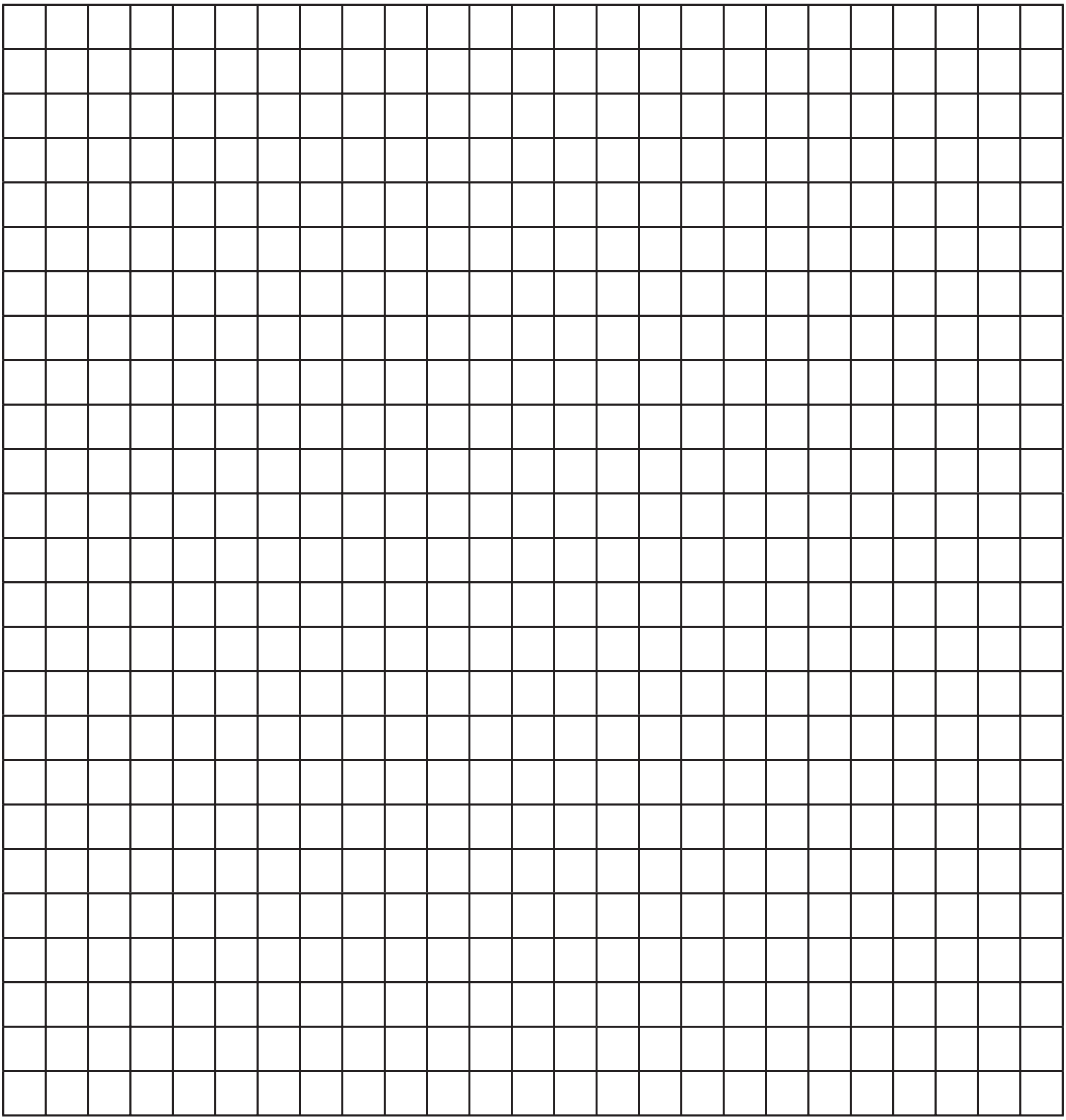


Chart-1

4.2. Examining the Hydrogen Fuel Cell Output Current with DAQ

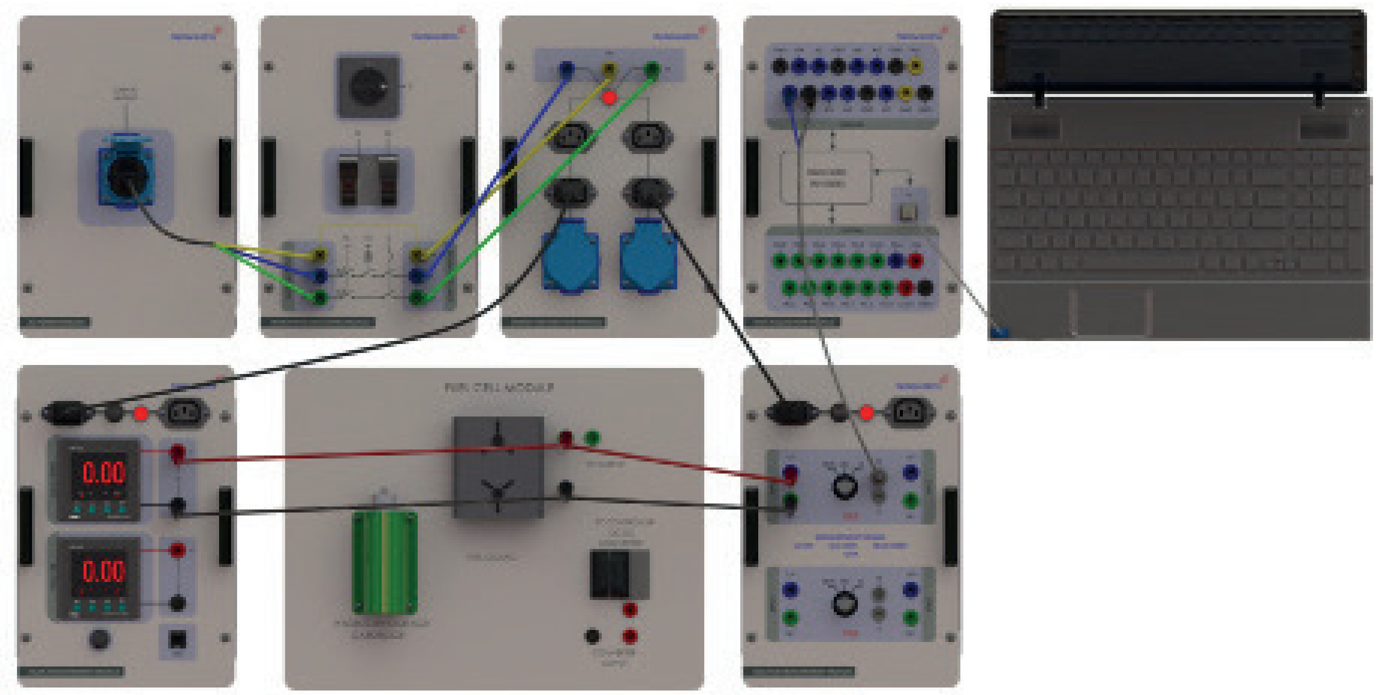
1) Fill the hydrogen tube and insert it in the hydrogen tube housing which is in the experiment set. Conduct all necessary preparations that are listed in other points before connection.

2) Prepare the experimental setup in fig.1.

