Faculty of Engineering and Technology

Department of Electrical Engineering

Technology of Renewable Energy Lab 1

مختبر الطاقة المستدامة /المتجددة 1

<u>Semester and Year:</u>
2022

Name of Lab Instructor	**Eng .Aseel Hamdan**

1. GENERAL POINTS ON PHOTOVOLTAIC SOLAR ENERGY

Renewable solar energy of photovoltaic origin is based on a combination of two phenomena: one natural, as is the radiation coming from the sun as a consequence of its nuclear reactions, and the other the result of a newly created technology, that of the photovoltaic cell as a direct means of conversion of electromagnetic energy into electrical energy and, therefore, exploitable for powering devices requiring this kind of energy.

In fact, the sun, which is the star closest to the earth, generates electromagnetic nuclear reactions over a wide spectrum, part of which is visible to human beings. This energy travels at its natural speed (that of light) and impinges on the earth's surface. Nevertheless, its attenuation is enormous since the quantity that finally arrives is inversely proportional to the square of the distance that separates us (150 million kilometres).

1.1 SOLAR CONSTANT

By definition, the solar constant is the incident energy from outside our atmosphere, and has a value:

$$I = P/4\ \text{л}d^2 = 1.37\ kW/m^2$$

Where:

I	=	Irradiation
P	=	Radiation power of the sun ($4x10^{26}$ watts)
d	=	Distance from the sun to the earth (150 million kilometers)

Nevertheless, water vapor and dust suspended in the atmosphere account for considerable losses, therefore this constant has an average value on the earth's surface, when the sun is at the zenith, of 1 KW/m^2, which is the value that is adopted for calculation purposes in installations.

In the above expressions the distance from the sun to the earth has been considered to be constant. But this is not the case. The earth describes an ellipse around the sun and, therefore, the solar constant undergoes seasonal alterations which, however, have a very small value. Nevertheless, when it is wished to be precise, it is necessary to turn to irradiation tables, in which the value at different moments throughout the year is stated.

1.2 RECEPTION POSITION

Another aspect to consider is the optimum inclination which the installed solar modules have to have in order to achieve the maximum energy, a condition that can be stated as follows:

$$I' = I \cos \alpha$$

Where:

I' = Resultant energy
I = Solar constant
α = Angle of inclination of the solar panels with respect to the radiation.

In the above expression just the elevation variable has been considered (inclination on the surface of the earth), assuming of course that the modules have south as their coordinate origin in the northern hemisphere and north as their coordinate origin in the southern hemisphere.

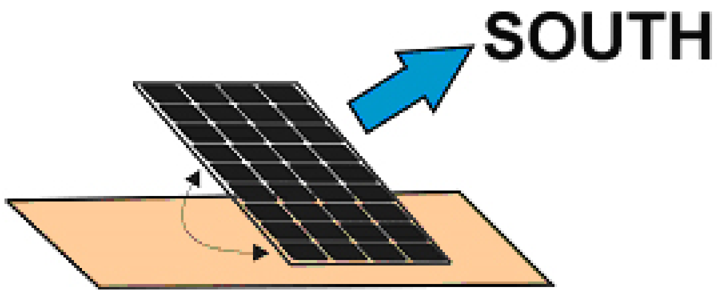


Fig. 1.1. - Detail of the orientation of a photovoltaic cell

For practical purposes of orientation, the parameters are as follows:

- **Azimuth**.
  Corresponds to the movement on the horizon. Its ideal position is south in the northern hemisphere and north in the southern.

- **Elevation.**
  Corresponds to the angle on the plane of the earth. Its average value in the year is that of the latitude of the site. Nevertheless, if precision is wished then the following corrector values have to be introduced:

  - Summer: + 10 ^{0}
  - Winter: - 10 0

Any alteration to the orientation parameters leads to energy losses, whose value is difficult to quantify without specific software.

1.3 PEAK SUN HOURS (PSH)

In order to dimension the photovoltaic installations the parameter peak sun hours needs to be known. This is defined as the interval or band of time for which the level of incident energy on the earth's surface is 1 KW/m^2.

This parameter is stated in W/h and its value (the number of hours in which this condition is maintained) depends on the site of the installation. Figure 1.2 shows an example of this time band.

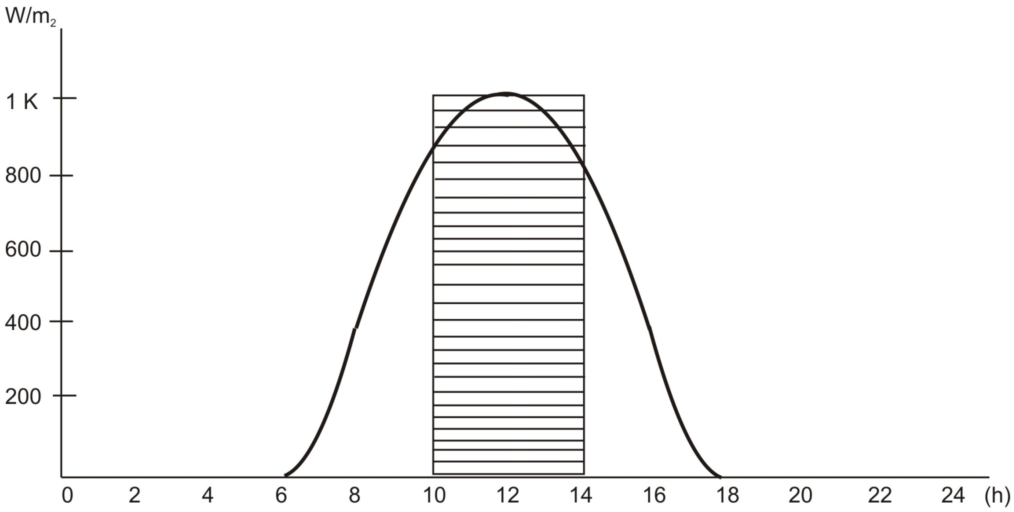


Fig.1.2. - Example of time band of peak sun hours

During the other hours of sunlight, energy is still being received from the sun, though with lower values. Nevertheless, this energy can be exploited. For that reason, the solar irradiation tables state the accumulated daily figure.
The following example:

SITUATION	SUMMER	WINTER
North peninsula:	4.8-5	1.1-1.3
South peninsula:	5.3-6.4	2.2-2.3

1.4 MAPS OF SOLAR IRRADIATION

The solar irradiation maps correspond to the amount of incident energy for a particular geographical surface. The data corresponds to the annual average, which is useful for installations having permanent use, though not for seasonal ones, for which specific tables and zones and months need to be resorted to.

Figure 1.3 show the irradiation map of Italy divided into climatic zones. The values correspond to the yearly average, as has been stated.

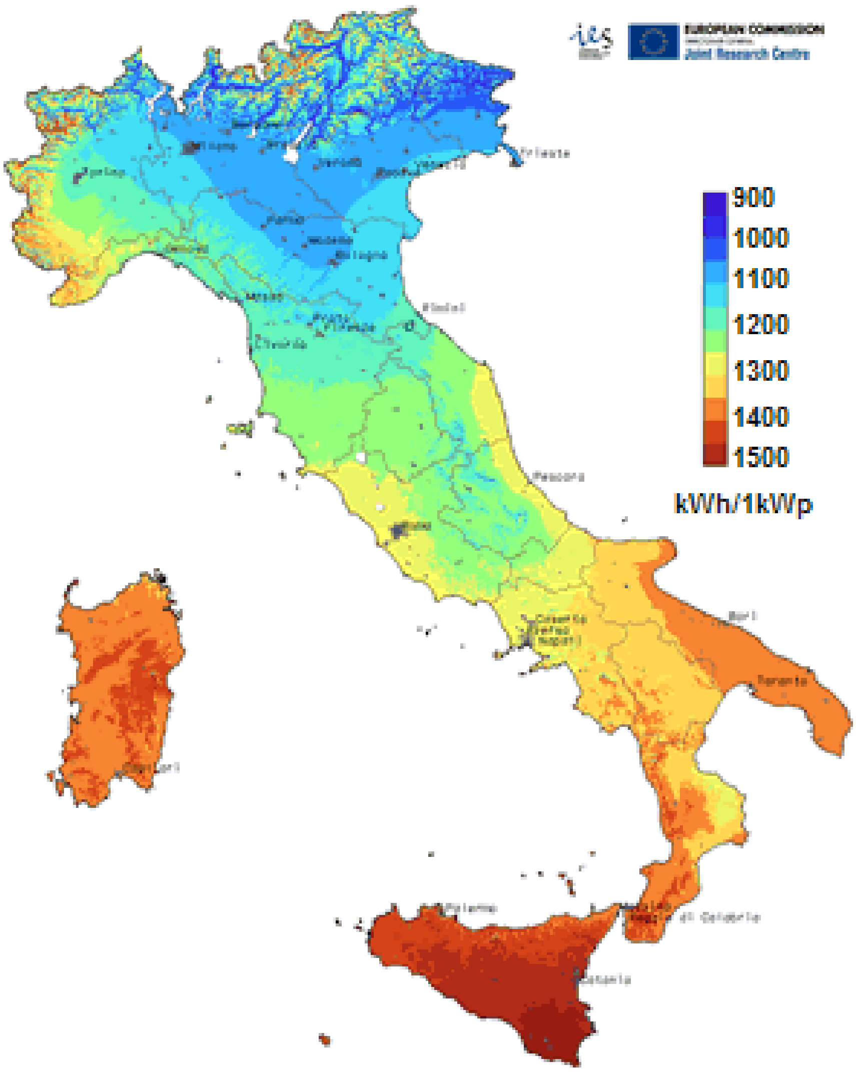


Fig.1.3. - Map of solar irradiation in Italy

2. COMPONENTS FOR ISOLATED SOLAR INSTALLATIONS

Photovoltaic solar energy installations of the type known as isolated consist of a set of components as shown in the figure below, and whose basic description is given in the following sections.

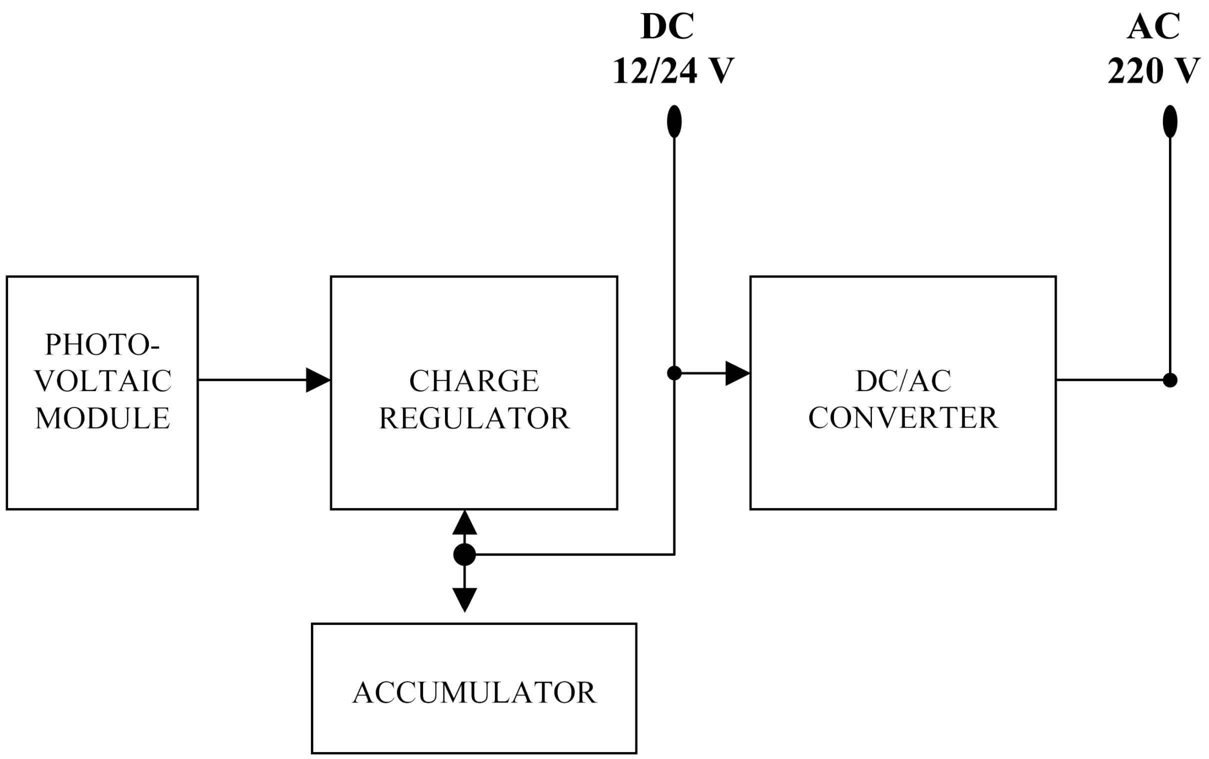


Fig. 2.1 - Main components of isolated photovoltaic installations

2.1 PHOTOVOLTAIC MODULES

What is known as a solar or photovoltaic cell is, in short, a transducer of light into electrical energy. An array made of cells creates the commercial module that is distinguished by the voltage and current it provides.

These cells are based on the photovoltaic effect which was demonstrated by Becquerel in 1887 and interpreted by Einstein in 1902, a work which led to his winning a Nobel Prize. With this background, in 1954 Chapin, Fueller and Perarson developed the first solar cell capable of producing electrical energy proportional to the light energy incident on its surface.

2.1.1. Technological foundations

Solar cells are made up of semiconductors, generally silicon, in which the photoelectric effect takes place. This effect consists of the transfer of energy to the valence electrons in the semiconductor so that they break their bonds by means of the photons they receive coming from the sun.

With each bond that is broken, a free electron is produced which can circulate throughout the semiconductor device, thereby generating an electric current. The absence of the electron of the bond that is broken in this way creates what is known as a hole and it too can be displaced through the semiconductor. The movement of the electrons and the holes in opposite directions generates the electrical current which can circulate outside of the device and thereby provide energy. Figure 2.2 shows a detail of this effect.

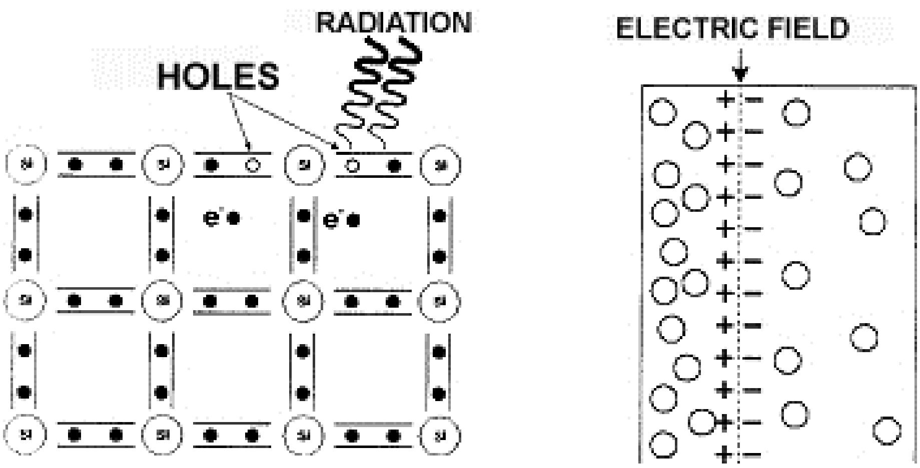


Fig. 2.2 - Photovoltaic effect

Each elemental cell is made up of a silicon semiconductor doped with various substances (phosphorus, boron, etc.) in order to achieve the stated effect of converting photons from incident light into electrical energy.

As can be seen in this figure 2.2, the movement of electrons (and therefore of holes) gives rise to the appearance of a potential difference at the ends of the semiconductor, which confers on the device the condition of an electric generator. Figure 2.3 shows this effect. The electrical energy generated is proportional to the incident light.

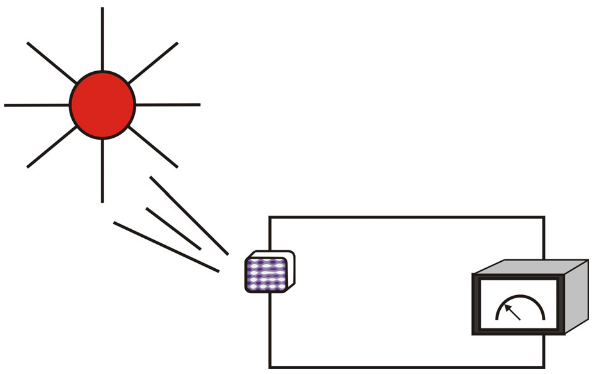


Fig. 2.3 - Current generated in the cell with sunlight

2.1.2. Characteristics of the cells

Grouped into what are known as photovoltaic modules, photovoltaic cells are defined by a set of electrical characteristics, the most important of which are mentioned below:

Short-circuit current

This refers to the maximum current that can be obtained. This parameter is quantified by short-circuiting its terminals via an ammeter and measuring the current flowing through it.

Voltage in open circuit

This is defined as the voltage provided by the panel when the flowing current is zero (no charge).

So, by way of example, a module of 12 V without charge, under the stated conditions, can give 20 V or more at maximum radiation (1000 W/m^2).

Peak power

This refers to the power (P = V.I) that can be supplied by a module at the specified voltage and current.

Efficiency

This is the most important parameter of a module, since it gives the maximum output or transfer of energy in the photoelectric conversion process.

It corresponds to the quotient between the power produced and the incident energy from the light source, as is the sun.

The highest efficiency achieved is around 20%.

So, the energy exploitation per m^2 would be, for an incident energy of 1 kW/m^2,
1 kW/m^2 x 20/100 = 200 W/m^2.

Rated peak power

This parameter refers to the power provided by the module when the energy incident on its surface is 1 KW/m^2 and the ambient temperature is 25ºC.

2.1.3. Types of photovoltaic cell

There exists a wide range of manufacturing technologies for photovoltaic cells having applications as diverse as lighting installations and similar at the domestic level, connections to networks and for clocks and calculators though, for obvious reasons, the only ones that we are interested in here are those used in isolated installations and those for connections to networks.

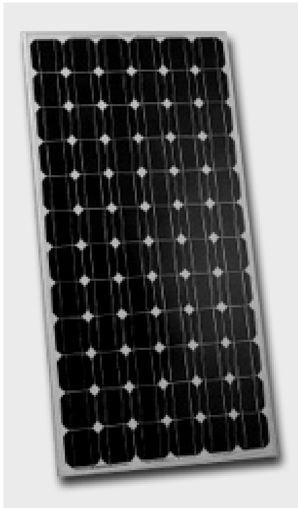
For these installations intended for supplying electrical energy for lighting, pumping of water, sale of energy to supplier companies, etc., different types of cell are used, as stated below:

MONOCRYSTALLINE

Cells characterized by being made of a single crystal and having an efficient of around 16%.

This cell captures a considerable quantity of diffuse light, which is important for obtaining energy on cloudy days.

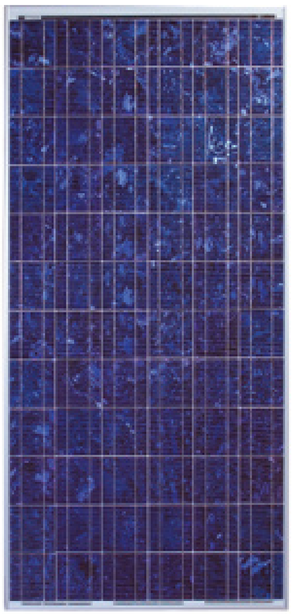
In addition to its high efficiency is also has a low rate of degradation, giving it a very long life.



POLYCRYSTALLINE

Unlike the previous cell, polycrystalline cells consist of silicon mixed with other materials. Their efficiency stands at around 14%.

The degradation of this cell is greater than the previous one.



AMORPHOUS

Modules with amorphous cells are characterized by having an average efficiency, greater weight than the others and they are more economical.

Nevertheless, they have the disadvantage of degradation with time, which leads to a reduction in output. These panels are generally used in small installations.

Cells with CIS technology, constructed with a fine layer, give modules that are more stable in time and with a good response in conditions of low solar irradiation.

Their main application is in alarm systems, weather stations and similar.

2.1.4. Connection of modules

The grouping of cells with connection of groups in series and these being connected in parallel gives rise to what are known as modules, which consist of four main components, these being:

- Solar surface with the stated groupings of solar cells.
- Surface glass for protection of the cells, on which the solar radiation impinges. The glass has a low iron content in order to cut down on the reflection of sunlight.
- An adhering lamina subjected to a heat process in order to fix the cells to the glass on the one side and, on the other, to the “Tedlar” or rear lamina, thus creating a “sandwich” of these components.
- Deposition of what is known as “Tedlar” (material existing in different colors) in order to guarantee the sealing between the cells and the outside.
- Metal protection frame, which is fixed to the ground support, mast, roof, etc. It is made of aluminum treated to withstand adverse weather conditions.
- Terminal box where the connection of the groups of cells ends. This box can have terminals for a single voltage output or different ones in order to obtain 6, 12 or 24 V, depending on whether the groups of cells are arranged in series or in parallel.

Connected to these terminals are the cables which link the module to the charge regulator.

The solar modules can be grouped together in order to achieve the necessary voltage or power, depending on whether they are arranged to be connected in series or parallel, though for this the following electro technical principles need to be born in mind.

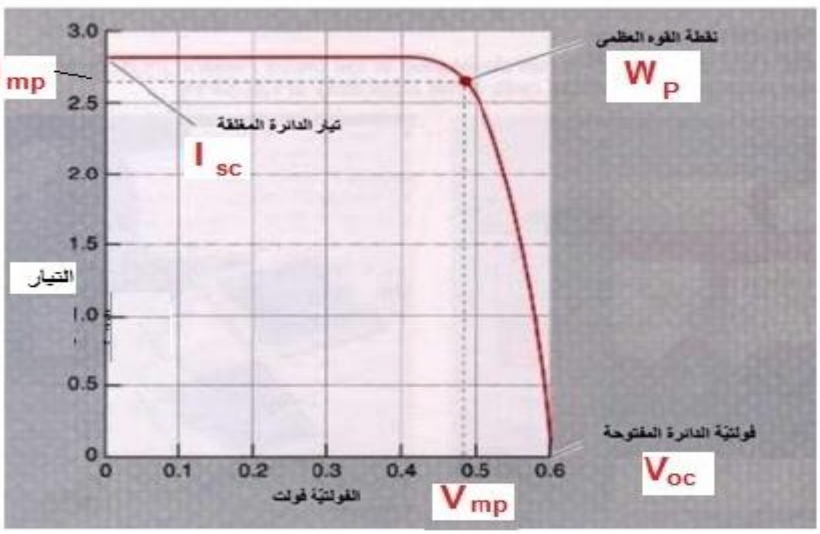
- For connection in series, the panels have to have the same current intensity.
- For connection in parallel, the panels have to have the same voltage.