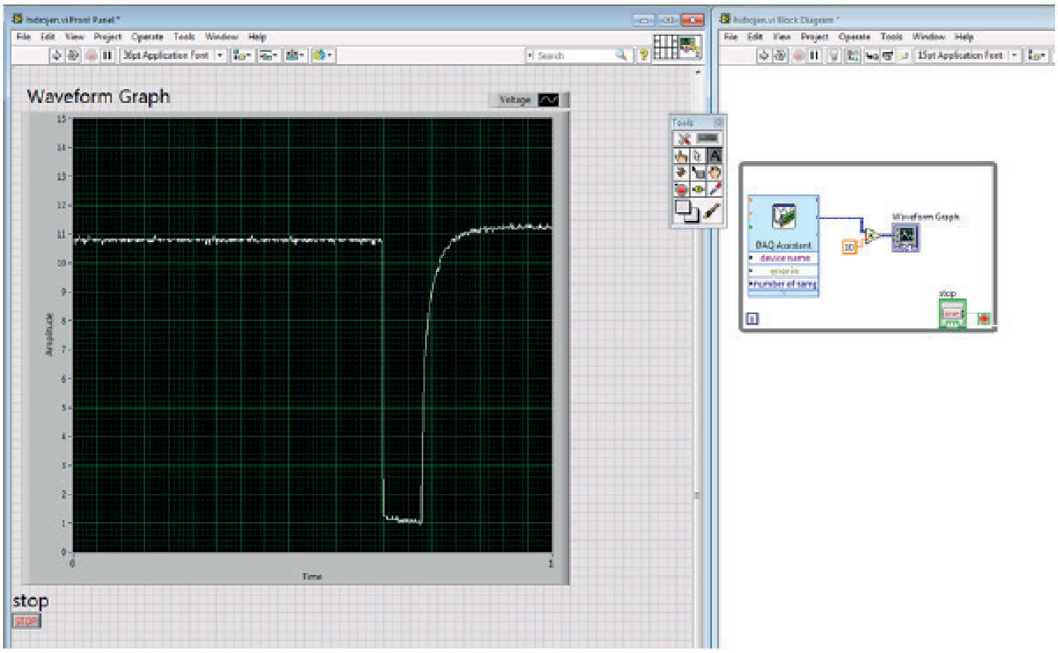
3) Set the commutator of CH1 channel that is on the Isolated Measurement Module at X0.1

4) Make the USB connection between the Data Acquisition Module and the computer.

5) Double click on DAQ Assistant icon and make the relevant settings on the window as shown in Figure-2.



Figure–1



Figue-2

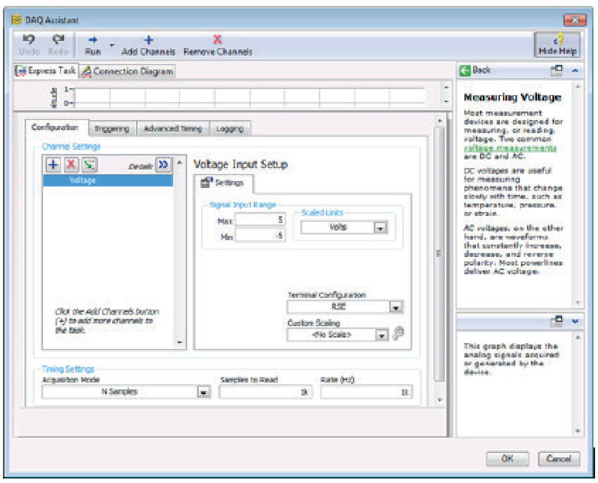
6) Connect the hydrogen tube. Safety is of paramount importance while making the connection.

7) Draw the signal figures seen in the Waveform Graph window by using the LabView software and draw it in Graphic-1.

8) Compare this graphic with the graphic of the previous experiment.

9) Record the value (Vo) shown in the voltmeter of AC/DC Measurement Module.

Vo=.................volt



Figue-3

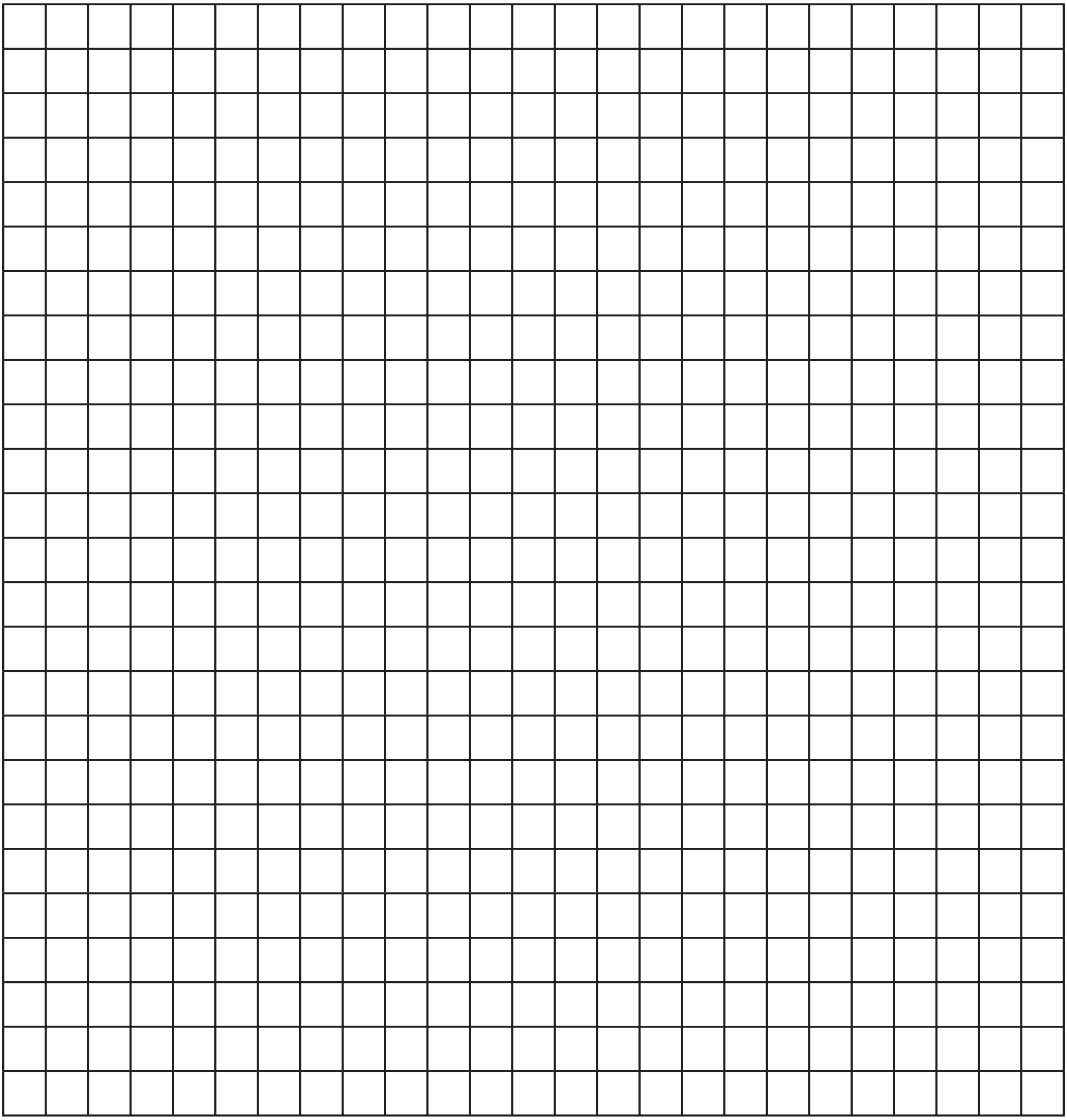


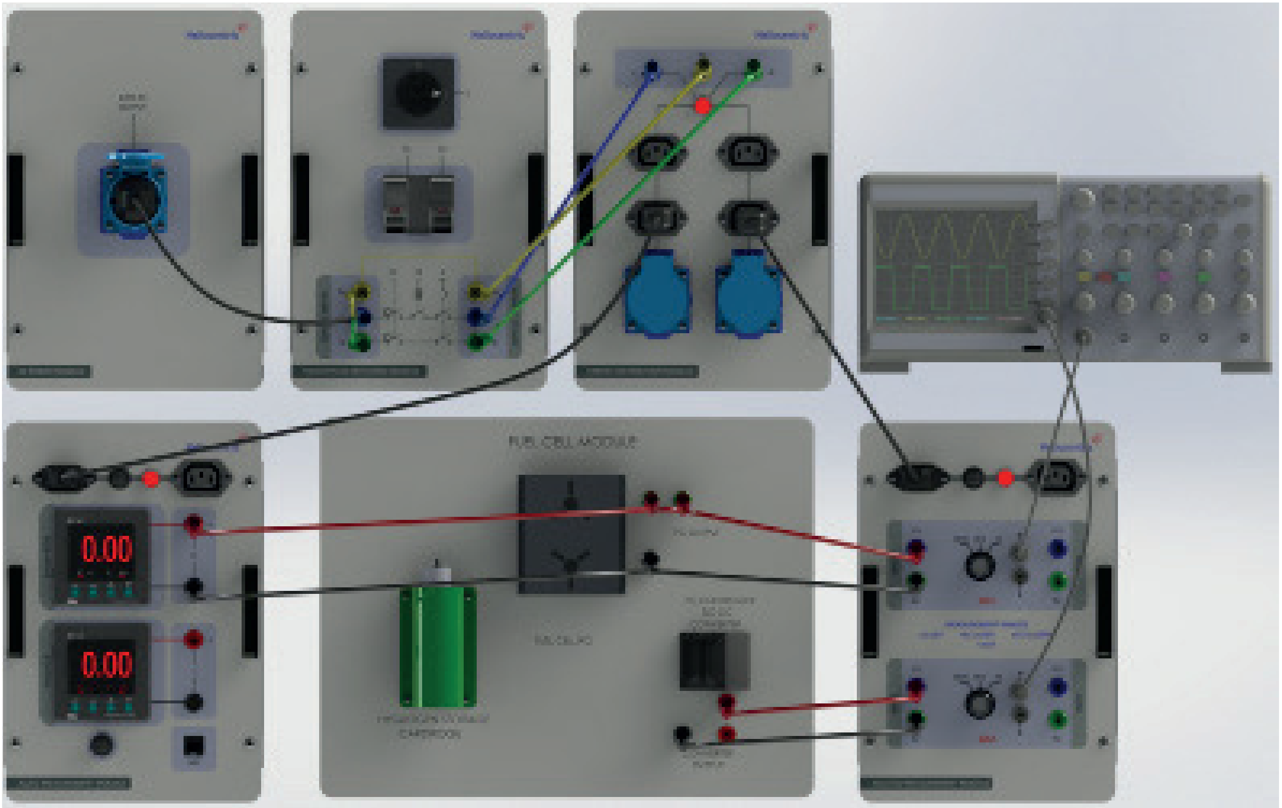
Chart-1

4.3. Examining the DC/DC Converter Output Current of the Hydrogen Fuel Cell with Oscilloscope

1) Fill the hydrogen tube and insert it in the hydrogen tube housing which is in the experiment set. Conduct all necessary preparations that are listed in other points before connection.

2) Prepare the experimental setup in fig.1.

3) Set the commutator of CH1 channel that is on the Isolated Measurement Module at X0.1



Figure–1

4) Connect the hydrogen tube. Safety is of paramount importance while making the connection.

5) Measure the output signal figures by making the necessary settings for oscilloscope. Draw the signal figures in graphic-1. Note that the signal is weakened by a ratio of 1:10 while measuring and drawing.

6) Reord the value (VoDC_DC)as shown in the voltmeter of the AC/DC Measurement.

VoDC_DC=.................volt

7) Explain the reason why there is a decrease at certain intervals in the signal figures.

8) Explain the operating principle of hydrogen fuel cell.