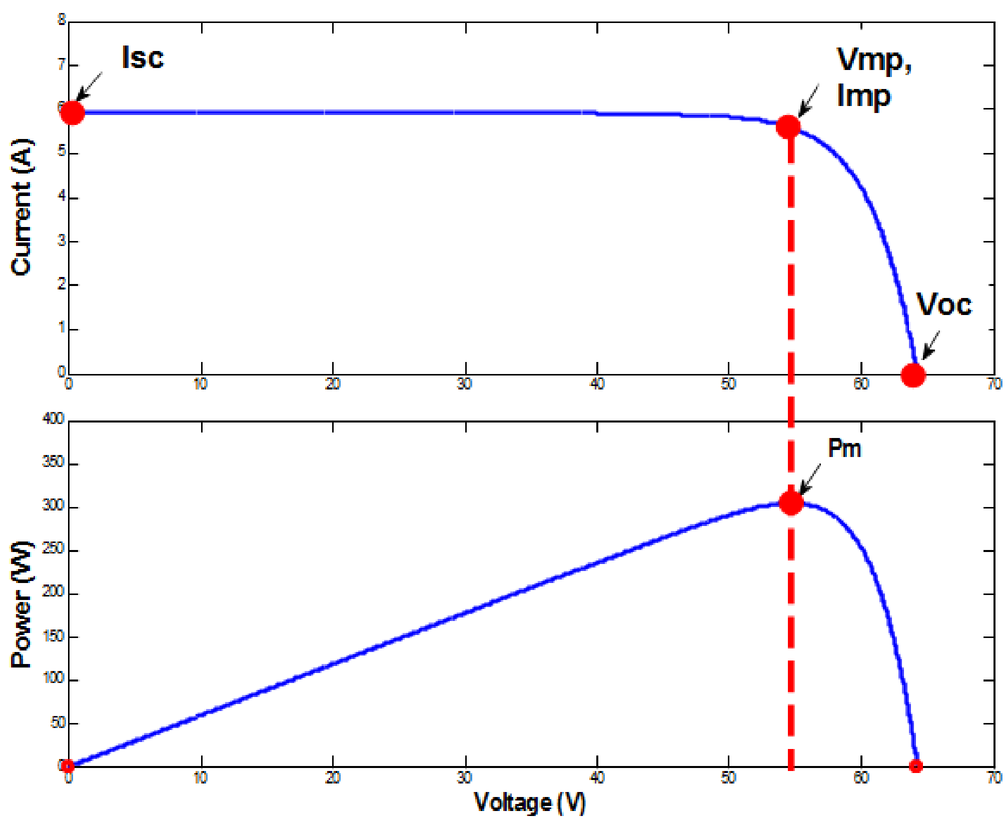
The figures below show some solar panels.

Fig. 2.4 - Solar modules

Exp.2: I-V characteristic curve of solar panel

Every PV panel have an special I-V curve , which is contain the main characteristic values (which is named on its name plate), but the total values of V and I values on the curve could be obtained by using variable load value.



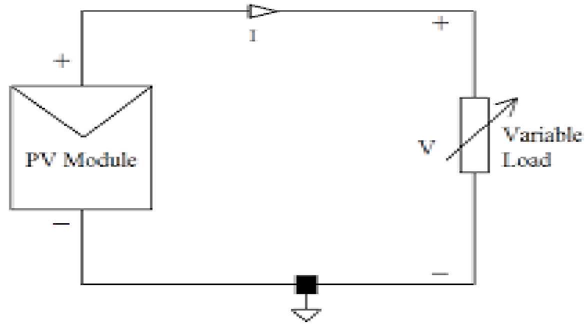


Objective:

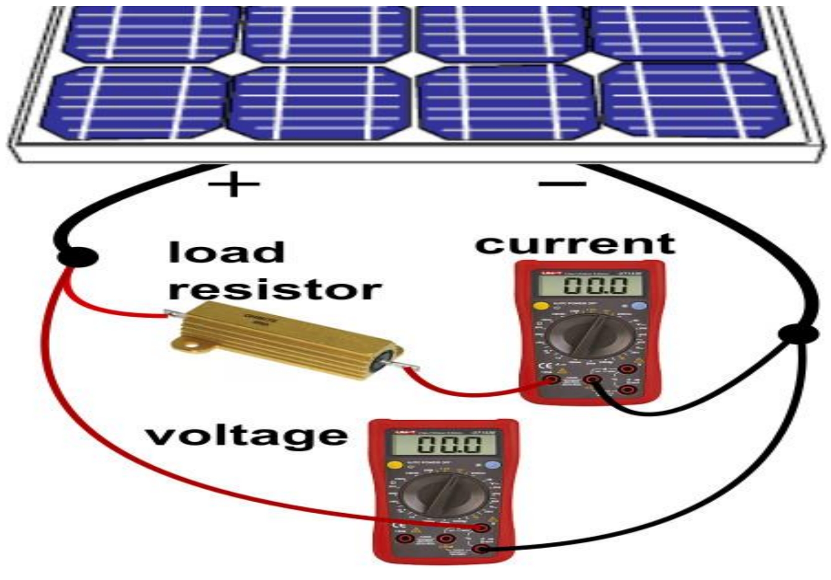
1- To draw the I-V curve of PV panel
2- To Draw the power curve of PV panel

Procedure:

1- Connect the circuit below which contain PV panel , voltmeter, ammeter, variable resistor



2- Locate the PV panel to have most radiation Irr = 1000w/m2 ,and a suitable angel, measure these values by the radiation meter (as Exp.1)
3- Measure the values of variable resistor by ohmmeter and followed it in table 1
4- Put the variable resistor from maximum value
5- Record the value of voltage(V) and current(I) at maximum resistor



6- **Change the variable resistor from maximum value to minimum value**
7- **Record all values of V and I at every value of R and put the values in a table 1.**

R (ohm)	V (v)	I (A)
Max R 100%		
90%		
80%		
70%		
60%		
50%		
40%		
30%		
20%		
10%		

Table 1

8- **Draw the curve between I and V (I and V relation)**

9- **Calculate by hand the value of PV power at every step an followed it in table 2**

R (ohm)	**V (v)**	**I (A)**	**P (W)=V * I**
Max R 100%			
90%			
80%			
70%			
60%			
50%			
40%			
30%			
20%			
10%			

10- **At the power column values , find the maximum produced value , its named Pmax , and V , I at same value named as Vmp, and Imp , Draw the power curve (P-V) relation and sure on these results**

Questions:

1- **What is the value of Irr used in the Exp.?**

2- **Why the value of variable resistor is starting with maximum one?**

3- The final value of variable resistor is 10 % not zero , explain ?

4- Is the resulted Pmax having Imp and Vmp at same point ? if not what is your reasons?

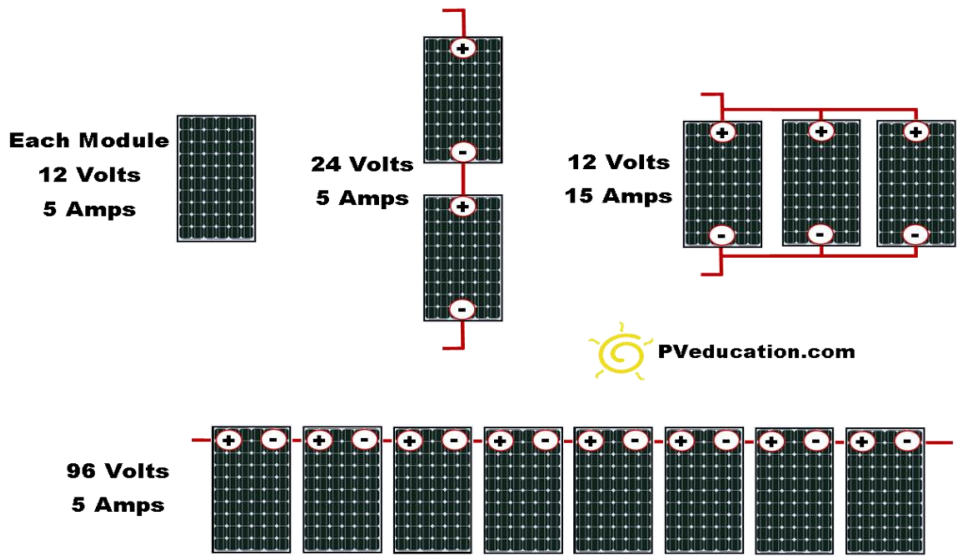
5- At point in 4 , what is the fames name of this point in PV panel , what is mean ?

Exp 3: Series and Parallel Wiring of solar panels

Objective: connect the PV panel on series and parallel and find total produced power

Series and Parallel Wiring

The following image is a great example of series and parallel wiring.



Series Wiring:

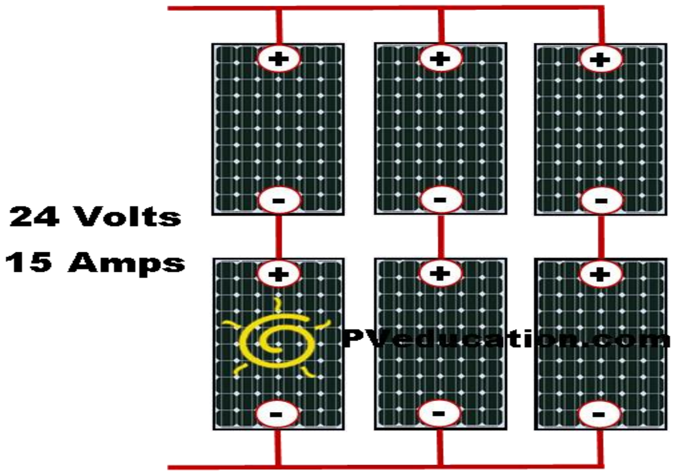
Series wiring is when the **voltage** of a solar array is **increased** by wiring the positive of one solar module to the negative of another solar module. This is similar to installing batteries in a flashlight. As you slide the batteries into the flashlight tube the voltage increases.

Parallel Wiring:

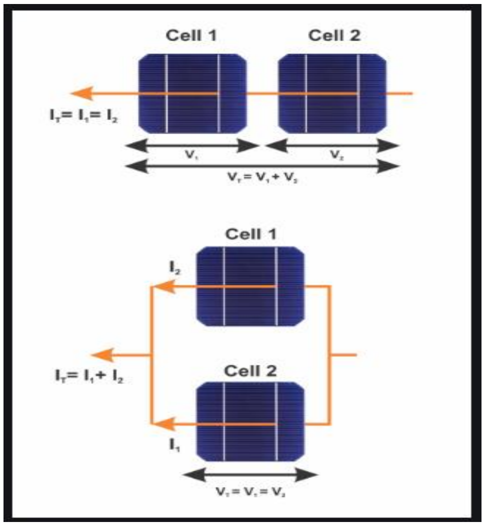
Parallel wiring **increases** the **current (amps**) output of a solar array while keeping the voltage the same. Parallel wiring is when the positives of multiple modules are connected together and all the negatives for the same modules are connected together.

Series Parallel Combination:

Here is an example of what is found in most large solar systems, a series and parallel wiring combination.

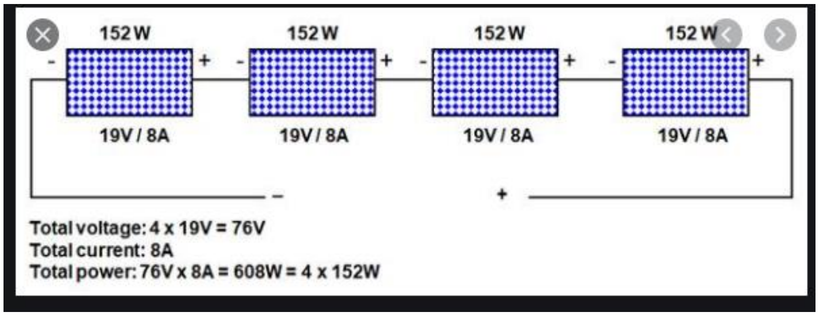


What applies to the solar panel is the same as that of a single cell in the law of succession and parallelity as in the adjacent form :

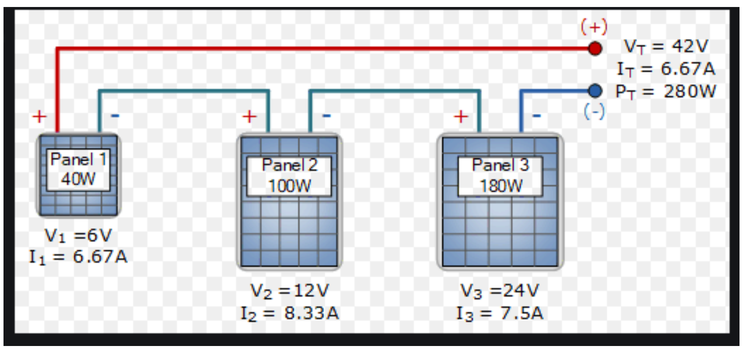


Examples of different connections to calculate total power :

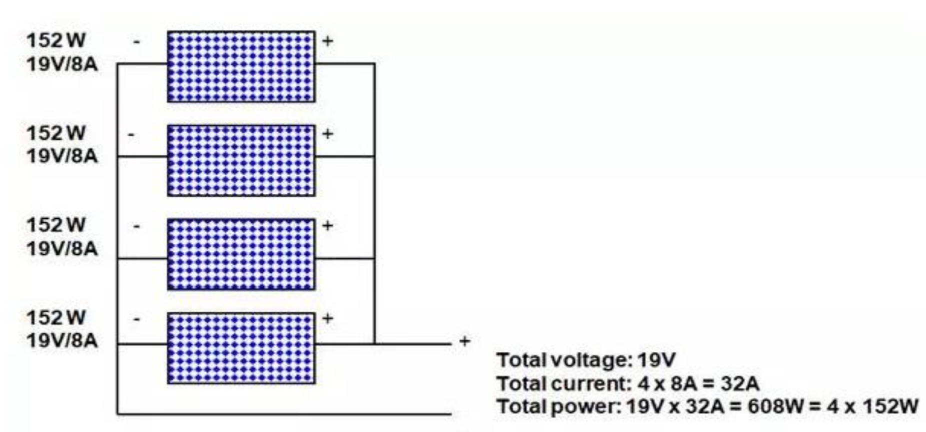
Connection 1:



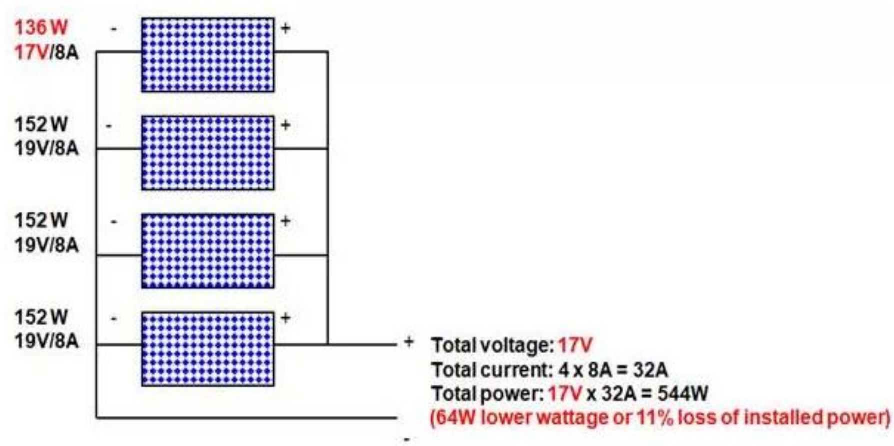
Connection 2:



Connection 3:

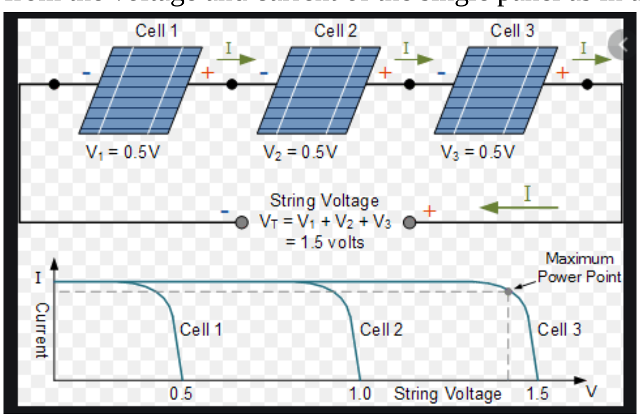


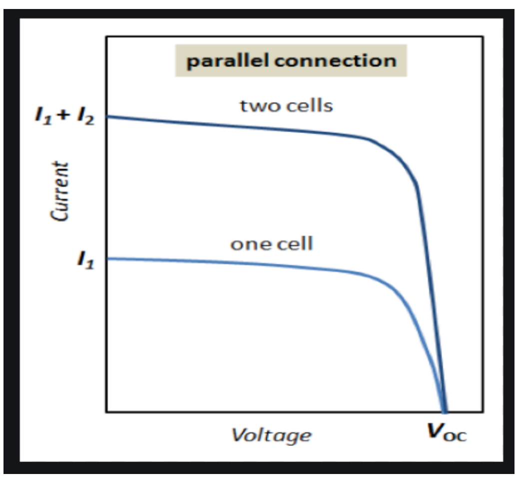
Connection 4:

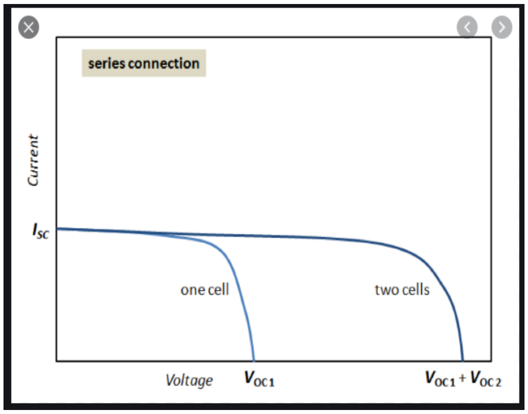


IV curve of PV panel different connections

The IV curve is produced for the panel connection and the voltage and current values on it are different from the voltage and current of the single panel as in the following connections:







Exp 3: solar panel connections:

Experiment Procedure's:

Solar panel number	Solar panel 1	Solar panel 2	Solar panel 3
	P theoretical =	P theoretical =	P theoretical =
	V theoretical =	V theoretical =	V theoretical =
	I theoretical =	I theoretical =	I theoretical =

1- **Case 1: Choose two identical solar panels and connect them in series ,fill the table:**

Solar panel number:………………

I tot	
V tot	
P tot	

2- **Case 2: Repeat the previous step but connect in parallel:**

I tot	
V tot	
P tot	

3- Case 2: Connect the three different solar panels in series and complete the table:

I tot	
V tot	
P tot	

4- Case 3: Repeat the previous step but connect in parallel:

I tot	
V tot	
P tot	

5- Compere between the measurement results and the theoretical values by calculating the percentage of error in each case:
Case 1: P error = (P theo – P meas)/P theo

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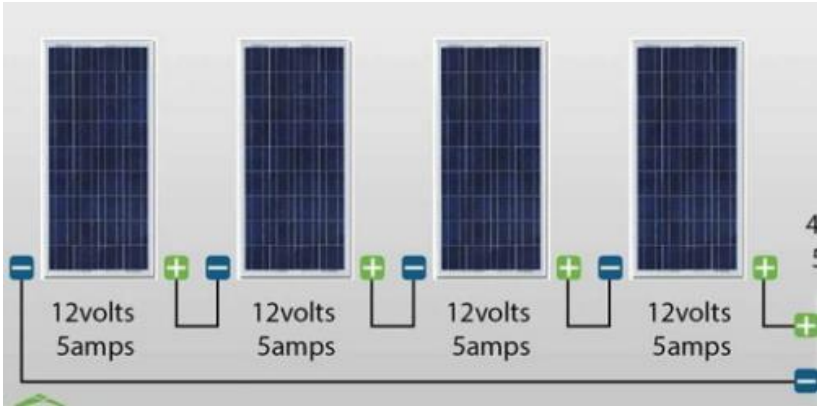
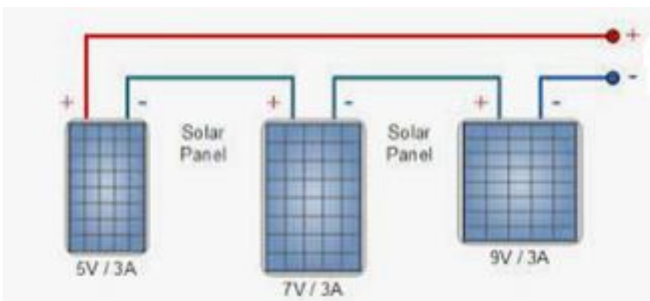
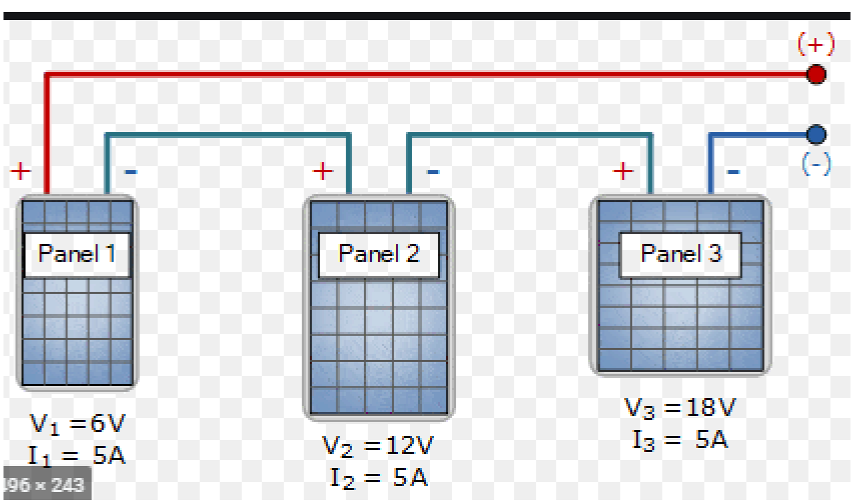
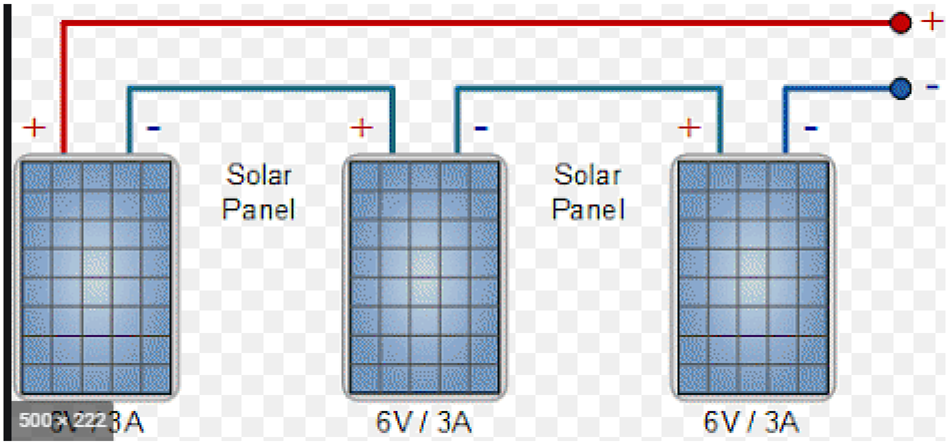
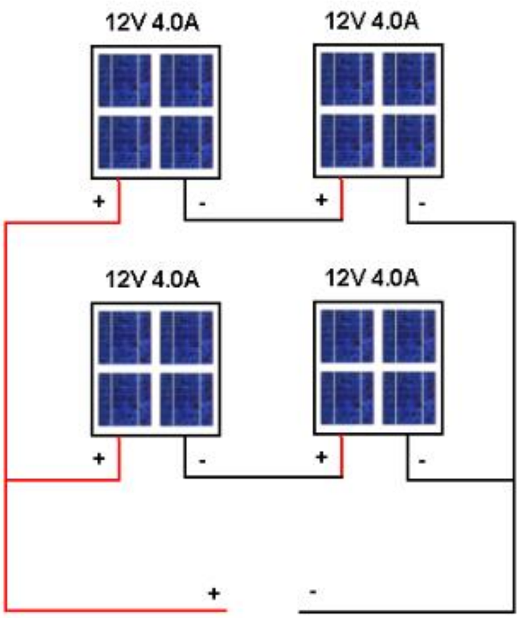
Find I total , V total, and total power at the following connection :

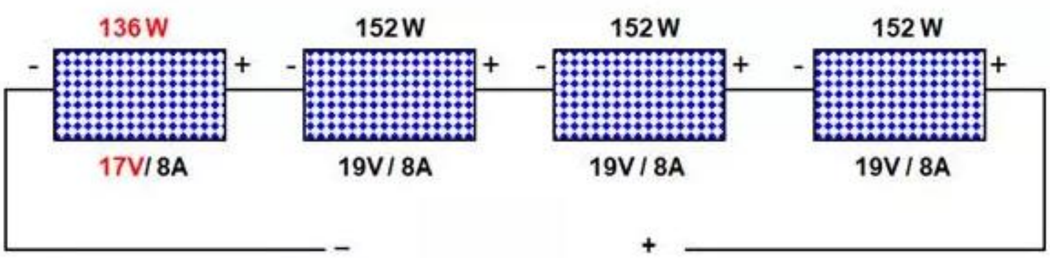
1- 

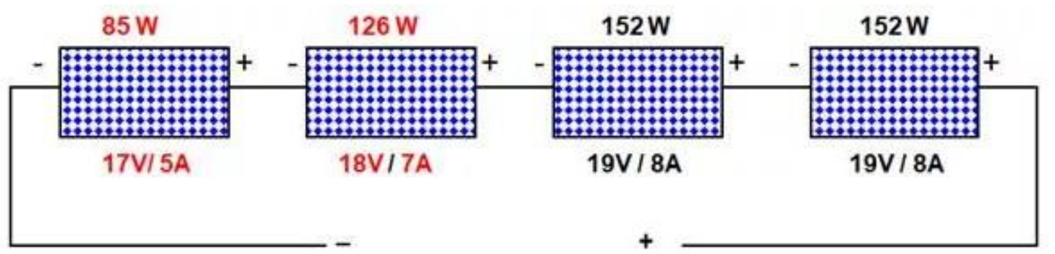
2- 

3- 

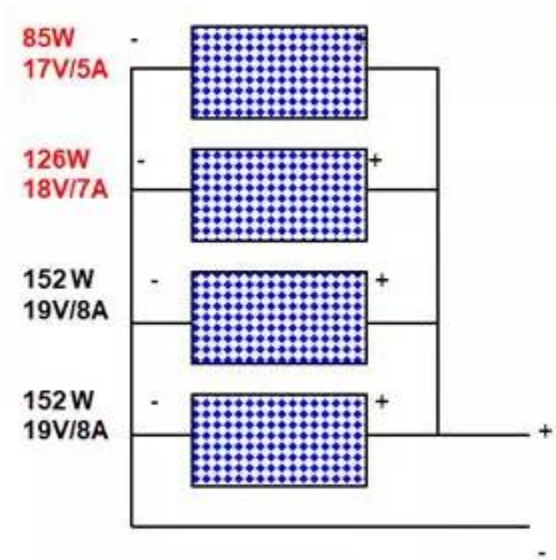
4- 
+
-
Solar
Panel
Solar
Panel
6V / 3A
6V / 3A

5- 
12V 4.0A
12V 4.0A
12V 4.0A
12V 4.0A
+
-

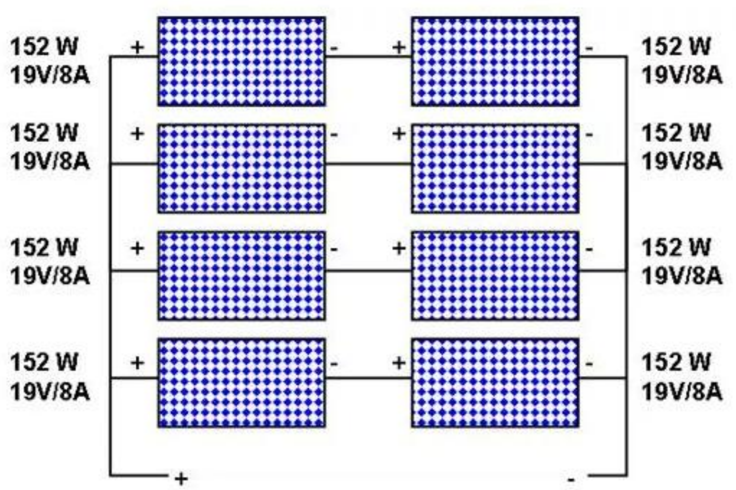
6- 
136 W
152 W
152 W
152 W
17V / 8A
19V / 8A
19V / 8A
19V / 8A
-
+


85 W
126 W
152 W
152 W
17V/ 5A
18V / 7A
19V / 8A
19V / 8A

7-


85W
17V/5A
126W
18V/7A
152 W
19V/8A
152 W
19V/8A

8-


152 W
19V/8A
152 W
19V/8A
152 W
19V/8A
152 W
19V/8A
152 W
19V/8A
152 W
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152 W
19V/8A
152 W
19V/8A

9-

2.2 CHARGE REGULATOR

A component of great importance in all photovoltaic solar energy installations is that known as the regulator, an electronic unit to which is the voltage from the modules is applied in order to control the transfer of energy between the accumulator and the utilization circuits.

Four fundamental connection lines of the regulator can be considered, which are the following:

INPUT VOLTAGE (Connections from the modules)

Input for the regulator circuit to which is applied the voltage coming from the modules.

OUTPUT VOLTAGE (Utilization)

Voltage output connection under the following conditions:

- Stabilized at 12 V or 24 V (or other values).
- The energy comes from the accumulator, the regulator being what permits the passage of the energy to the accumulator, depending on the status of the latter.

BATTERY

Connection of the accumulator in order to store the harnessed energy in the event of excess with regard to the amount being consumed, or for supplying energy in the opposite case, for example during the night.

CONTROL

Line via which the converter or regulator provides information on situations, such as status of the accumulator, of the output voltage, charging, discharging, etc.

In short, the regulator is the charge control device for the accumulator, since the utilization energy is always taken from the latter component.

Figure 2.5 shows its basic block diagram.

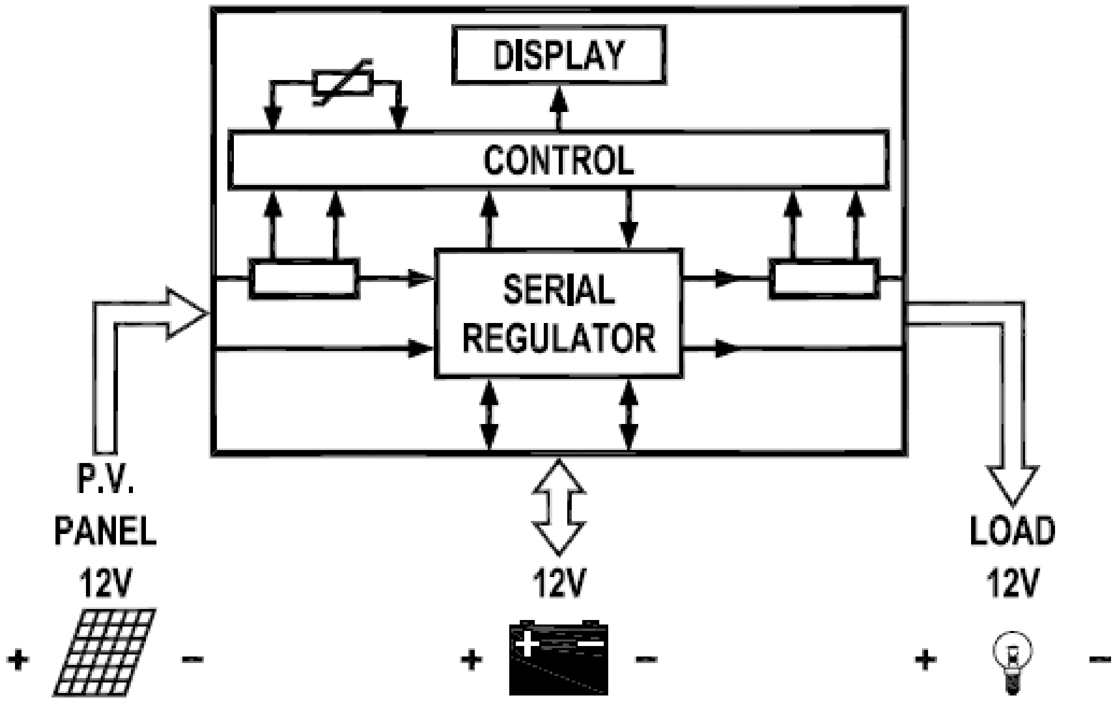


Fig. 2.5 - Block diagram of the regulator

2.3 ACCUMULATORS

The accumulator is the storage component for the energy of the installation during times of zero consumption or consumption less than the level provided by the photovoltaic harnessing system. It also acts as an energy reserve for when the contribution from the modules is less than the demand.

The accumulator has a highly important function in isolated installations of the type known as “weekend”, in which all the energy received during weekdays is stored in order to supply it at weekends and holidays. In this way the dimensioning of the modules can be made smaller, unlike the accumulator, which has to be large.

The accumulator included in the DL SUN-WIND trainer is of the solid electrolyte type (acid gel) in order to prevent possible spillages during practices.

The most important parameter of the accumulator is its capacity, implying a discharge current corresponding to a tenth of the rated value, which is represented in a graph like that of figure 2.6, which is an example.

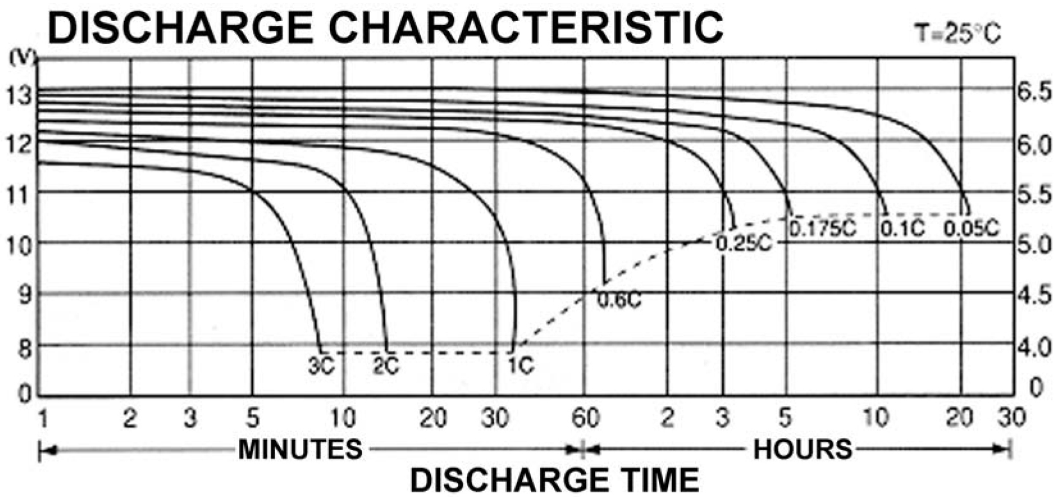


Fig. 2.6 - Example of discharge of an accumulator

The discharge hours correspond to the time in which the accumulator delivers all the determined current. So:

$$\text{Discharge hours} = \frac{\text{C100 (Ah)}}{X} \qquad X = \text{Hours}$$

It can be seen in the above graph that the voltage of the accumulator is higher than 12V, since it consists of six cells of 2.45V, giving a value of 13.7V.

Regarding the fundamental concepts of accumulators in relation to the applications, these are as follows:

- **Charge efficiency**

  This is the ratio between the energy used to charge the accumulator and that actually stored. If the efficiency is low a large number of photovoltaic modules will have to be used.

- **Self-discharge**

  This is the process by which the accumulator tends to discharge when not in use. The usual value is 3% a month.

- **Discharge depth**

  This refers to the value in percentage terms (%) of the energy that has been consumed in a single discharge by an accumulator that was fully charged.
  The accumulator must never be subjected to discharge processes that exceed 70%, since a discharged accumulator can be seriously damaged and lose a large part of its charge capacity.
  In a photovoltaic installation, an accumulator must be discharged by between 10 and 30% a day.

- **Charge and discharge cycles**

  In an installation the accumulator can be subjected to a series of work cycles; each cycle consists of discharging the accumulator followed by its subsequent recharging, which implies that it has to be designed to withstand the greatest possible number of charge-discharge cycles. This number of cycles reduces as the discharge depth increases.
  During the day, the modules generate the energy that is used to satisfy consumption and the surplus is accumulated. At night, the necessary energy for consumption is taken exclusively from the accumulators, thus completing a daily cycle of charge-discharge.
  During a period of cloudy days, a large part of the consumption is taken from the accumulator, which is unable to be recharged. Once these cloudy days have passed, the modules will recharge the accumulator though it will take several days before it reaches full capacity since consumption will continue to exist and so only part of the energy will be stored. This process is known as the autonomy cycle, and is calculated in advance depending on the type of use of the installation and on the safety criteria that are required. For example, in a weekend-type of installation the autonomy is usually 3 days and in one having application in telecommunications, such as repeaters or similar, the autonomy is extended to 10 days.

In these conditions, the safety margin is established as follows:

$$\frac{\text{C100 x days of autonomy}}{\text{Safety coefficient}}$$

Where:

C100 = Amperes of the accumulator in C100

- **Charge state. Voltage and density**

  The rated voltage of each element of a solar accumulator is 2V. Nevertheless, the real voltage depends on the charge state in which it is found. The voltage drops as the battery discharges and it increased when the latter is charging.

  The accumulator is considered to be fully charged when the voltage under no load per element is between 2.20 and 2.30 V.

- **Density**

  A complementary yet indispensable aspect for determining the good state of the accumulator is the density, since the voltage on its own does not reliably determine the state of the accumulator.

  The optimum density of a stationary accumulator is 1.24, though a working density can be considered of from 1.20 to 1.8, below which there is a risk of permanently exceeding 1.15 which is the critical density that considerably reduces the life of the accumulator.

EXP 4.1: Charging battery using solar panel

Objective of the exercise

• Charge the battery using solar energy.

• Learn the importance of the battery as a storage device in solar panel systems.

• Learn the battery charge regulator basics.

Equipment used:

1 ________

2 ________

3 ________

4 ________

5 ________

6 ________

Practical procedures :

1- Write the rating values such as named voltage of each device, by reading it from the name plate on the device, or search it on the data sheet of the device, and fill the following table:

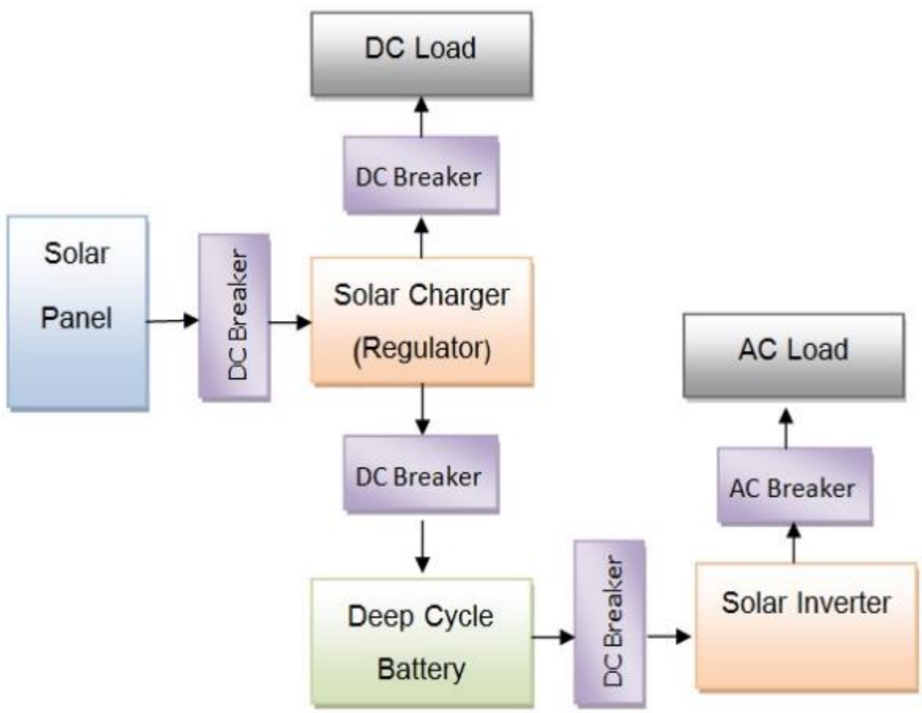
Device	**Current type electricity**	**Voltage difference**		**Named voltage**	**Current**		**Power**
Solar panel							
Battery							
Charge regulator input							
Charge regulator output							
Inverter input							
Inverter output							
C.B 1							
C.B 2							
C.B 3							
C.B 4							
C.B 5							
Light load 1							
Light load 2							
Light load 3							

2- Be sure that all device is working in suitable voltage and current range , same named value , and based on some specification such as :

a) The charge regulator must covered the Voc and Isc of solar panel , in addition , adding a safety factor 25%
b) The charge regulator must covered the battery voltage , which must be less than solar panel voltage at all cases that make an energy production
c) The inverter must covered the max. voltage of the battery , knowing that battery voltage will increase with increasing the time of charging, and the high charging levels of battery (equalization)
d) The loads must be able to work in the devices voltage range
e) The circuit breaker must covering the normal current and the short circuit current

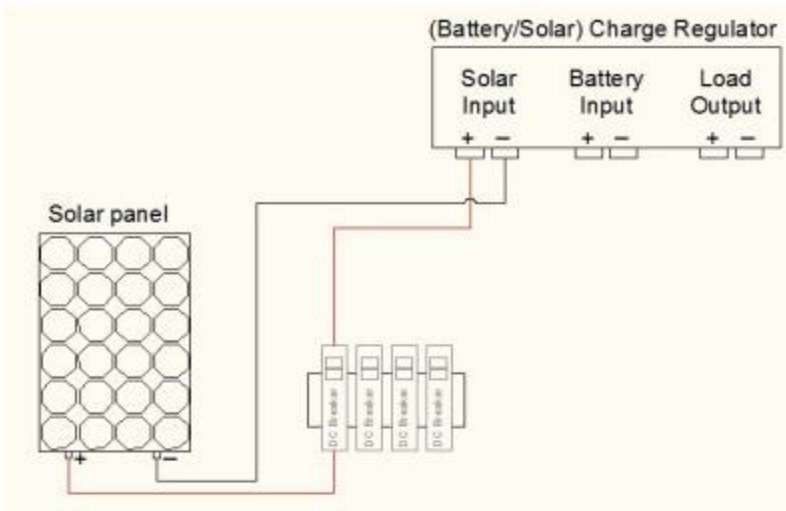
$$\text{breaker capacity(A)} = \frac{\text{Maximum power}}{Minimum\ voltage} * 1.4$$

f) Draw an outline diagram describe the connection between the devices using the following schematic diagram :

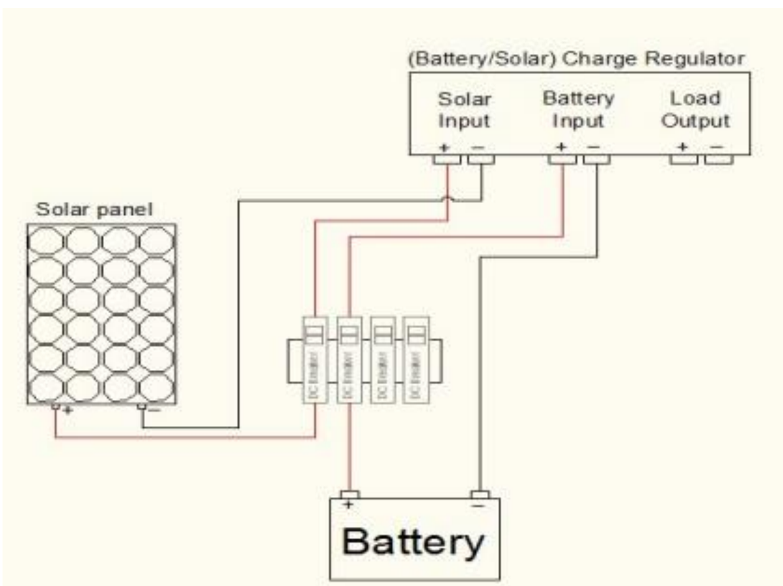


3- Connect the devices as the following steps :

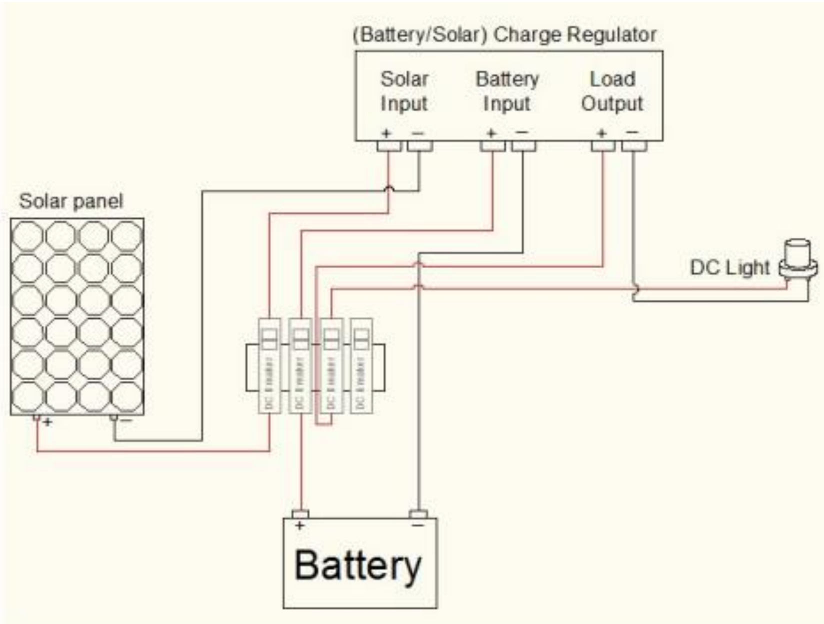
a) Connect the solar panel with C.C through a dc C.B



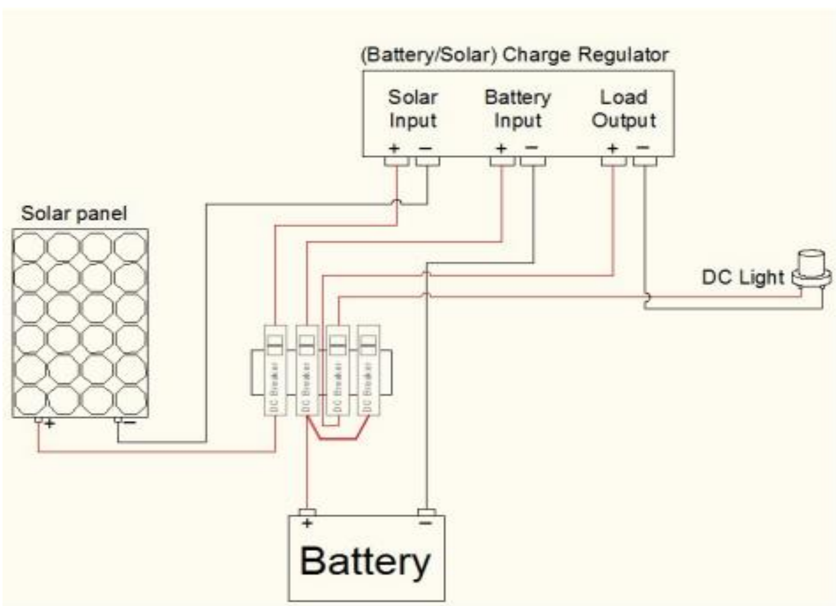
b) Connect the battery with C.C through a dc C.B