Chart-1

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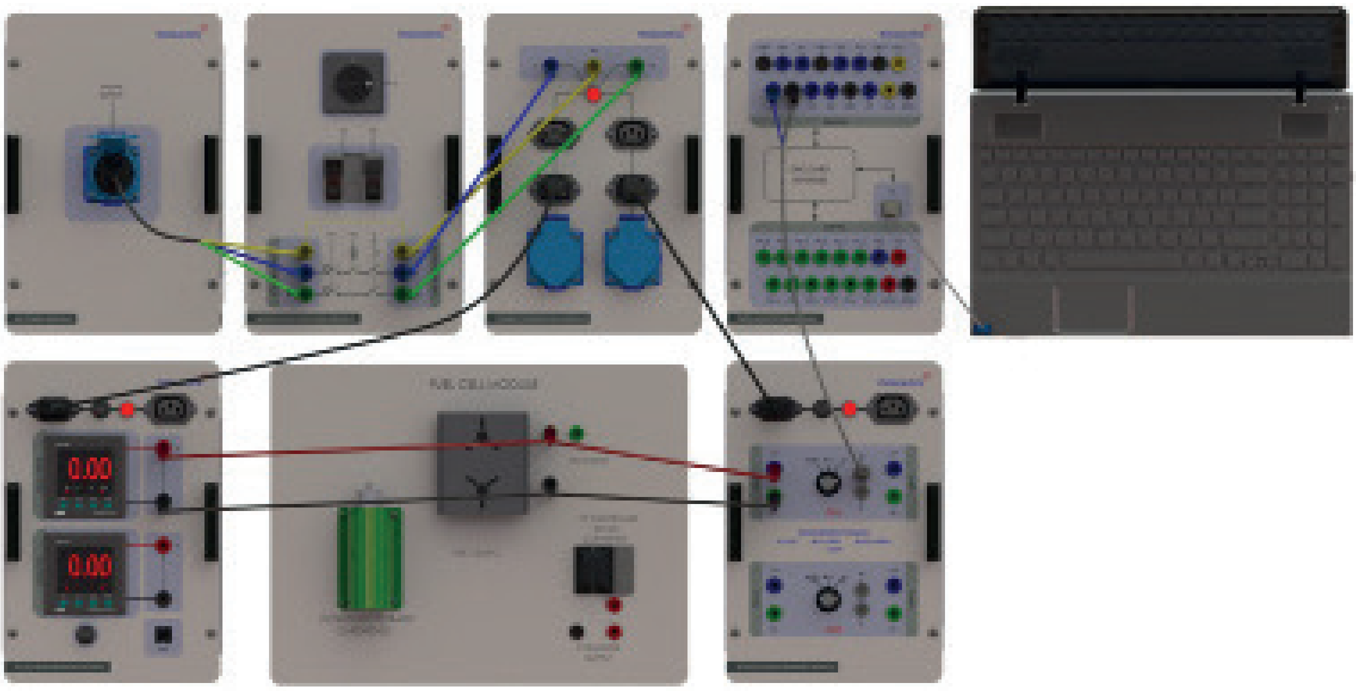
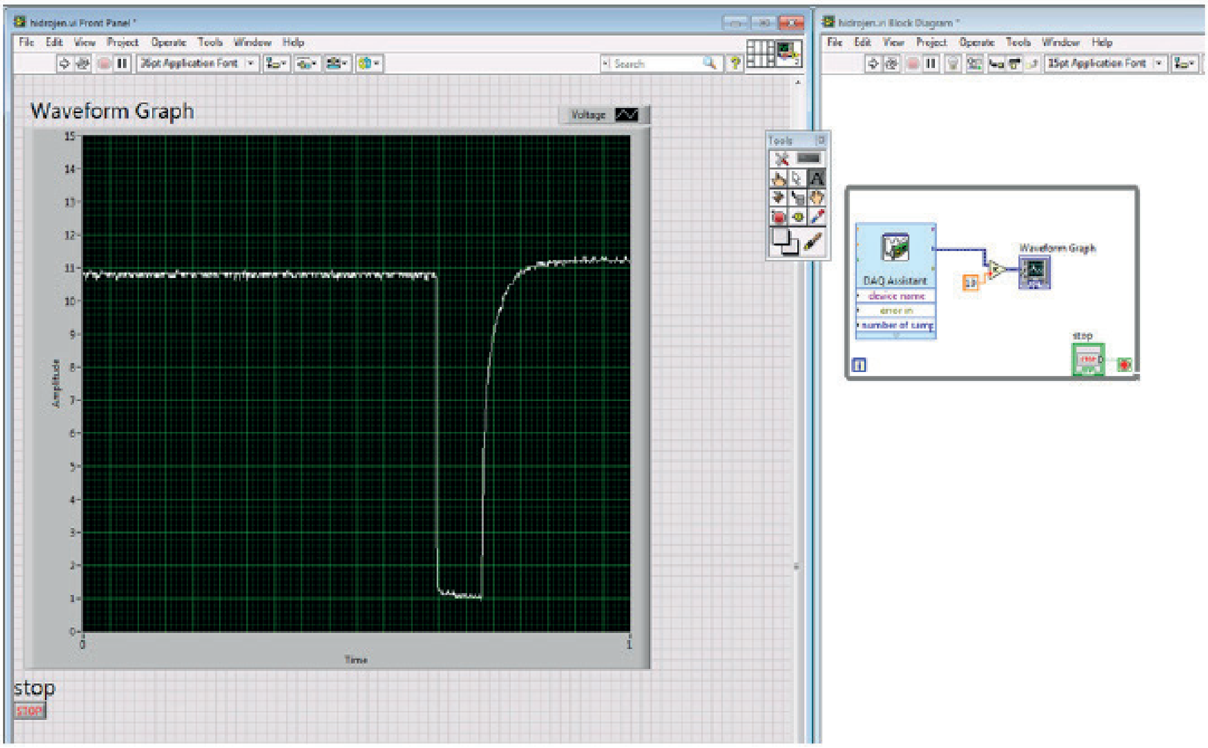
4.4. Examining the DC/DC Converter Output Current of the Hydrogen Fuel Cell with DAQ Module