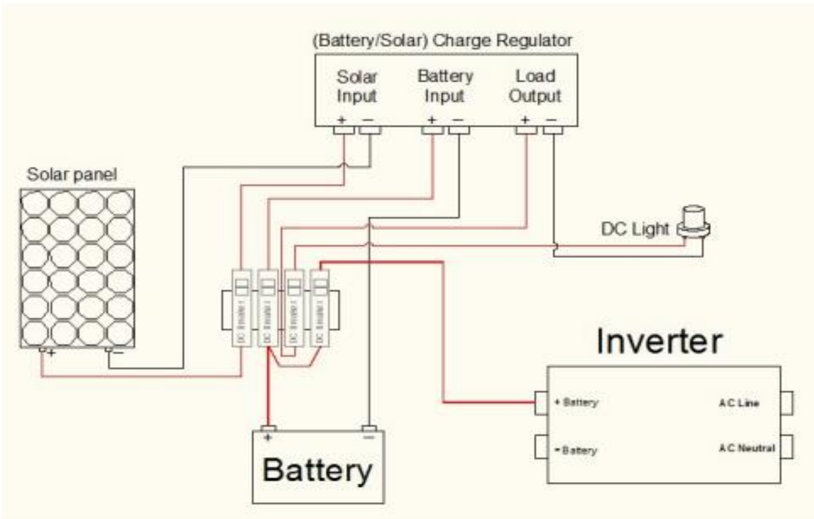


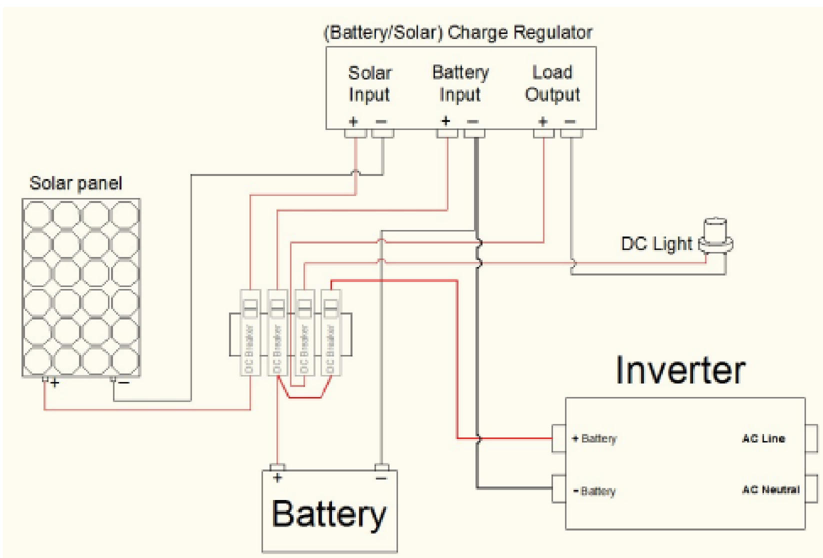
c) Connect the dc load with C.C through dc C.B



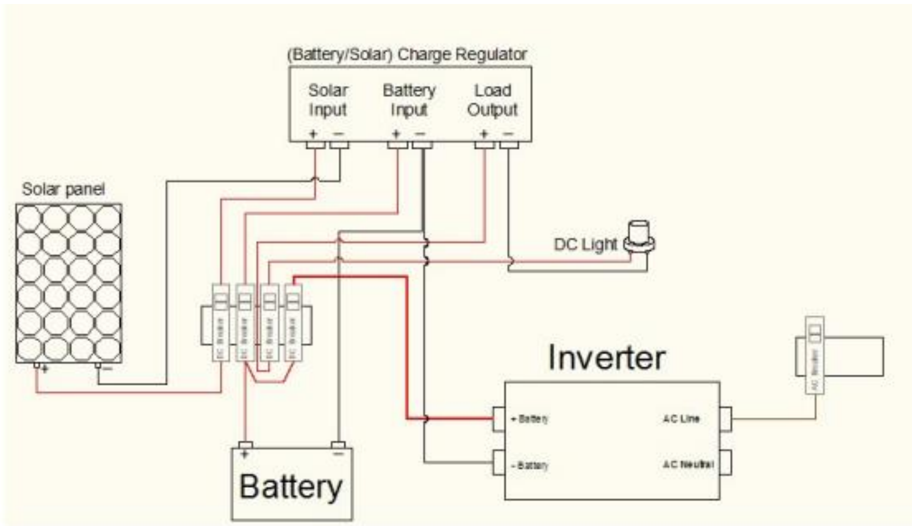
d) connect the battery with dc input of the inverter using dc C.B

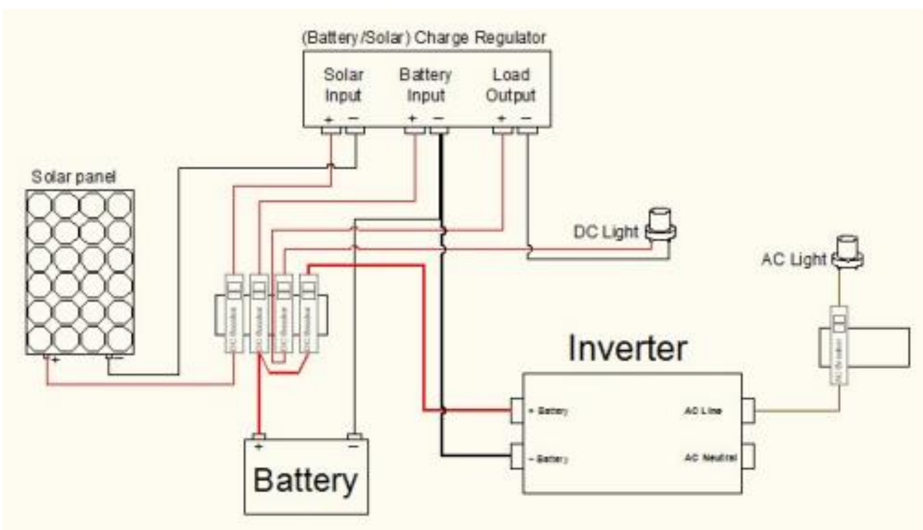


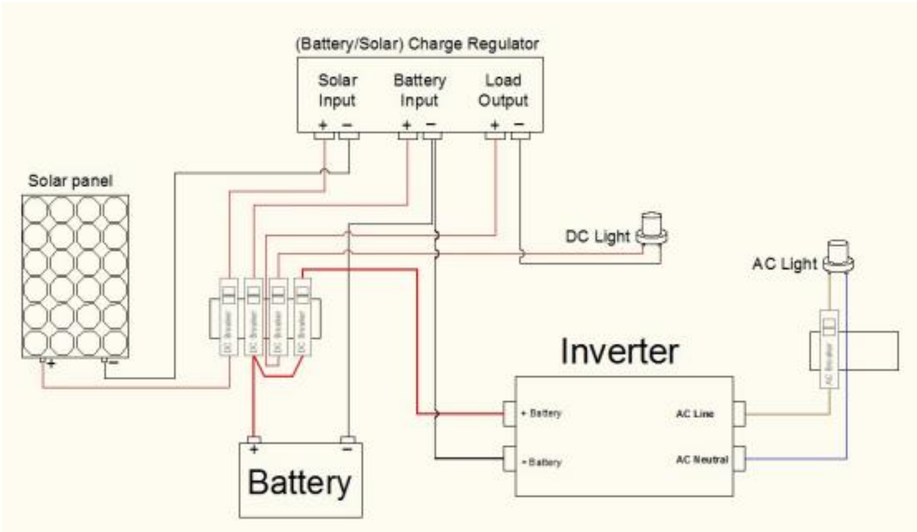

(Battery/Solar) Charge Regulator
Solar Input
Battery Input
Load Output
Solar panel
DC Light
Inverter
+ Battery
- Battery
AC Line
AC Neutral
Battery


(Battery/Solar) Charge Regulator
Solar Input
Battery Input
Load Output
Solar panel
DC Light
Inverter
+ Battery
- Battery
AC Line
AC Neutral
Battery

e) connect the AC terminal of the inverter with AC load through an AC C.B



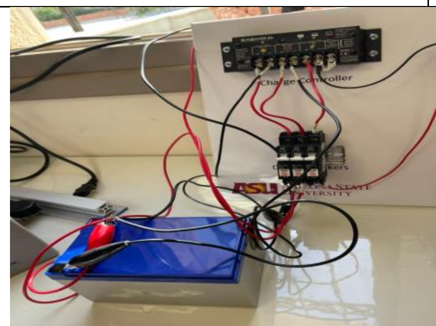
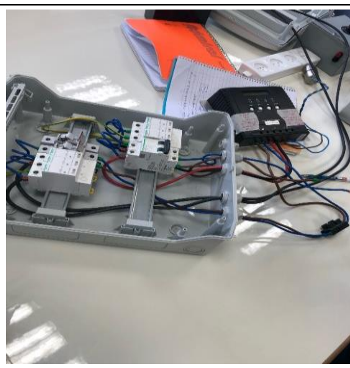
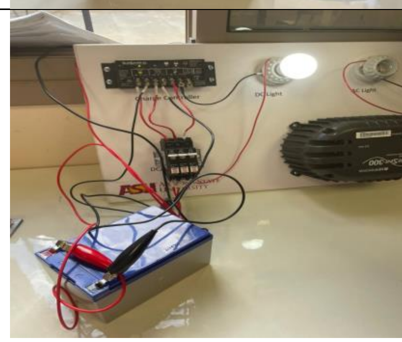
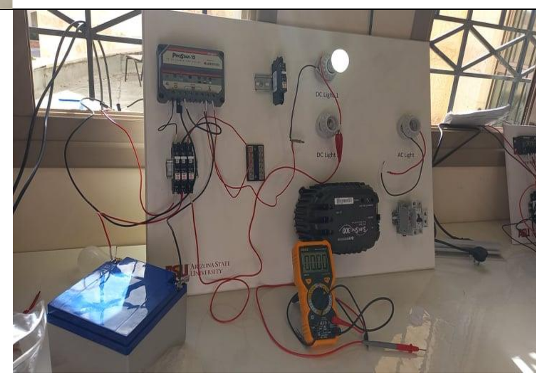
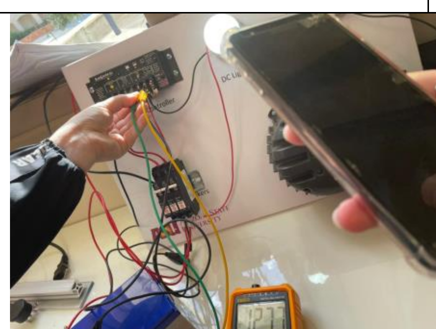
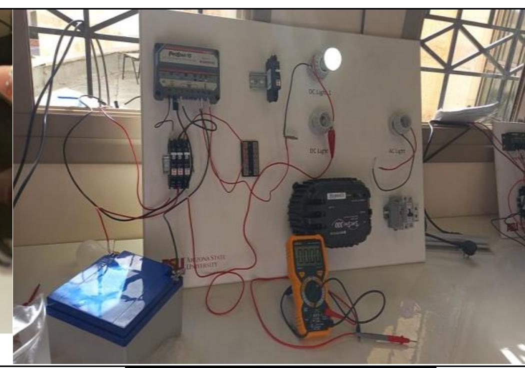




f) first turn on the battery C.B , then the solar C.B , then the DC load C.B , then the DC inverter C.B , then the AC load C.B (in this arrangement)

practically : the students work in different teams , with different devices, the working is by filling the following table with their data, results, and required information

<table>
<tr><th>Connection</th><th>Team 1</th><th>Team 2</th><th>Team 3</th></tr>
<tr><td>Solar panel type</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>PV rating</td><td>Pp=165w
V=18.5V
I=8.9A
Vo.c=22.1V
I=9.15A</td><td></td><td></td></tr>
<tr><td>Charge regulator type</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>Charge regulator rating</td><td>Rated battery = 12/24v
Rated current =30A
Vo.c=0-24v
24-38v</td><td></td><td></td></tr>
<tr><td>Battery type</td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td>load type</td><td></td><td></td><td></td></tr>
<tr><td>Protection 1</td><td></td><td></td><td></td></tr>
<tr><td>Protection 2</td><td></td><td></td><td></td></tr>
<tr><td>Total connection</td><td></td><td></td><td></td></tr>
<tr><td>Results</td><td>
</td><td></td><td></td></tr>
<tr><td>Tables</td><td><table>
<tr><td>V.bat.</td><td>B</td><td>Power solar</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table></td><td><table>
<tr><td></td><td></td></tr>
<tr><td>Load</td><td></td></tr>
<tr><td>Battery</td><td></td></tr>
<tr><td>Solar panel</td><td></td></tr>
</table></td><td><table>
<tr><td>V pv</td><td>V batt.</td><td>V load</td></tr>
<tr><td></td><td></td><td></td></tr>
</table></td></tr>
</table>

EXP 4.2 : Charging Battery

1-Using Solar Panel to Charge the Battery

Required equipment

Solar panel, battery, protective module (DL 9014), measurement module (DL 9021), charge regulation module (DL 9012)

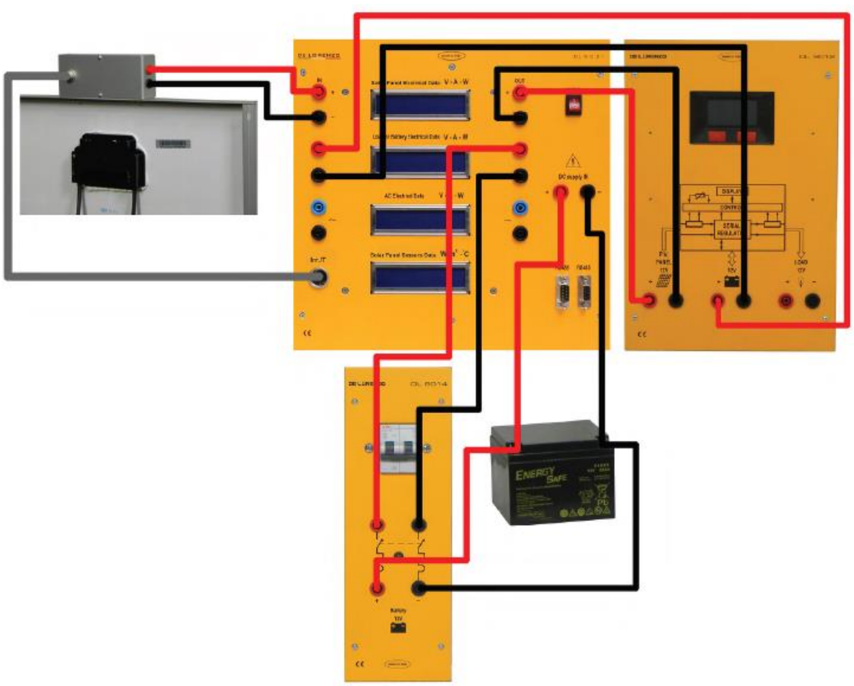
Introductory examples

1. Which type of energy is stored in the battery?

____

2. Draw the symbol of the battery which contains three serially connected 1.2 cells. What is the voltage of this battery? _______ V

Drawing

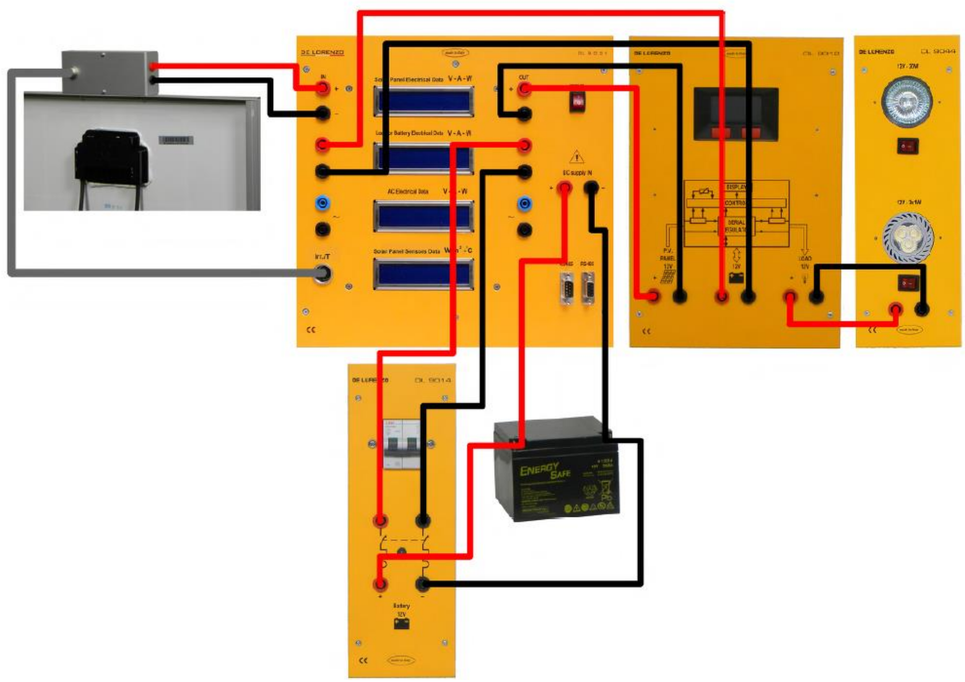


2- Using Solar Panel and Battery to Power DC Load

Objective of the exercise

• Use both solar power and energy stored in the battery to power the DC load.

• Learn the importance of the battery as a storage device in DC load Systems



Follow the described procedure and fill in the following table.

1. Find the position in which the solar panel provides highest irradiation (read the azimuth using compass and inclination using the angle-meter built-in to the side of the solar panel): ______° from the north and ______° from the horizontal position.

2. Enable the breaker of the DL 9014 module, to connect the battery to the circuit.

3. Switch on the halogen lamp.

4. Using **<u>the charge regulation</u>** module DL 9012 **read the voltage of the**

battery.

5. Using **<u>the charge regulation</u>** module DL 9012 **read the load current flow.**

6. Calculate the **lamp power.**

7. Using the **<u>charge regulation</u>** module DL 9012 read **the solar panel to battery current flow**.

8. Switch off the halogen lamp and switch on the LED lamp.

9. Repeat points 4-7.

10. Switch on the halogen lamp.

11. Repeat points 4-7.

12. Disable the breaker of the DL 9014 module, disconnecting the battery from the circuit.

	Halogen	LED	Halogen + LED
Voltage (V)			
Load current (A)			
Power (W)			
Solar panel to battery current (A)			

13. Disconnect the solar panel.

14. Repeat points 2-11 and fill

	Halogen	LED	Halogen + LED
Voltage (V)			
Load current (A)			
Power (W)			
Solar panel to battery current (A)			

2.4 DC/AC CONVERTERS

The need for alternating voltage with standardized values of frequency and amplitude for supplying domestic appliances has led to the incorporation into photovoltaic installations of what is known as the direct to alternating (DC/AC) converter or **inverter**, which is the more widely used term.

This is a device based on an oscillator at the mains frequency (50 or 60 Hz) and on a final electronic switch in which various inductive components intervene in order to provide the stated alternating voltage. Figure 2.7 shows a basic block diagram of this device, with accords with the stated architecture.

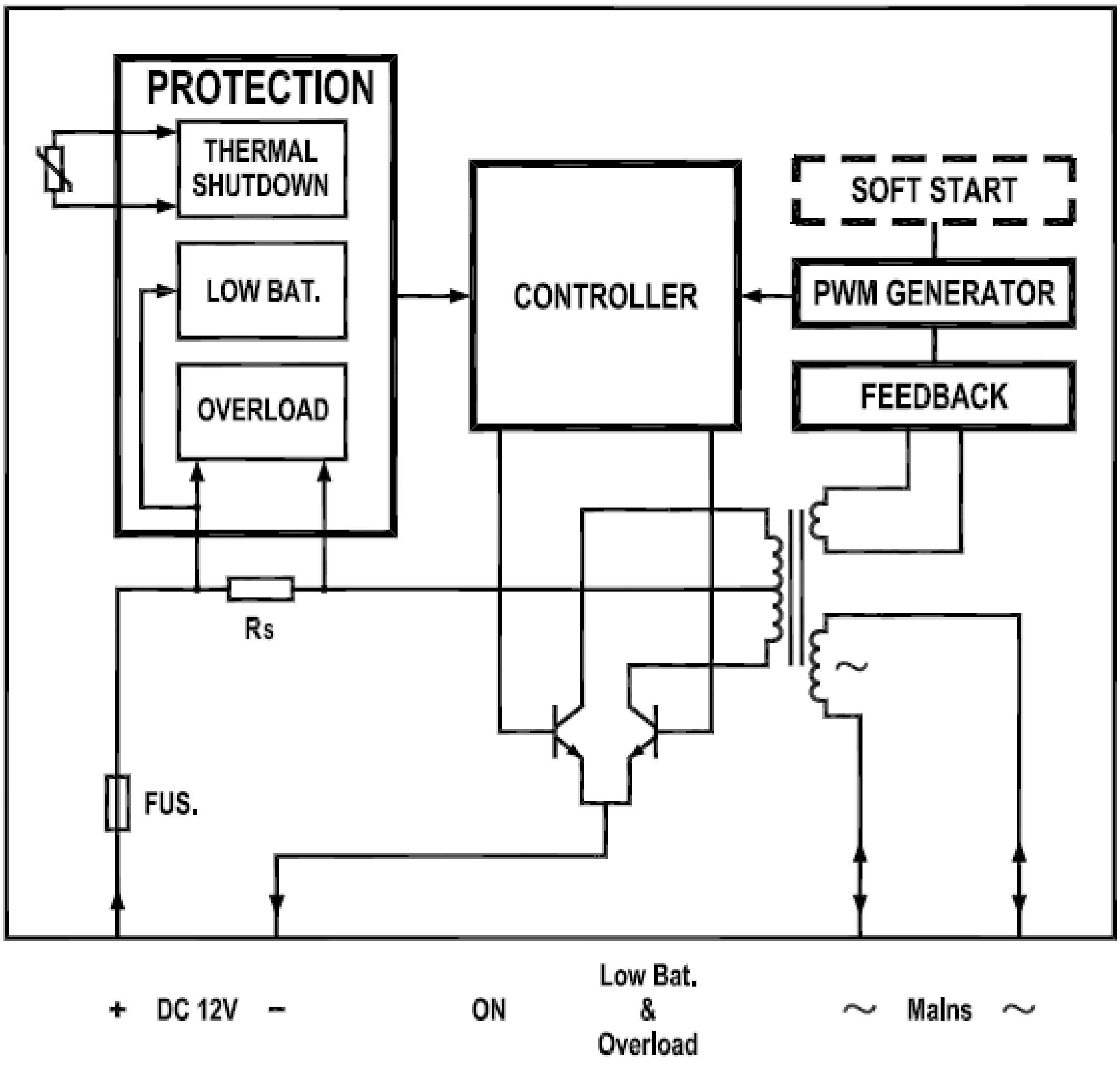


Fig. 2.7 - Basic block diagram of the converter

There exist two types of DC/AC converters or commercial inverters, differentiated by the output waveform, which are the following:

SEMI-SINE WAVE OUTPUT

Some DC/AC converters are referred to in this manner, when their alternating voltage output is formed by discreet amplitude patterns.
They are based on the PWM modulation (Pulse Width Modulation) of their power stage, and their semiconductors work in a commutation mode. They are characterized by low cost, high performance and reduced size, however their output wave form limits their use to equipment with resistive, non-inductive load characteristics. It is not recommended to use power from these converters to operate low noise equipment, such as HI-FI.
For inductive load (such as motor), the soft start function allows a reduced consumption at start up.

SINE WAVE OUTPUT

This type of DC/AC converter provides continuous-time sine waves, just like grid electricity.
Its power stage is formed by transistors that receive sine waves from the oscillator and thus operate in a linear mode, not in commutation like the previous, and by a transformer whose secondary provides the indicated alternating voltage.
The volume of this converter is greater than the previous, because it includes a transformer, its energy performance is less because the transistors operate in a linear manner, and naturally, its price is higher.
This type of converter is required when it is necessary to supply power to equipment with inductive components, and very low noise equipment.

GENERAL GUIDELINES

Make sure not to exceed the input voltage (see “Technical Specifications”). · When connecting the inverter with audio equipment, it is possible to hear noise through the speakers. This is not due to a faulty inverter. Cheaper audio devices are generally equipped with inferior noise filters. The inverter produces its signal at a high frequency and this high frequency signal can be equal to the audio signal. You can correct this by placing a decent filter.

REMARK

It is not recommended to connect small devices powered by batteries to the inverter with modified output. These devices can be damaged or can damage the inverter. · Do not connect rapid chargers to the inverter with modified output. These devices can be damaged or can damage the inverter. Connect these devices to an inverter with a pure output.
Switching power supplies (e.g. power supplies for laptops) can be damaged or can damage the inverter. Some power supplies only operate with a pure sine wave.
Lots of devices need a larger amount of power during the start-up period (switch-on power). This power can be several times more important than the operating power. You will usually find this phenomenon with devices of the “inductive” type, like motored devices. A 600W electric drill can easily need 1800W of switch-on power! With some devices the power will be much higher than the mentioned power.
Multiply the device’s operating power by 3.
This value has to be inferior to the continuous (maximum) power of the inverter.
Operating power of the device x 3 < inverter’s capacity

2.4.1. Characteristics of DC/AC converters

DC/AC converters are differentiated by a set of technical specifications among which the most notable are the following:

INPUT VOLTAGE	Range of input direct voltage that can be applied to the converter (for example, 10.5 – 16 V).
OUTPUT VOLTAGE/FREQUENCY	Rated values of the output alternating voltage and its corresponding frequency.
RATED POWER	This parameter refers to the power stated in watts which the converter can provide in direct mode.
PEAK POWER	Power which the converter can provide during a specified time (for example, Wp = 370 W during 2 minutes).
STARTING POINT	This corresponds to the power that the converter can provide in an instant, in other words, during the moment of the demand for consumption if this is inductive/reactive, which can reach up to 300% of the rated figure.
EFFICIENCY	Ratio of energy transfer between input and output expressed as %. It corresponds to the quotient between the energy consumed by the input circuit and the input to the charge as the output. Some converters can achieve an efficiency of 95%, which implies an energy loss of 5%.

PROTECTION AND CONTROL	This parameter corresponds to the features provided by the equipment for protection of the output voltage and control of its circuits. The most notable of these are the following: • Protection by disconnection of the output circuit in case of short-circuits, excess consumption or high temperature. • Warning of low input voltage. • Warning of insufficient input current for the consumption that is demanded. Control via series port of the input and output parameters of the converter.
SOFT START FUNCTION	Inverters with soft-start circuit inverter are intelligent, in fact, before generate the nominal output voltage perform a check of the connected load, and only if everything is in place provide output voltage. This check takes about few seconds. The output voltage also does not appear immediately on the user control, but increases in a linear mode from zero to the rated voltage in 1-2 seconds. Thanks to this operation, when a motor, a refrigerator, an air conditioner, or at least an inductive load, the strong inrush current that would normally require these types of users at the start, is provided by the inverter in a gradual manner in order to allow starting.

2.4. Solar Panel Voltage-Irradiation Curve, Current-Irradiation Curve and Resistance of the Solar Panel

Objective of the exercise

- Investigate how the solar irradiation influences the solar panel output voltage.
- Investigate how the solar irradiation influences the solar panel short-circuit current.
- Measure the solar panel resistance.

Required equipment

Solar panel, DC power source (DL 9032), solar panel measuring unit (DL 9021)

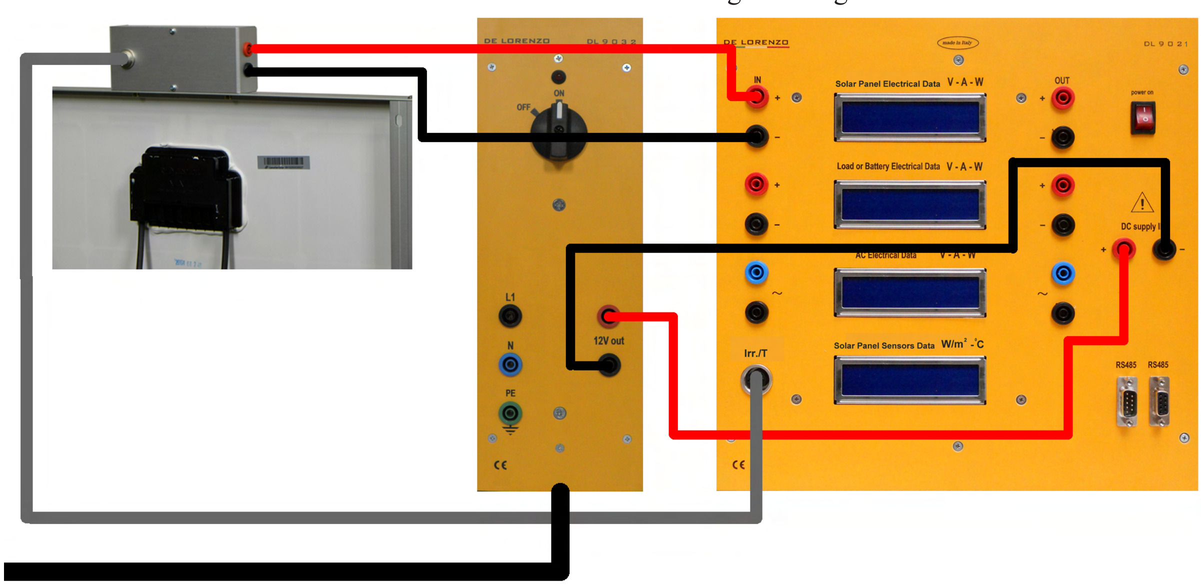
Introductory examples

1. At irradiation 1 kW/m^2 a solar cell provides maximum power at loading 10 Ω and voltage 0.48 V. The area of a solar cell is 6 cm^2. Calculate the efficiency of a solar cell.

Calculation area:

Exercise 1: Obtaining the solar panel voltage-irradiation curve

Connect the module according to the figure 2.4-1.



2.4-1 Connection scheme of exercise 1

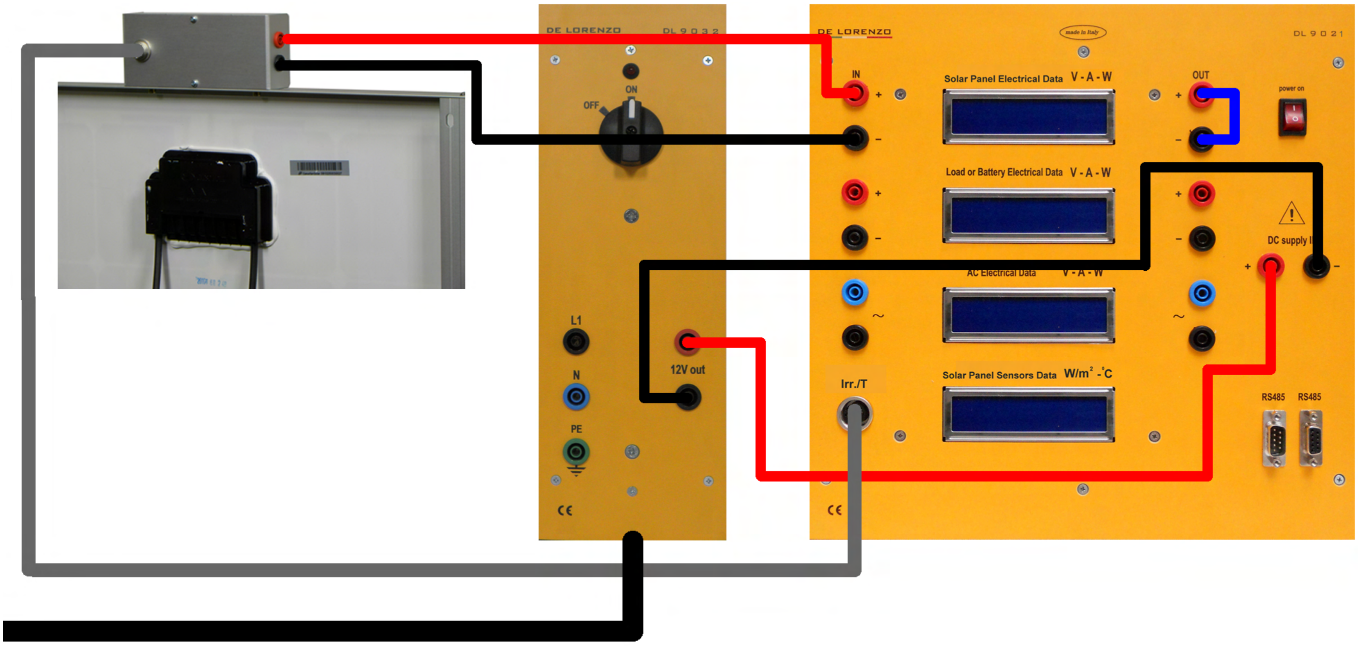
1. Find the position in which the solar panel provides highest irradiation (read the azimuth using compass and inclination using the angle-meter built-in to the side of the solar panel): _____ ° from the north and _____ ° from the horizontal position.
2. Fill in the first row in the table.
3. Change the inclination and direction of the solar panel in order to obtain at least 8 different irradiation values (between zero and maximum irradiation value). Fill in the output voltage of the solar panel for each of them in the table.
4. Draw the voltage-irradiation graph.

Irradiation (W/m^2)	Voltage (V)

5. Find the position in which the solar panel provides highest irradiation again.
6. Measure the open-circuit voltage: ______ V.

Exercise 2: Calculating the inner resistance of the solar panel

Connect the module according to the figure 2.4-2.



2.4-2
Connection scheme of exercise 2

Irradiation (W/m²)	Current (A)

1. Find the position in which the solar panel provides highest irradiation (read the azimuth using compass and inclination using the angle-meter built-in to the side of the solar panel): ________° from the north and ________° from the horizontal position.
2. Fill in the first row in the table.
3. Change the inclination and direction of the solar panel in order to obtain at least 8 different irradiation values (between zero and maximum irradiation value). Fill in the short-circuit current of the solar panel for each of them in the table.

4. Draw the current-irradiation graph.

5. Find the position in which the solar panel provides highest irradiation again.
6. Measure the short-circuit current: _______ A.
7. Using the open-circuit voltage from point 6 of the previous exercise, calculate the solar panel inner resistance: ________ Ω.

Questions for evaluation

1. Is the connection between the output voltage and the irradiation of the solar panel linear?

____

2. At which irradiation value does the saturation occur?

____

2.5. Current-Voltage Characteristics of the Solar Panel

Objective of the exercise

- Obtain the current-voltage graph of the solar panel.

Required equipment

Solar panel, DC power source (DL 9032), rheostat (DL 9018), solar panel measuring unit (DL 9021)

Introductory examples

1. Draw the typical current-voltage curve of a solar cell and mark the typical points on it (maximal voltage and maximal current, short-circuit current, open-circuit voltage and maximum power point).

2. If the open-circuit voltage is 0.65 V, and short-circuit current is 3 A, what is the value of the solar cell inner resistance?

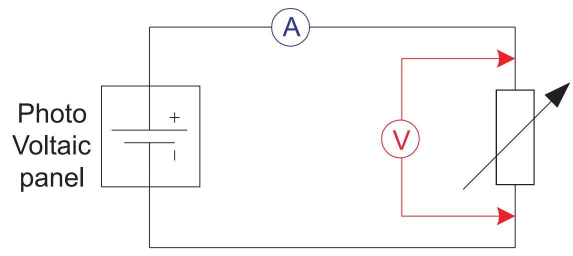
Calculation area:

3. If we know that I_{SC} is 110% of the value of maximum current of the solar panel, and that U_{OC} is 105% of the maximal voltage, what is the fill factor of the solar cell? Is this a good cell?

Calculation area:

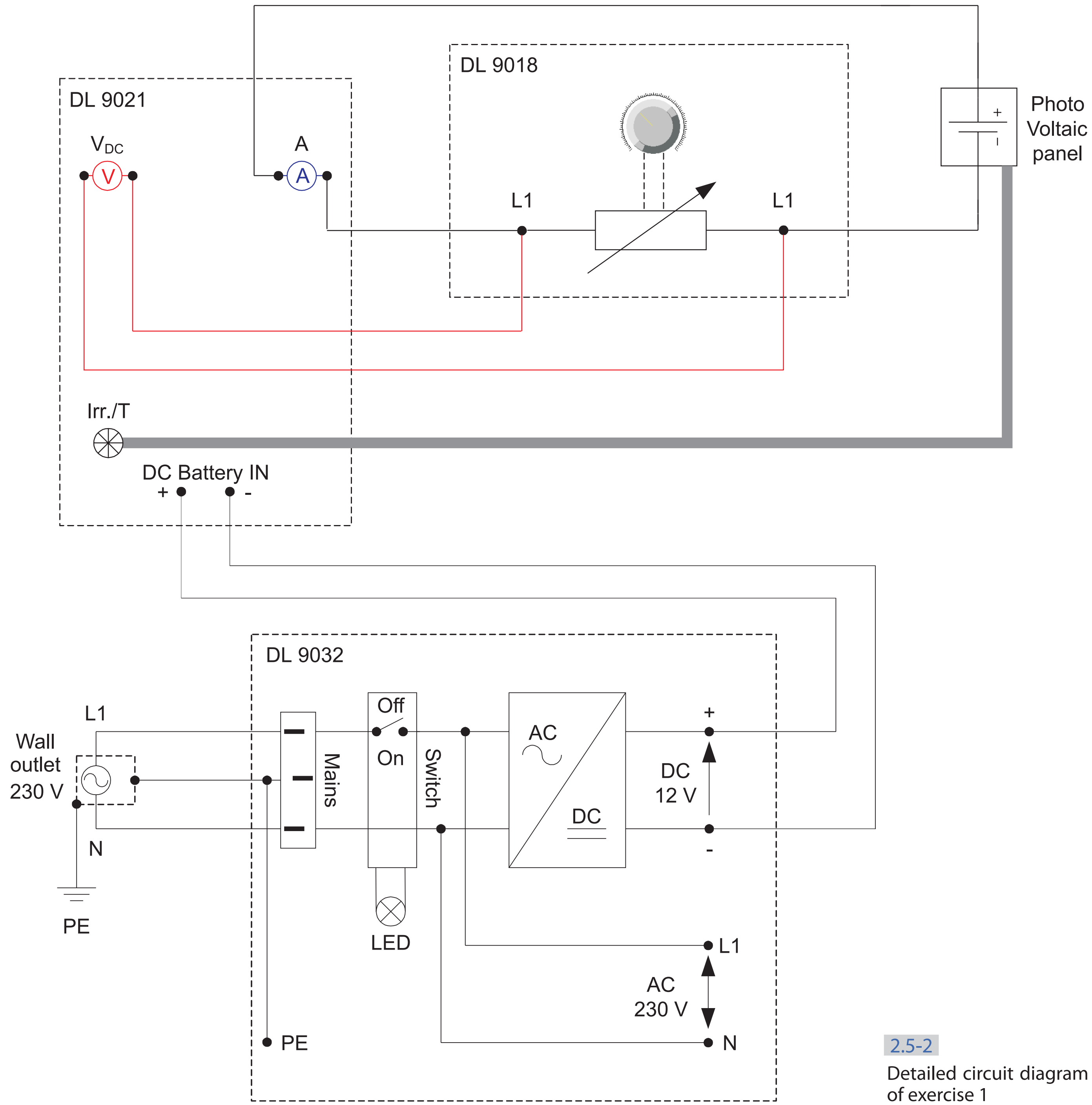
Exercise 1: Obtaining the solar panel current-voltage curve

The circuit diagram of this exercise is provided in figure 2.5-1, while figure 2.5-2 provides a detailed circuit scheme.



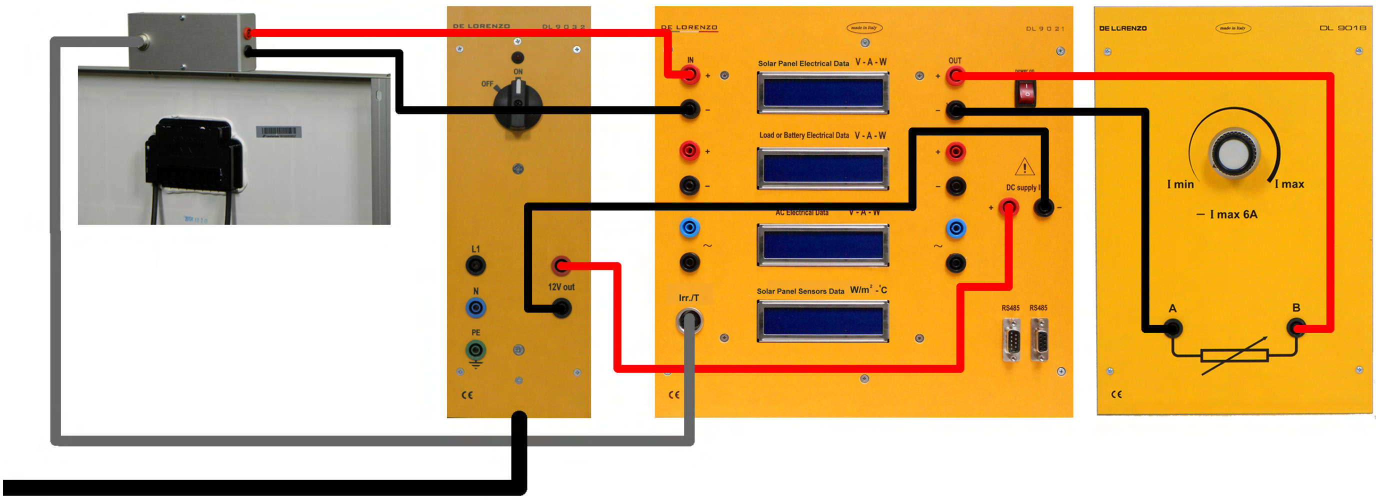
2.5-1

Circuit diagram of exercise 1



2.5-2
Detailed circuit diagram of exercise 1

Connect the module according to the figure 2.5-3.



2.5-3
Connection scheme of exercise 1

Resistance of the rheostat (%)	Current (A)	Voltage (V)
100		
90		
80		
70		
60		
50		
40		
30		
20		
10		
0		

1. Find the position in which the solar panel provides highest irradiation (read the azimuth using compass and inclination using the angle-meter built-in to the side of the solar panel): ______° from the north and ______° from the horizontal position.
2. Set the rheostat to the maximum resistance position.
3. Fill in the values of voltage and current into the table.
4. Lower the resistance of the rheostat to app. 90% and fill in the values of voltage and current into the table.
5. Repeat point 4 in 10% steps until reaching the minimum resistance position of the rheostat.

Resistance of the rheostat (%)	Current (A)	Voltage (V)
100		
90		
80		
70		
60		
50		
40		
30		
20		
10		
0		

6. Change the inclination and direction of the solar panel in order to obtain app. 75% of the maximum irradiation. Repeat the procedure described in points 2-5.

Resistance of the rheostat (%)	Current (A)	Voltage (V)
100		
90		
80		
70		
60		
50		
40		
30		
20		
10		
0		

7. Change the inclination and direction of the solar panel in order to obtain app. 50% of the maximum irradiation. Repeat the procedure described in points 2-5.

Resistance of the rheostat (%)	Current (A)	Voltage (V)
100		
90		
80		
70		
60		
50		
40		
30		
20		
10		
0		

8. Change the inclination and direction of the solar panel in order to obtain app. 25% of the maximum irradiation. Repeat the procedure described in points 2-5.

9. Draw the current-voltage graph for all 4 irradiation scenarios.

Questions for evaluation

1. In which two specific parts can the current-voltage graph be divided?

2. Which is the point of maximum power in the current-voltage graph?

3. Which way does solar irradiation determine the current-voltage graph?

2.6. Solar Panel Electricity Delivered to the Mains Grid

Objective of the exercise

• Measure the electricity delivered to the mains grid.

Required equipment

Solar panel, DC power source (DL 9032), protective module (DL 9031), solar panel measuring unit (DL 9021), grid tie power inverter (DL 9013G), AC measurement module (DL 9030)

Introductory examples

1. How does the grid tie power inverter operate?

____

2. When does the island operation occur?

____

3. Solar panel produces constantly 100 W of electricity during one hour. If the grid tie converter uses 2 W of electricity, how much electricity is delivered to the mains grid during that hour?

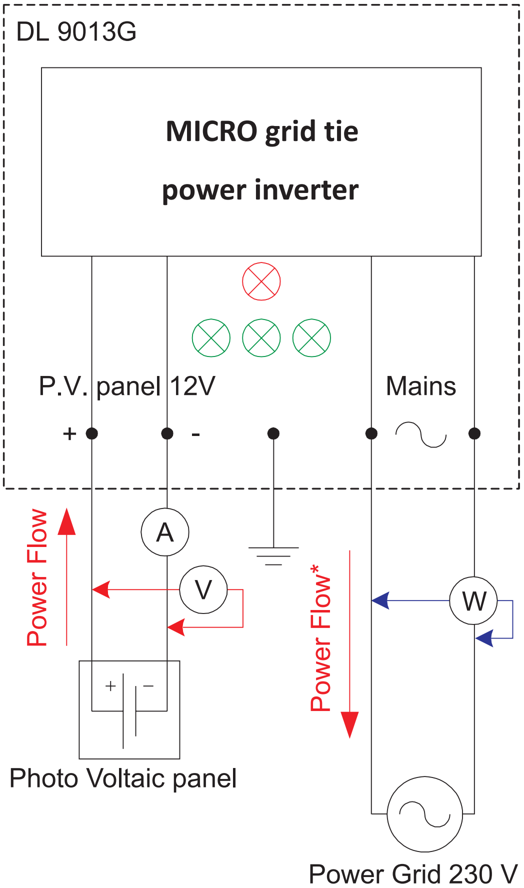
Calculation area:

4. If the solar electricity is subsidized with 0.48 €, what is the revenue in the example in point 3?

Calculation area:

5. If the solar panel with capacity 2 kW has 2 Sun peak hours daily in average throughout a year, and solar electricity is subsidized with 0.50 €, what is the revenue of this solar plant?