1) Fill the hydrogen tube and insert it in the hydrogen tube housing which is in the experiment set. Conduct all necessary preparations that are listed in other points before connection.
2) Prepare the experimental setup in fig.1.
3) Set the commutator of CH1 channel that is on the Isolated Measurement Module at X0.1
4) Make the USB connection between the Data Acquisition Module and the computer.
5) By using the LabView software, add a waveform graph to the front panel as shown in Figure-2. Set the time Time-scale at 0.1 seconds.
6) By using the LabView software, add a waveform graph to the front panel as shown in Figure-2. Set the time Time-scale at 0.1 seconds.
7) Double click on DAQ Assistant icon and make the relevant settings on the window as shown in Figure-3.



Figure–1



Figure–2

8) Connect the hydrogen tube. Safety is of paramount importance while making the connection.

9) By using the LabView software, draw the signal figure seen on Waveform Graph window in Graphic-1.

10) Compare this graphic with the graphic of the previous experiment.

11) Record the value (Vo) shown in the voltmeter of AC/DC Measurement Module.

VoDC_DC =.................volt

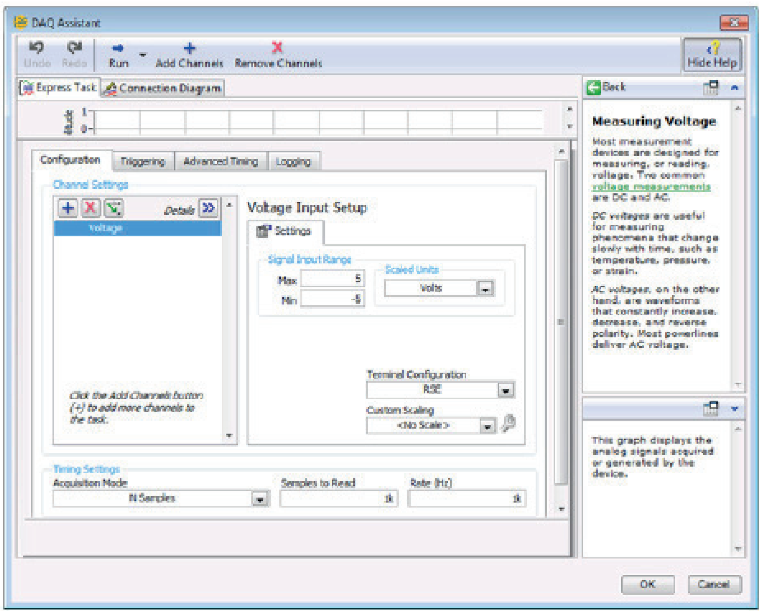


Figure-3

Heliocentris

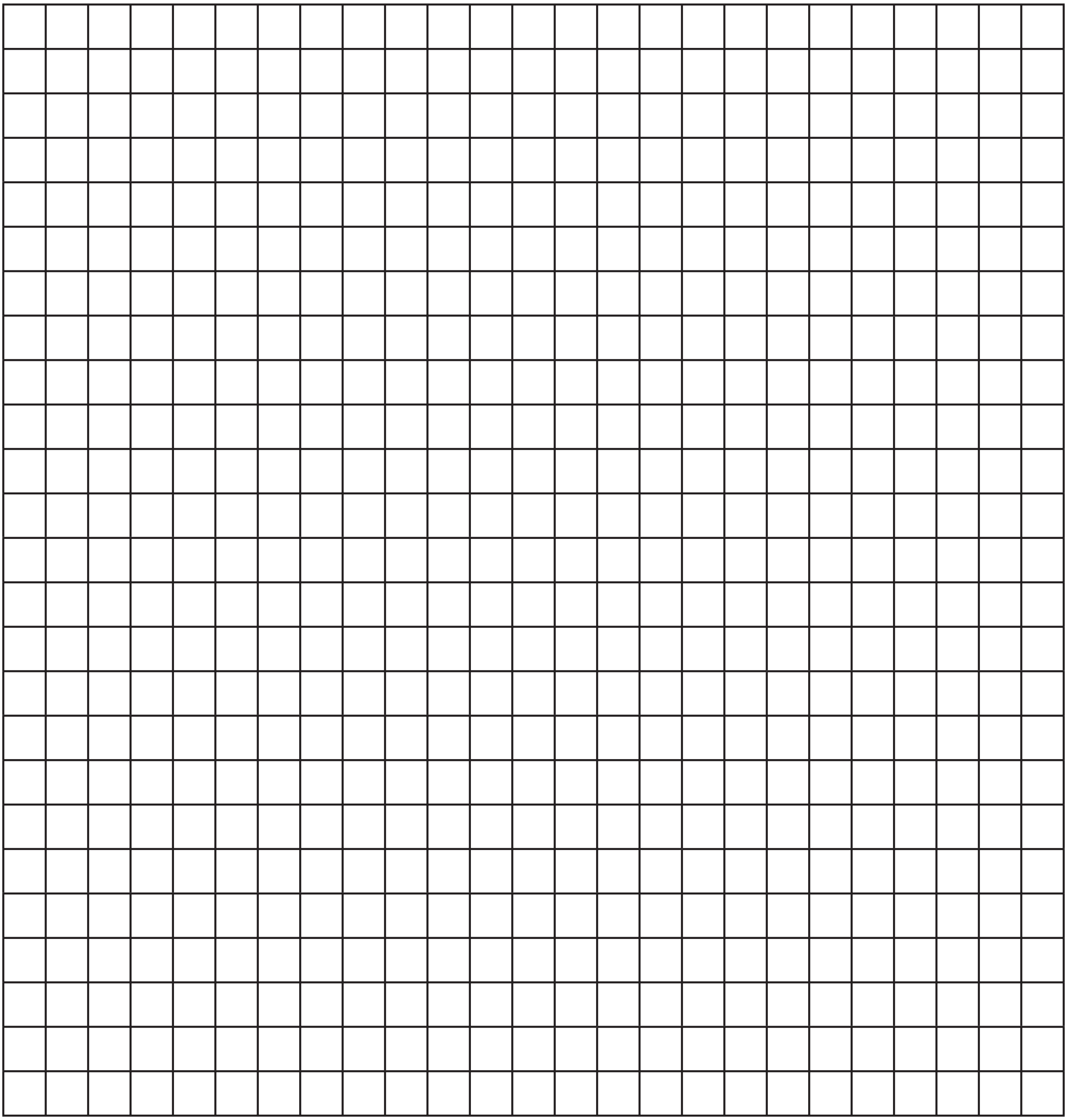


Chart-1

DIAL POTENTIOMETER	AC VOLTAGE	FREQUENCY	VOLTAGE Vdc NO LOAD

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WIND GENERATOR POWER .. . . . .

DIAL SPEED POTENTIOMETER	SPEED	VOLTAGE V1	VOLTAGE Vdc V2	CURRENT	GENERATOR POWER

Heliocentris

BATTERY CHARGE

DIAL POTENTIOMETER	VOLTAGE GENERATED Vdc1	Battery voltage Vdc2	Current		Power	
			A1	A2	P1	P2

Heliocentris

Speed dial potentiometer	Power generated P1		Battery Power P2		Load Power P3	
	V1	A1	V2	A2	V3	A3

Heliocentris

Heliocentris

Heliocentris