Calculation area:



2.6-1
Circuit diagram of exercise 1

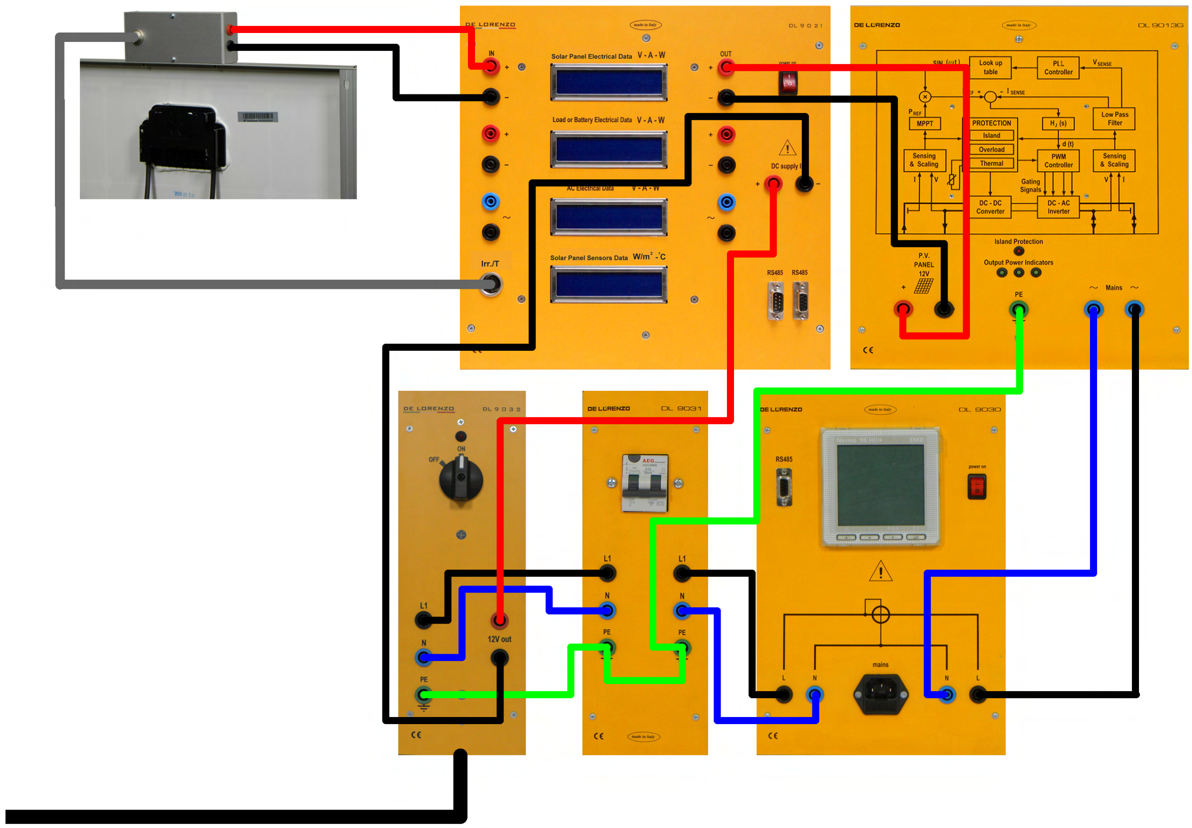
Exercise 1: Measuring the electricity delivered to the mains grid

The circuit diagram of this exercise is provided in figure 2.6-1.

Connect the module according to the figure 2.6-2.

Note

* If PV panel produces no power then DL9013G takes power from the grid to work properly (less than 0.5 W)



2.6-2 Connection scheme of exercise 1

Note

DL 9021 module contains AC wattmeter, and solar panel produced DC power. Therefore, we can not measure the solar panel power directly. The power is calculated by multiplying voltage and current measured with DL 9021 module.

Irradiation (W/m²)	Current (A)	Voltage (V)	Delivered electricity (W)

1. Find the position in which the solar panel provides highest irradiation.
2. Using DL 9030 read the value of electricity being delivered to the mains grid.
3. Fill in this value into the table.
4. Set the solar panel in order to obtain the irradiation app. 90% of the highest irradiation value and fill in the appropriate row in the table.
5. Repeat point 4 in 10% steps until reaching the minimum irradiation is reached, i.e. 0 W/m².

6. Draw the delivered electricity-irradiation graph.

Questions for evaluation

1. How does the irradiation influence the electricity delivered to the mains grid? Is this relation linear?

2. If the subsidized price of electricity produced by the solar panel is 0.52 €, how much would we earn selling the electricity from the solar panel in one hour?

Calculation area:

2.7. Solar Panel Supplying Load

Objective of the exercise

- Supply the load with both the electricity from the solar panel and from the mains grid.
- Measure the electricity produced by the solar panel and supplied from the mains grid.
- Evaluate the scale of the loads that can be supplied by the electricity produced by the solar panel.

Required equipment

Solar panel, DC power source (DL 9032), protective module (DL 9031), solar panel measuring unit (DL 9021), loads module (DL 9017), grid tie power inverter (DL 9013G), AC measurement module (DL 9030)

Introductory examples

1. How can the DC electricity produced by the solar panel supply the AC loads?

   ____

   ____

2. How is the electricity produced by the solar panel synchronized with the mains grid electricity?

   ____

   ____

3. Which error occurs if the mains grid is disconnected from the grid tie inverter?

   ____

4. The solar panel with capacity 3 kW has 3 Sun peak hours daily in average throughout a year. The price of electricity is 0.05 €/kWh, and the household uses 8450 kWh per year.

   a. How much is saved on electricity bill because the part of electricity is supplied by the solar panel?

   b. If investment for the solar module is 15 000 €, what is the return of investment period?

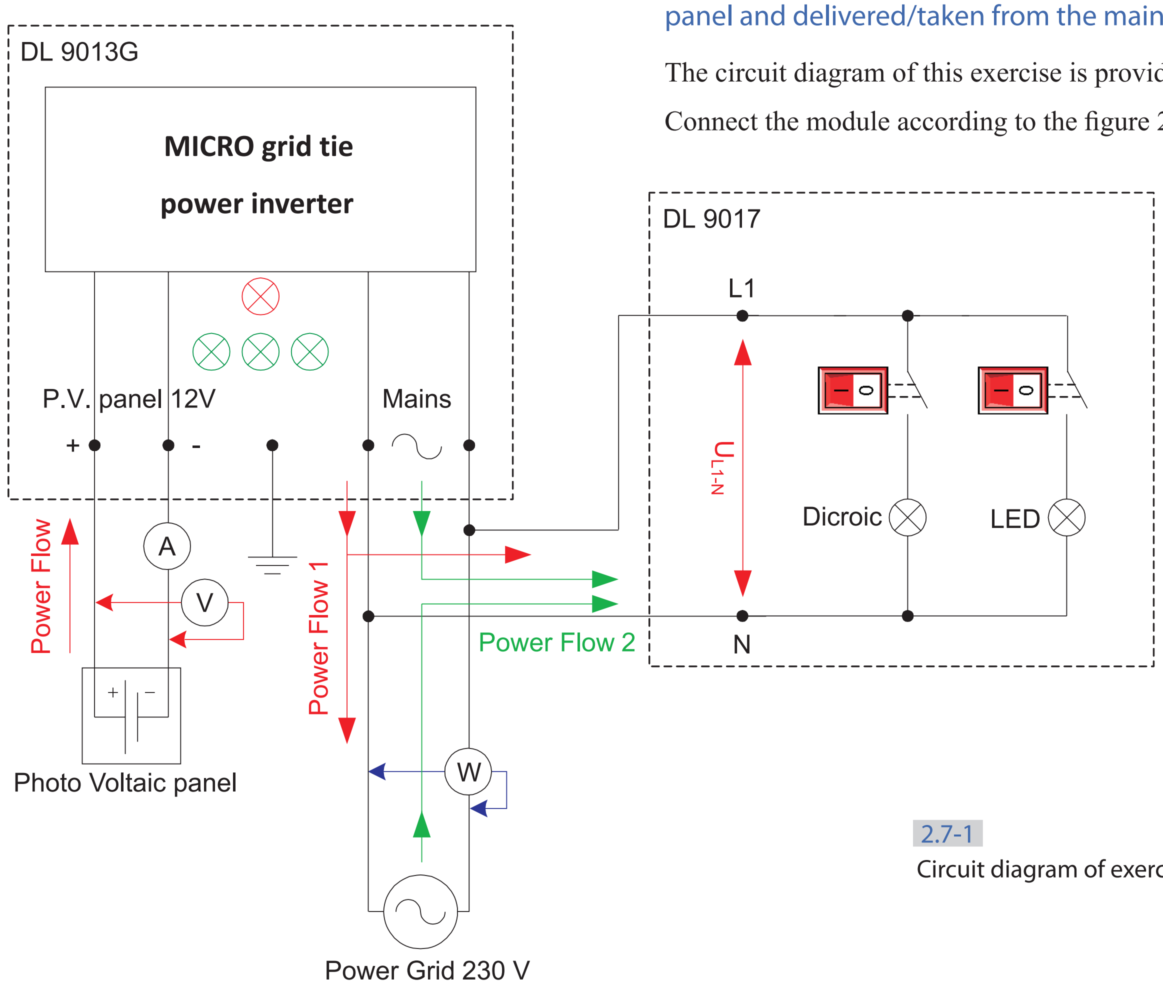
   c. If all electricity that household uses is supplied from the mains grid, and all the electricity produced by the solar panel is sold to the distribution network for 0.55 €/kWh, what is the return of investment period for a solar panel in this case?

Calculation area:

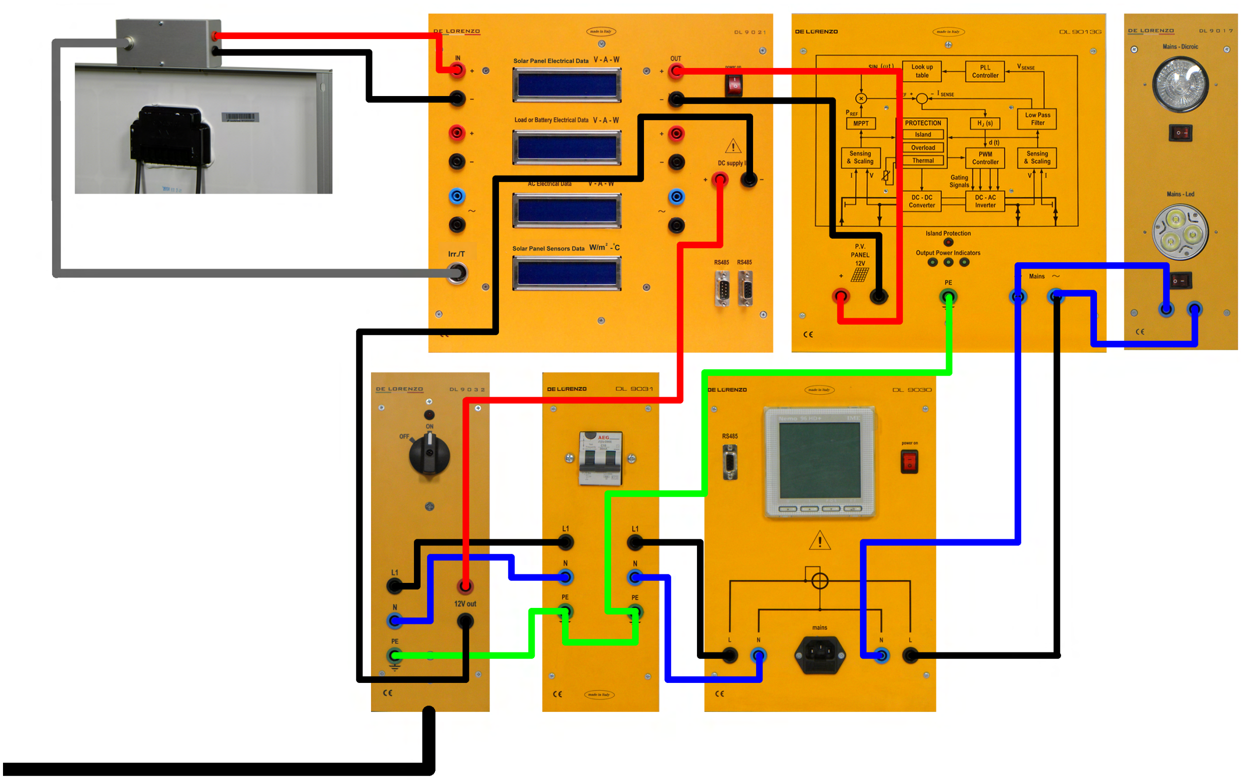
Exercise 1: Measuring the electricity produced by the solar panel and delivered/taken from the mains grid

The circuit diagram of this exercise is provided in figure 2.7-1.

Connect the module according to the figure 2.7-2



2.7-1
Circuit diagram of exercise 1



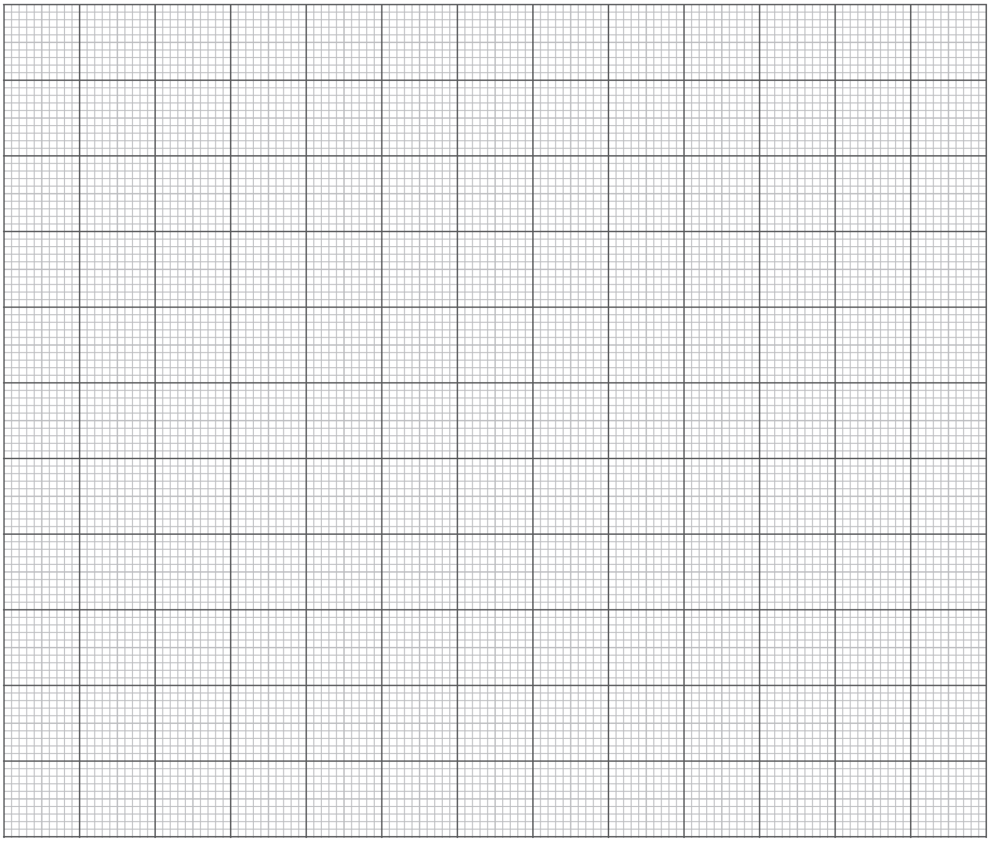
2.7-2
Connection scheme of exercise 1

> **Note**
>
> DL 9021 module contains AC wattmeter, and solar panel produced DC power. Therefore, we can not measure the solar panel power directly. The power is calculated by multiplying voltage and current measured with DL 9021 module.

1. Find the position in which the solar panel provides highest irradiation.
2. Switch on the LED lamp on DL 9017 module.
3. Use DL 9021 to read the value of power produced by the solar panel and DL 9030 to read the value of power being delivered to the mains grid.
4. Fill in the produced and delivered electricity values in case of LED lamp turned on in first row of the table.
5. Switch off the LED lamp and turn on the dichroic lamp on DL 9017 module.
6. Use DL 9021 to read the value of power produced by the solar panel and DL 9030 to read the value of power being delivered to the mains grid.
7. Fill in the produced and delivered electricity values in case of dichroic lamp turned on in first row of the table.
8. Switch on both the LED lamp the dichroic lamp on DL 9017 module.
9. Use DL 9021 to read the value of power produced by the solar panel and DL 9030 to read the value of power being delivered to the mains grid.
10. Fill in the produced and delivered electricity values in case of both LED lamp and dichroic lamp turned on in first row of the table.
11. Set the solar panel in order to obtain the irradiation app. 90% of the highest irradiation value and fill in the appropriate row in the table.
12. Repeat points 2-10 in 10% steps until reaching the minimum irradiation is reached, i.e. 0 W/m^2.

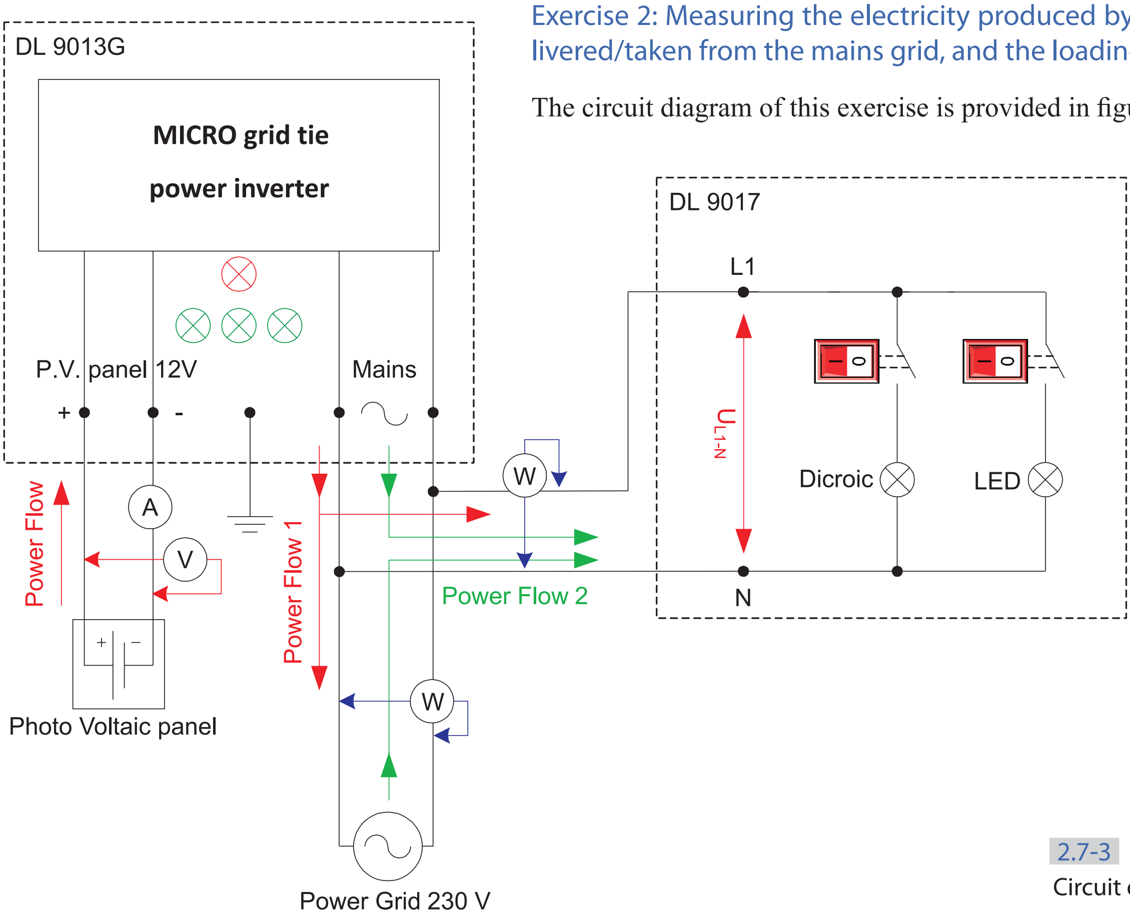
Irradiation (W/m^2)	LED lamp		Dichroic lamp		LED and dichroic lamp	
	Produced electricity (W)	Delivered electricity (W)	Produced electricity (W)	Delivered electricity (W)	Produced electricity (W)	Delivered electricity (W)

13. Draw the produced electricity-irradiation and delivered electricity-irradiation graphs for all three cases.



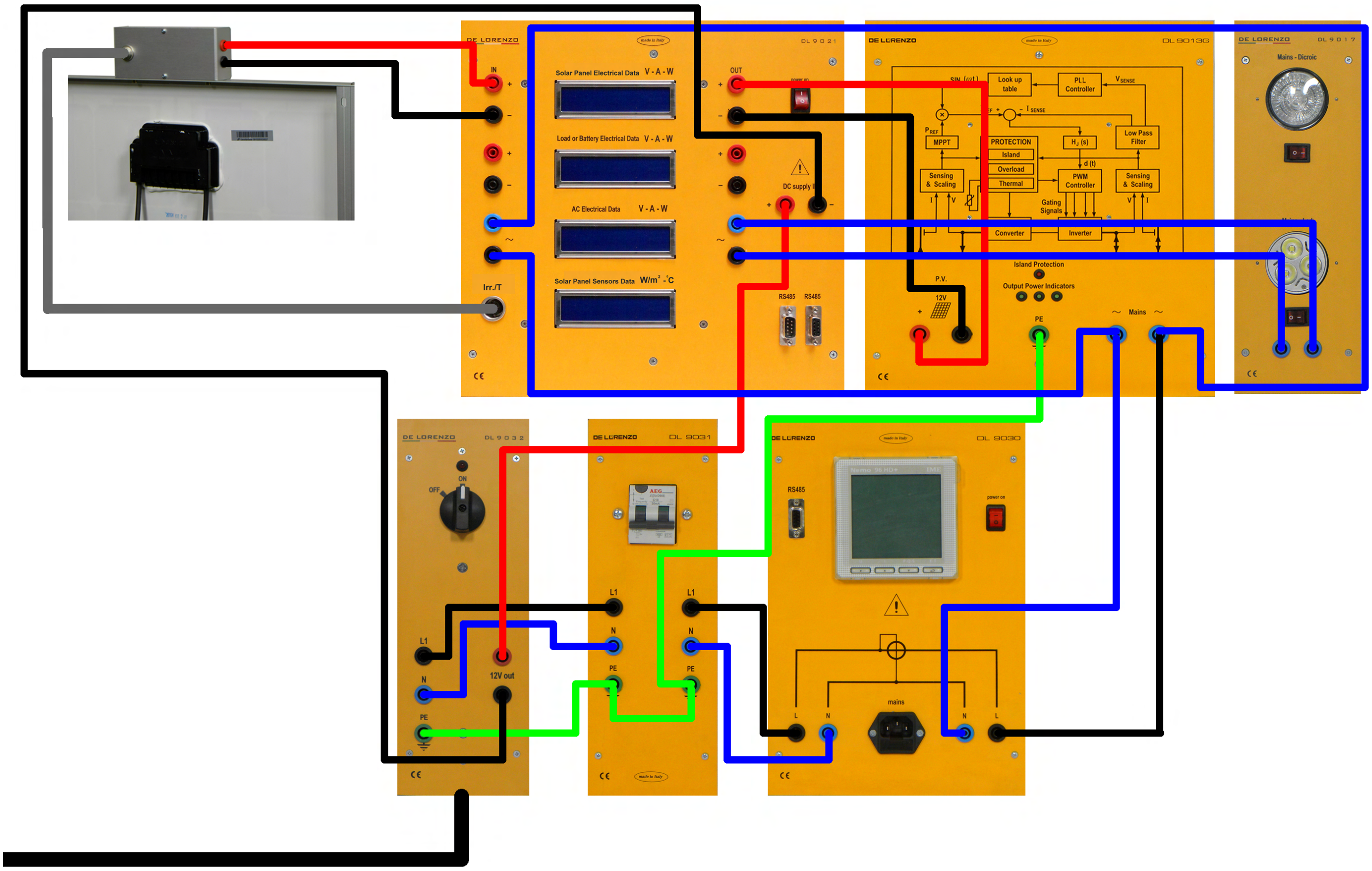
Exercise 2: Measuring the electricity produced by the solar panel, delivered/taken from the mains grid, and the loading of DL 9017 lamps

The circuit diagram of this exercise is provided in figure 2.7-3.



2.7-3
Circuit diagram of exercise 1

Connect the module according to the figure 2.7-4.



2.7-4

Connection scheme of exercise 2

1. Find the position in which the solar panel provides highest irradiation.
2. Switch on the LED lamp on DL 9017 module.
3. Use DL 9021 to calculate the value of power produced by the solar panel (use ammeter and voltmeter), and to read the value of DL 9017 loading. Use DL 9030 to read the value of power delivered to the mains grid.
4. Fill in the produced electricity, loading value and delivered electricity to the mains grid in case of LED lamp turned on in the table.
5. Switch off the LED lamp and turn on the dichroic lamp on DL 9017 module.
6. Use DL 9021 to calculate the value of power produced by the solar panel (use ammeter and voltmeter), and to read the value of DL 9017 loading. Use DL 9030 to read the value of power delivered to the mains grid.
7. Fill in the produced electricity, loading value and delivered electricity to the mains grid in case of dichroic lamp turned on in the table.
8. Switch on both the LED lamp the dichroic lamp on DL 9017 module.

Note

DL 9021 module contains AC wattmeter, and solar panel produced DC power. Therefore, we can not measure the solar panel power directly. The power is calculated by multiplying voltage and current measured with DL 9021 module.

9. Use DL 9021 to calculate the value of power produced by the solar panel (use ammeter and voltmeter), and to read the value of DL 9017 loading. Use DL 9030 to read the value of power delivered to the mains grid.

10. Fill in the produced electricity, loading value and delivered electricity to the mains grid in case of both LED lamp and dichroic lamp turned on in the table.

11. Set the solar panel in order to obtain the irradiation app. 90% of the highest irradiation value and fill in the appropriate row in the table.

12. Repeat points 2-10 in 10% steps until reaching the minimum irradiation is reached, i.e. 0 W/m^2.

Irradiation (W/m^2)	LED lamp			Dichroic lamp			LED and dichroic lamp		
	Produced electricity (W)	Loading (W)	Delivered electricity (W)	Produced electricity (W)	Loading (W)	Delivered electricity (W)	Produced electricity (W)	Loading (W)	Delivered electricity (W)

13. Draw the produced electricity-irradiation, delivered electricity-irradiation and loading-irradiation graphs for all three cases.

Questions for evaluation

1. Why is power being delivered to the mains grid smaller in case of LED lamp than in case of dichroic lamp?

2. Why is the loading value constant regardless on the irradiation or produced electricity values?

SOLAR POSITION TRACKING SYSTEM

DL SUN-TRACKER

SOFTWARE PANEL

Main panel

Show the most meaningful parameters of the sun tracker, and allow the comparison with expected optimal setting according to the actual / "given time" Sun position.

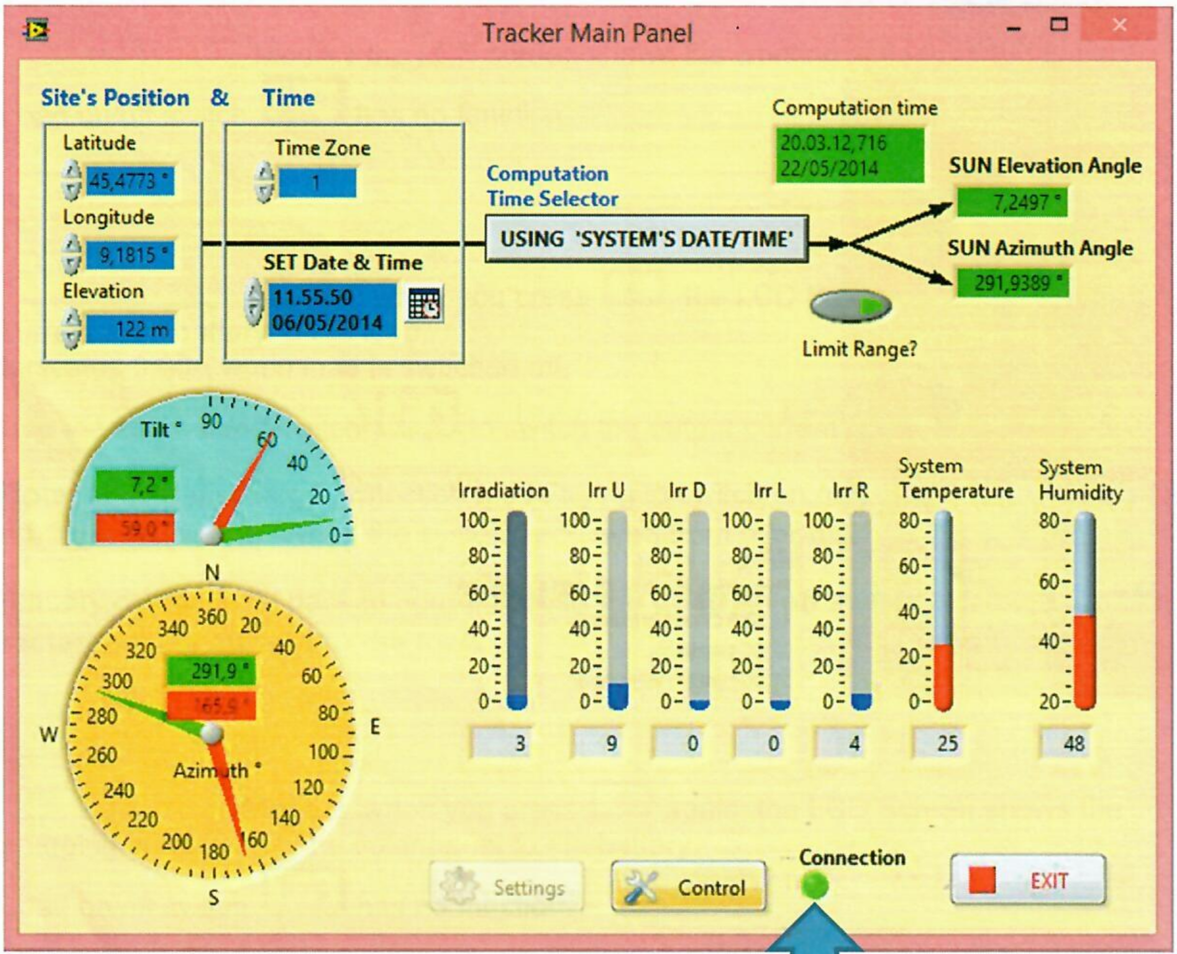


Figure 2: Main Control panel

Setting 9600 Address 1

Control Panel

Allow to control the solar tracker Manually or let it work autonomously.

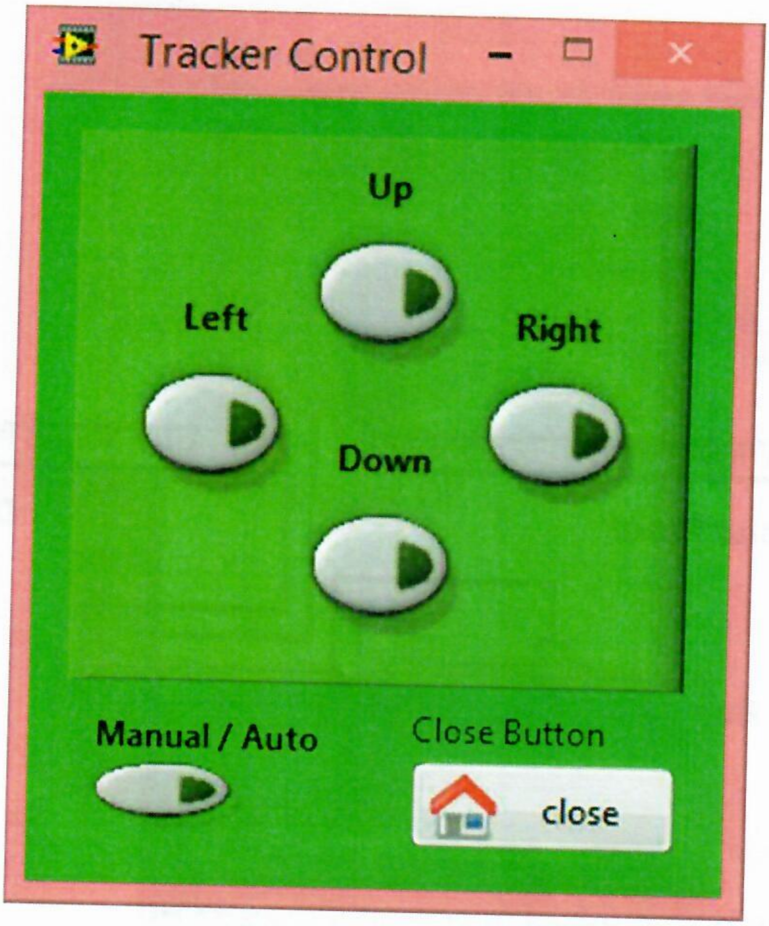


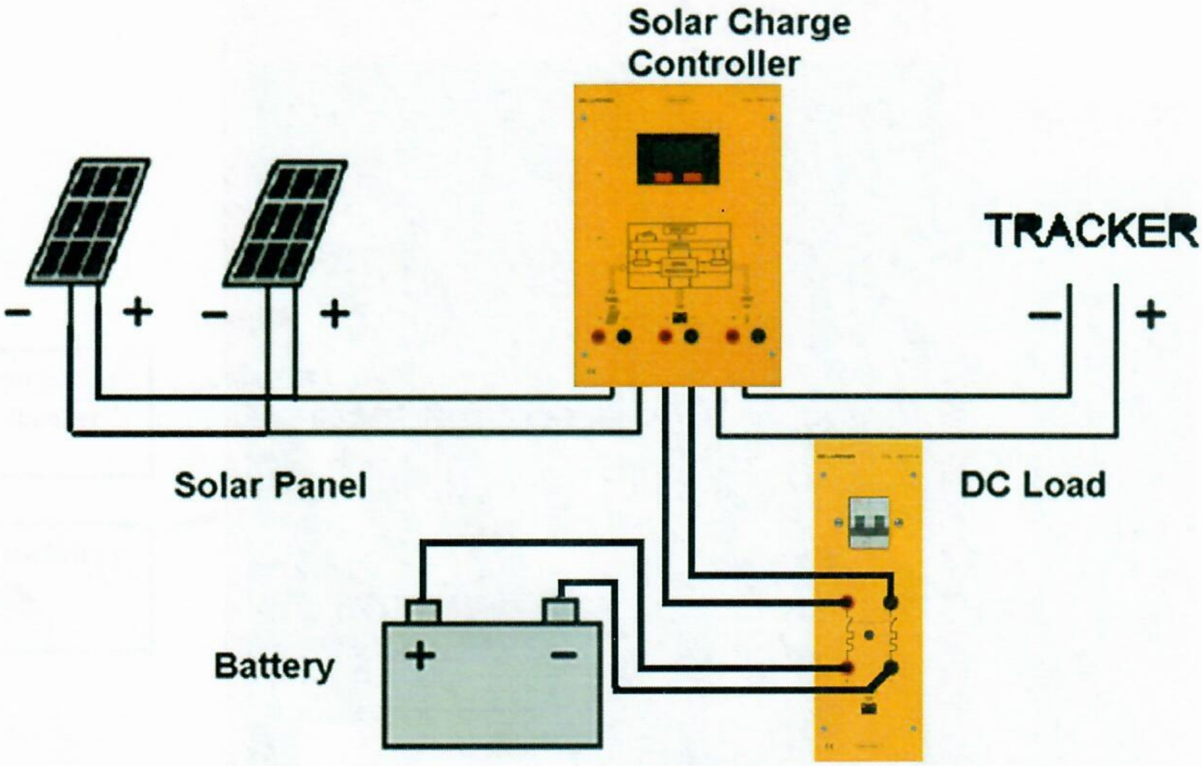
Figure 5: manual movement control panel

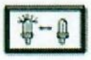
Set the Manual/Auto button to Manual position and use the 4 direction button to control the direction of the panel.

Set the Manual/Auto button to Auto to let the tracker seek the best direction to optimize per collected power.

PROCEDURE

1) Wire the tracker like shown in picture

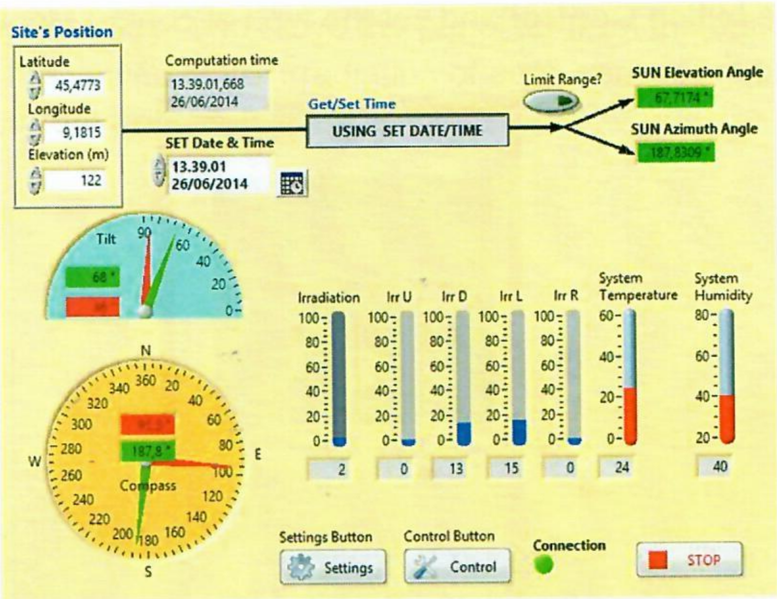


2) Press the Button  to power on the Tracker

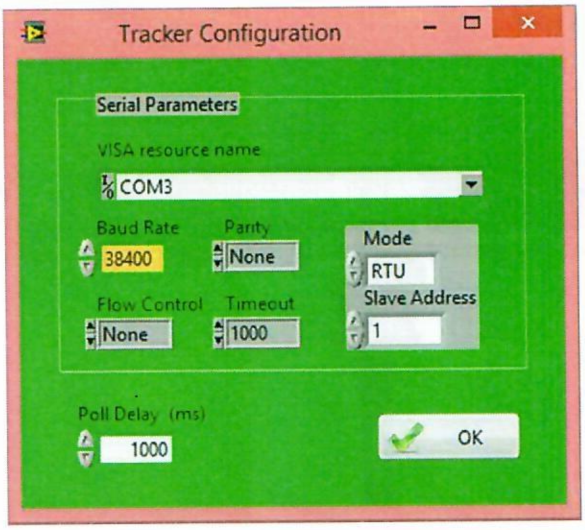
3) Insert the USB to RS485 Converter and install the driver by using the CD

4) Install the Tracker Software by using the CD

5) Open the Tracker software

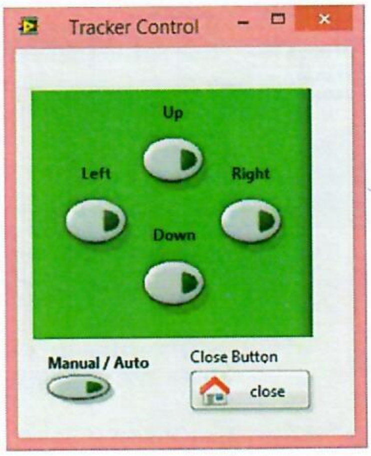


6) Press the button **setting** and configure the port communication (Default Address=1 Baudrate=9600) and press OK



7) Check the connection led

8) Press the button **Control** and set the type of control Manual or Auto

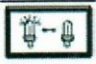


9) Set to Auto and observe when the SUN Light is sensed.

10) Set to Manual and move the panel far from the optimal direction; observe the values of the irradiation of each sensor ant the produced power (current from the panel).

10) Set to Manual and move the panel far from the optimal direction; observe the values of the irradiation of each sensor ant the produced power (current from the panel).

Troubleshooting

Problem	Possible cause	Possible solution
Charging not indicated on display when solar panel is connected	1. Reverse polarity 2. Loose connection 3. Not enough sunlight	1. Correct polarity 2. Secure connection(s) 3. Reposition solar panel
No output on load connections	1. Load switch off 2. Battery not connected, loose connection or wrong polarity. 3. Polarity load reversed 4. Over-discharge protection Enabled 5. Short circuit or overload protection enabled	1. Press switch  2. Connect a battery to the regulator, check correct polarity and secure connection 3. Correct load polarity 4. Disconnect load and fully recharge battery 5. Verify that load is not short circuited and draws no more than 30A. Press switch  when everything is OK.

2.1. Basics of the Solar Trainer

2.1.1. Identification of the components of the trainer

Objective of the exercise

Become familiar to all the components of the solar trainer, and learn how to use them properly.

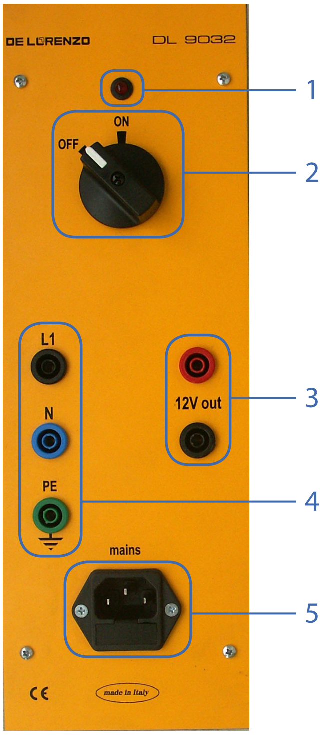
Required equipment

- **DL 9032** (figure 2.1-1) is a power source with one input and two distinct outputs, as shown in figure 2.1-2. **ATTENTION**: Input and one output terminal are at 230 V potential in respect to the ground. Power cable is used to connect DL 9032 to the electrical outlet (230 V, 50 Hz).

  One module output is AC voltage source that has the same characteristics as module input, i.e. 230 V and 50 Hz. It is used to provide AC voltage for DL modules that require one. There is also a green terminal which is used for protective grounding of various DL modules that require grounding.

  The other output is a 12 V DC voltage source. 12 V DC voltage source is obtained by transforming 220 V AC voltage to 12 V DC voltage using AC/DC converter.

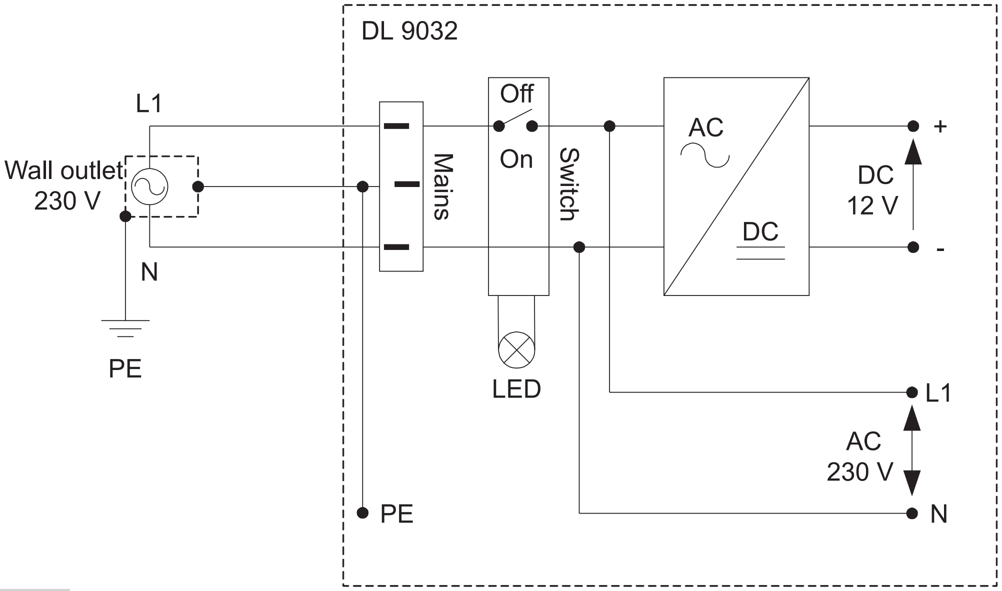
  For module DL 9032 to work properly, power cable must be connected to wall outlet (220 V, 50 Hz) and power switch must be turned to ON position. The red LED is turned ON (glows red) when voltage is present. For safety reasons wall outlet must not be used if residual current device is not installed in electrical circuit that contains wall outlet. The residual current device in wall outlet circuit must also be tested before DL 9032 is used. If residual current device does not work as it should, do not use DL 9032 module.



2.1-1

Power source 9032 contains:

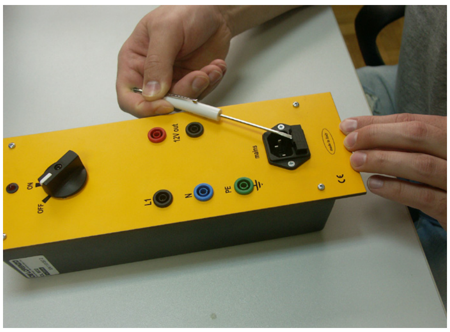
1) signal lamp
2) on/off switch
3) 12 V DC output
4) 230 V AC output
5) mains socket

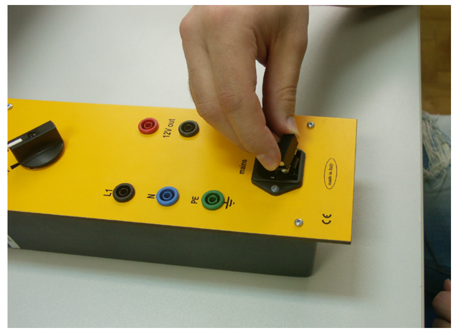


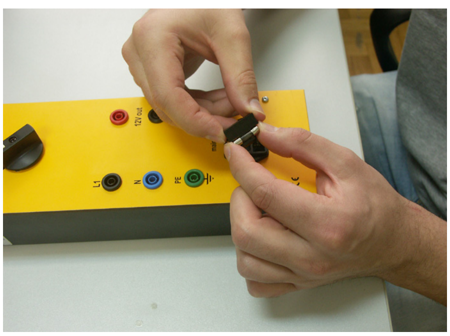
2.1-2

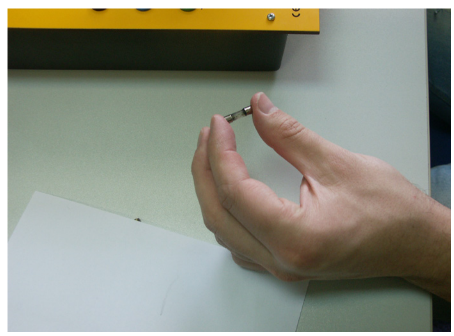
Circuit diagram of DL 9032 module

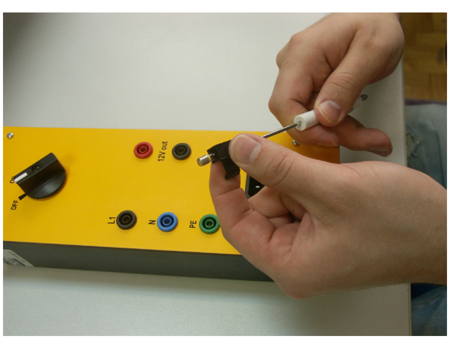
It should be noted that the "Mains" input contains fuse. Its purpose is to protect equipment from short circuit. If the module DL 9032 does not work when it is supplied with electricity, it means that the fuse is burnt and it should be replaced. Figure 2.1-3 shows a series of photos describing how to replace the burnt fuse. The spare fuse is contained in the "Mains" element, as can be seen in figure 2.1-3.

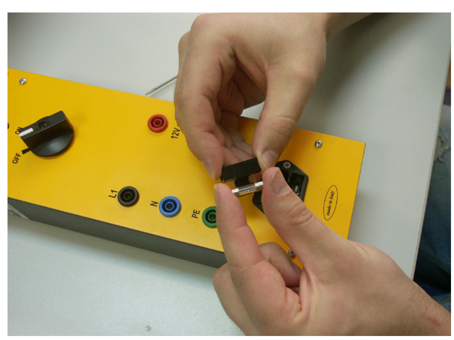
a)


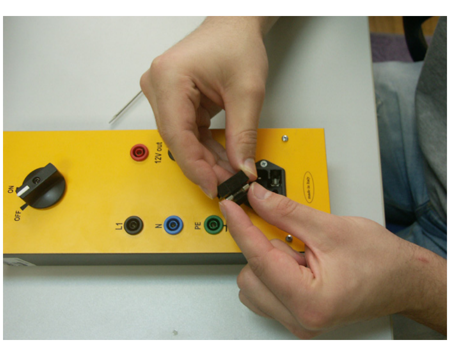
b)


c)


d)


e)


f)


g)


h)


2.1-3

Replacing the burnt fuse:

a) use a screw-driver to set free the plastic lid

b) take the plastic lid out

c) remove the burnt fuse

d) the burnt fuse is unclear (grey)

e) use a screw-driver to set free the spare fuse placed in a separate compartment

f) the new fuse is clear

g) put the new fuse to the appropriate position in the plastic lid

h) press the plastic lid until it clicks

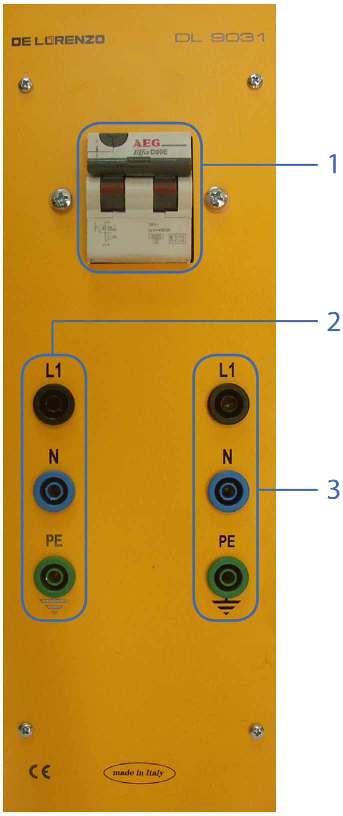
2.1-4
The voltage probe

When connecting wall outlet to DL 9032 one should use the probe (a screwdriver which is lit when the voltage is present) to check if L1 output is at a potential (fig. 2.1-4). If that is not the case, the power cable should be disconnected from the wall outlet, turned for 180 degrees and then plugged again to the same outlet. Test with the screw driver should be preformed again. If L1 output still has no potential then the wall outlet should be checked by authorized personnel.

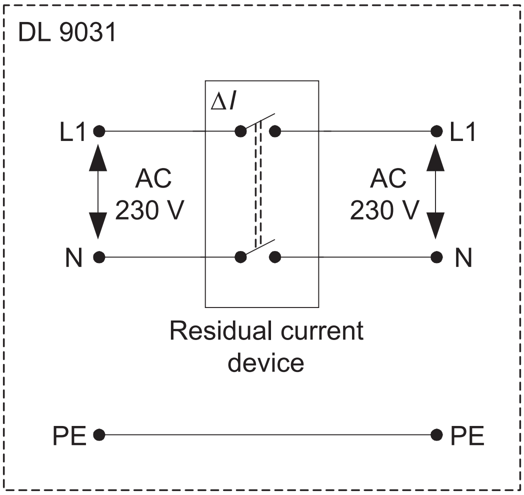
- **DL 9031** (figure 2.1-5) is a protective module that contains one input, one output and a 2-pole residual current device. DL 9031 should always be used when AC 220V voltage source from DL 9032 is used to provide power for various other DL modules. Everything that is connected after output is protected by residual current device (including output). Figure 2.1-6 shows circuit diagram of DL 9031 module.

What is the purpose of residual current device?

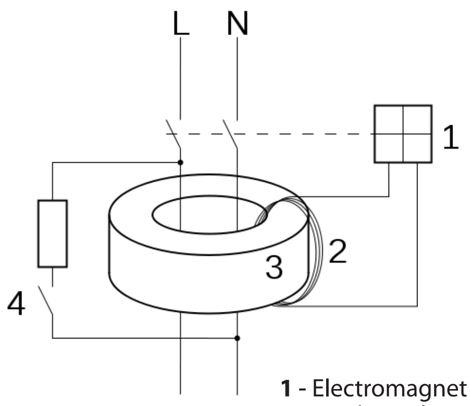
Residual current device (RCD) is an electrical wiring device that disconnects a circuit whenever it detects that the electric current is not balanced between the energized conductor and the return neutral conductor. Such an imbalance may indicate current leakage through the body of a person who is grounded and accidentally touching the energized part of the circuit. A lethal shock can result from these conditions. RCDs are designed to disconnect quickly enough to prevent injury caused by such shocks. They are not intended to provide protection against overcurrent (overload) or short circuit conditions; fuses are used for that purpose.



2.1-5
Protective module DL 9031 contains:
1) Residual current device
2) AC input terminals
3) AC output terminals



2.1-6
Circuit diagram of the DL 9031 module



1 - Electromagnet with auxiliary electronics
2 - Current transformer secondary winding
3 - Transformer core
4 - Test switch
L - phase conductor
N - neutral conductor

2.1-7
Residual current device scheme

2.1-8
Load module DL 9017 contains:
1) dichroic lamp on/off switch
2) LED on/off switch
3) terminals

Purpose and operation of RCD

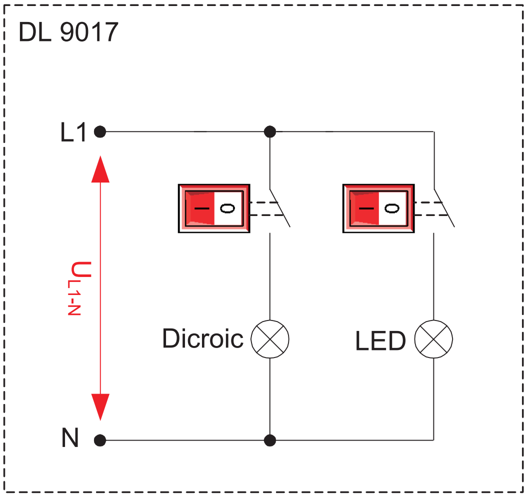
RCDs are designed to prevent electrocution by detecting the leakage current, which can be far smaller (typically 5–30 mA) than the currents needed to operate conventional circuit breakers or fuses (several amperes). RCDs are intended to operate within 25-40 milliseconds, before electric shock can drive the heart into ventricular fibrillation, the most common cause of death through electric shock. In Europe, the commonly used RCDs have trip currents of 10–300 mA.

RCDs operate by measuring the current balance between two conductors using a differential current transformer, as shown in figure 2.1-7. This measures the difference between the current flowing out the live conductor and that returning through the neutral conductor. If these do not sum to zero, there is a leakage of current to somewhere else (to earth/ground, or to another circuit), and the device will open its contacts.

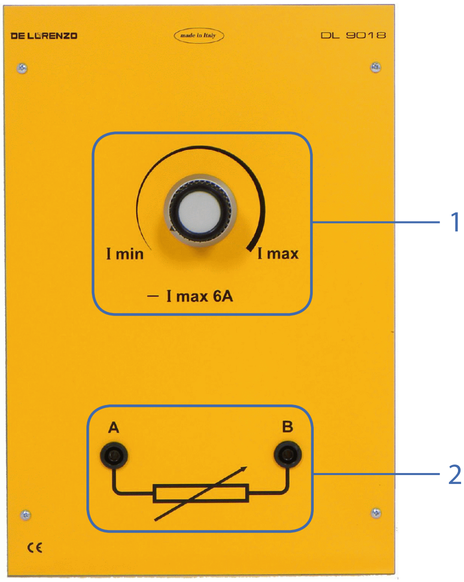
An RCD will help protect against electric shock where current flows through a person from a phase (live / line / hot) to earth. It cannot protect against electric shock where current flows through a person from phase to neutral or phase to phase, for example where a finger touches both live and neutral contacts in a light fitting; a device can not differentiate between current flow through an intended load from flow through a person.

Residual current device that is integral part of module DL 9031 should not be confused with residual current device mentioned in description of module DL 9032. The one in DL 9032 is used in electric outlet circuit, and the one in DL 9031 is used for additional instantaneous protection. Exercises should not be done if both residual current devices are not present or do not work properly.

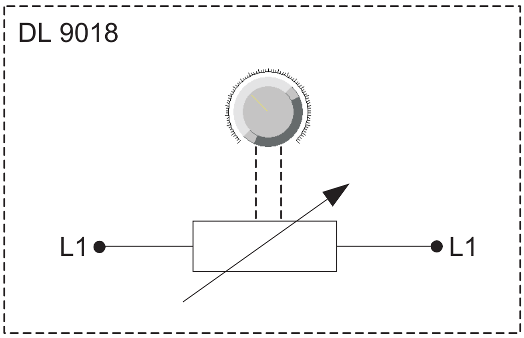
- **DL 9017** (figure 2.1-8) contains two AC loads (230 kV, 50 Hz). The upper one is a 35 W halogen lamp, and the lower one is a 3 W LED lamp. They are connected in parallel and can be switched on/off independently. Because of parallel connection voltage on each lamp is the same as voltage on input terminals (see DL 9018 for details). Figure 2.1-9 shows circuit diagram of DL 9017 module.



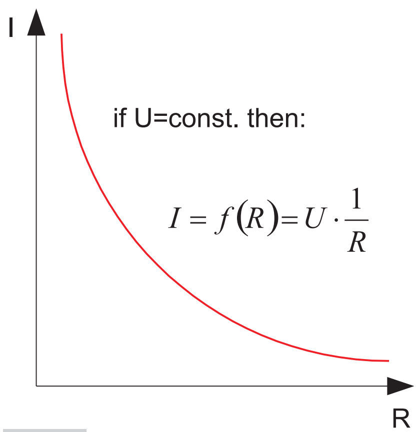
2.1-9
Circuit diagram of the DL 9017 module



2.1-10
Rheostat module DL 9018 contains:
1) knob for changing the resistance
2) terminals



2.1-11
Circuit diagram of the DL 9018 module



2.1-12
Current-load characteristic

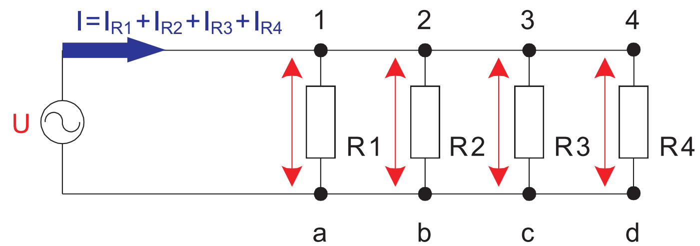
- **DL 9018** (figure 2.1-10) is a rheostat. The knob is used to change the resistance in the 0-80 Ω range. The circuit diagram of the DL 9018 module is provided in figure 2.1-11.

As the resistance of the load is changed, so is the current according to the Ohm's Law:

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

The voltage is obtained from power grid or from PV panel and it should be noted that it does not change when the load is changed. Analogy is the wall outlet, i.e. the voltage in outlet is always 230 V no matter how many consumers are connected to the outlet; e.g. it does not matter if one light bulb is connected to the same outlet, or ten light bulbs, voltage will always be the same. Current and load of the whole circuit will, of course, change but voltage is constant. Figure 2.1-12 shows how the current changes when the load changes for constant voltage.

It is seen that larger the load, the smaller the current. This is logical because if resistance is large, the electrons move slowly and if the resistance is small, the electrons move faster because nothing obstructs their movement. Analogy can be drawn with running water. If the pipe is clean (no resistance) large amount of water will move through the pipe and, vice versa, if the pipe contains obstacles (resistance) the smaller amount of water will move through the pipe at the same time. Dependence of current and resistance must be carefully observed or some wrong conclusions might come up. If figure 2.1-12 is misunderstood it might be concluded that if one connects more load to the circuit, i.e. light all the bulbs and machines in the house (large resistance), that current will be smaller than when only one light bulb is connected. That is definitely not the case because the more load consumer connects the larger the current is. This can also be seen from utility bill; the more current we spend the more money we have to pay. Why is that different then figure 2.1-12? There is actually no difference if figure 2.1-12 is properly understood. Figure 2.1-12 shows what is happening when only one load is connected to constant voltage source. In homes there are various loads that are connected in parallel, as shown in figure 2.1-13.



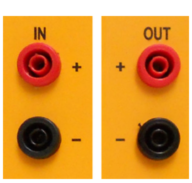
2.1-13
Parallel loads

2.1-8
DL 9021

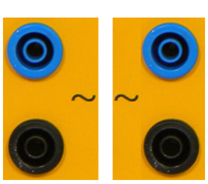
2.1-9
Connector for calibrated cell and for the temperature sensor.

2.1-10
Power supply connectors of the module.
Voltage must be between 10V and 35V.

2.1-11
Power switch, for the module ignition.



2.1-12
Connectors for DC signals measuring: voltage, current and power.



2.1-13
Connectors for AC signals measuring.

2.1-14
Communication port , for the SW application interface.

- **DL 9021** (figure 2.1-8) the module is made for realizing the measurements of a photovoltaic system.
  It includes a series of instruments; input terminals +/- are placed on the left of each instrument, and the output are on the right.
  It provides DC measure, AC measure and environmental quantity.
  All instrument show readings using automatic decimal point position, staring from 1/1000 up to the maximum value according the maximum magnitude of each measure.
  Communication terminals are located on the right low part of the panel; two RS485 outlet, one male and one female, are available for the connection with the PC running the acquisition software and/or with other module in a chain configuration.
  Instruments support MODBUS RTU protocol over RS485 interface, used by the DL RE-SW software application, available separately, to perform a guided analysis of the electrical characteristics on trainer modules.
  It must be feed by the Battery module; it has also a switch to disconnect the module when not in use, leaving the experiment connections intact.

INSTRUMENTS CHARACTERISTICS:

- ***Solar Panel Electrical Data***: usable for measure of voltage, current and power provided by photovoltaic panel to the load directly or to the charge regulator; can be connected to PFS output, but the user could also use it as DC voltmeter to measure other variables in the laboratory; the unit of measurement are V for voltage , A for current, W for power.

- ***Load or Battery Electrical Data***: usable for measure of voltage, current and power flowing through the battery or to the connected load; typically it is connected between the battery and the charge regulator connector (battery plugs). The measured value can be simply compared to the value indicated on the charge regulator (if available). The unit of measurement are V for voltage , A for current, W for power.

- ***AC Electrical Data***: usable for measure of AC voltage, current and power flowing to the AC load, connected at the inverter output. The unit of measurement are V for voltage , A for current, W for power.

- ***Solar Panel Sensors Data***: the instrument measures typical environmental quantity that influence a solar panel output: the power of irradiation on the PV module and the temperature of PV cells; the signal is provided by the 5 poles cable; the unit of measurement are

2.1-15
Multifunction display

Table-1

Instrument specification

Instrument	Input Range	Resolution	Output Range
DC Voltmeter	± 65V	1/1000	Measured
AC Voltmeter	512 V	1/1000	Measured
Ammeters	± 30 A	1/1000	Measured
Power Meters	± 1000 W	1/1000	Computed
Solar irradiance meter	0 ÷ 1000 W/m^2	1/1000	0.4mA (W/m^2) = 400mA @ 1000 W/m^2
Thermometer	0 ÷ 400°C	1/1000	10mV/°C = 400mV @ 400°C

Note

DC power measurement using voltmeter and ammeter

The power of the load P_t is equal to the product of its current I_t and voltage U_t:

$$P_t = I_t \cdot U_t .$$

When measuring power, the voltmeter can be connected to the load terminals (figure 1) or to the voltage source terminals (figure 2). If the instrument consumption is much lower than the load, both cases will result in practically the same result. Otherwise, it is necessary to take the instrument consumption into account. In first case it is the ammeter, and in second one is the voltmeter.

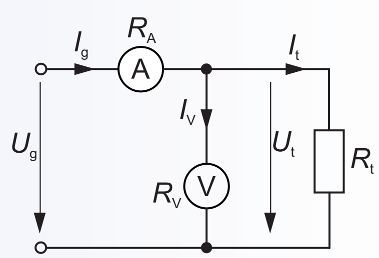


figure 1

Voltmeter connected to the load terminals

If measuring load power with voltmeter connected to the load, the power is:

$$P_t = U_t I_t = U_t \left(I_g - I_V \right) = U_t I_g - U_t I_V = U_t I_g - \frac{U_t^2}{R_V} .$$

If the voltmeter consumption is neglected, i.e. $R_t << R_v$, the power of the source is:

$$P_g = \left(U_t + I_g R_A \right) I_g = U_t I_g + I_g^2 R_A .$$

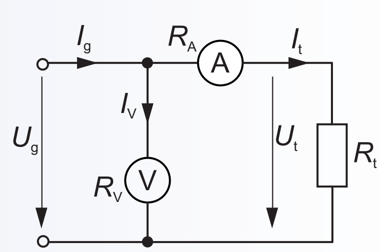


figure 2

Voltmeter connected to the source terminals

If measuring load power with voltmeter connected to the source, the power is:

$$P_t = U_t I_t = \left(U_g - I_t R_A \right) I_t = U_g I_t - I_t^2 R_A .$$

If the ammeter consumption is neglected, i.e. $R_t << R_A$, the power of the source is:

$$P_g = U_g \left(I_t + I_V \right) = U_g I_t + \frac{U_g^2}{R_V} .$$

Since both cases are equivalent, it is better to use the connection in which the instrument consumption is lower. If it is the same, it is better to use the connection in which the voltmeter consumption requires correction. This is because the voltage resistance R_v is always known and it does not depend on temperature.

Note

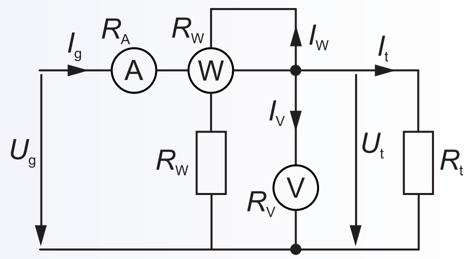


figure 3

DC power measurement using wattmeter with voltage branch connected to the load

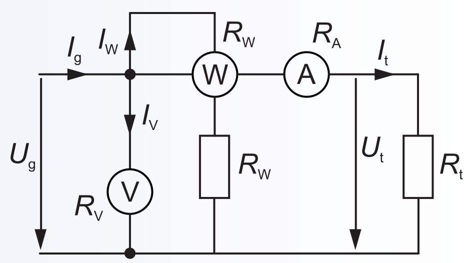


figure 4

DC power measurement using wattmeter with voltage branch connected to the source

DC power measurement using wattmeter

It is always more accurate to measure power using a **wattmeter**. In this case, the power can also be measured two ways:

- the voltage branch of the wattmeter is connected to the load,
- the voltage branch of the wattmeter is connected to the source.

In first case it is necessary to take into account the consumption of voltage, and in the other the consumption of the current branch, just like in the case of measuring power using voltmeter and ammeter.

In case of voltage branch being connected to the load (figure 3) the load power is:

$$P_t = U_t I_t = U_t \left(I_g - I_w - I_v \right) = U_t I_g - U_t I_w - U_t I_v = P_W - \frac{U_t^2}{R_W} - \frac{U_t^2}{R_Y}.$$

The power of the source is:

$$P_g = U_g I_g = I_t \left(U_t + I_g R_W + I_g R_A \right) = P_W + I_g^2 \left(R_W + R_A \right).$$

In case of voltage branch being connected to the source (figure 4) the load power is:

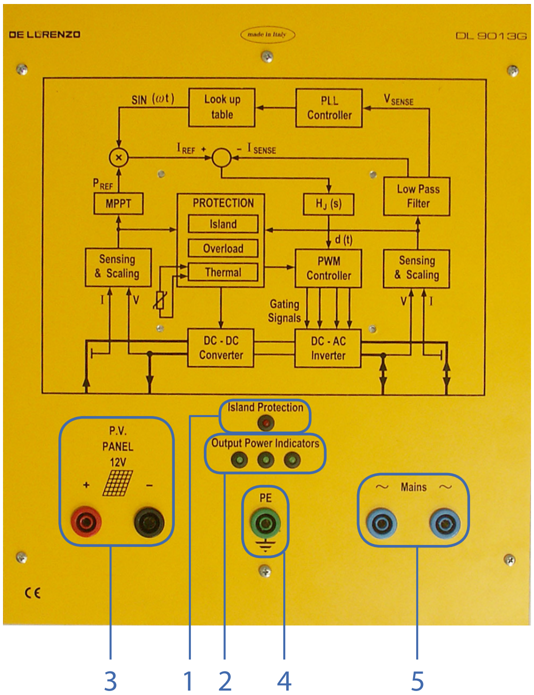
$$P_t = U_t I_t = I_t \left(U_g - I_t R_w - I_t R_a \right) = U_t I_g - I_t^2 R_w - I_t^2 R_a$$

$$P_t = P_W - I_t^2 \left(R_w - R_a \right).$$

The power of the source is:

$$P_g = U_g I_g = U_g \left(I_t + I_W + I_Y \right) = P_W + U_g^2 \left(\frac{1}{R_W} + \frac{1}{R_V} \right).$$

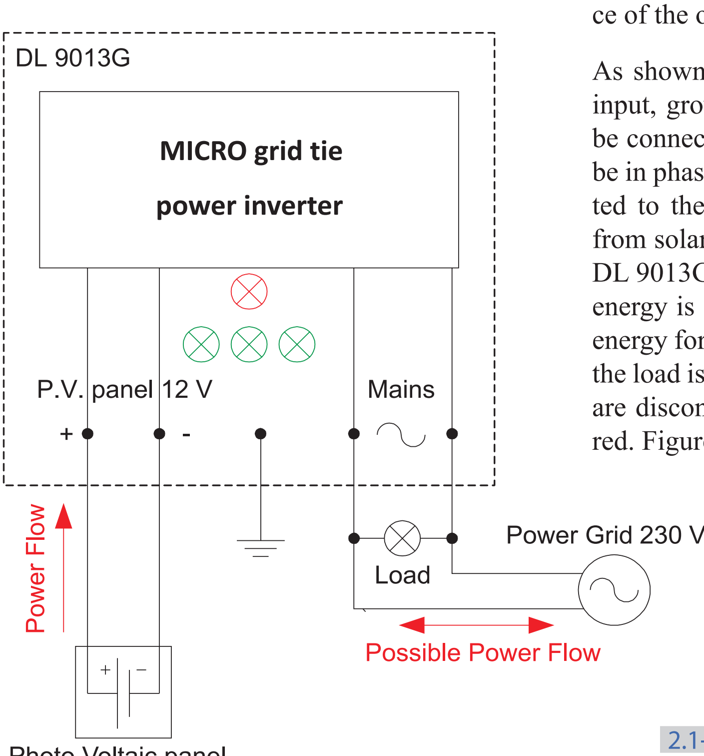
Power is equal to the product of current and voltage. Thus, the wattmeter will show the same value in case we have $\left(\frac{U}{2} \cdot 2I \right)$ or $\left(\frac{U}{10} \cdot 10I \right)$. This means that the overload of either voltage either current coil cannot be identified just from the displayed value of the power. Therefore, it is necessary to control the voltage in the voltage branch and current in the current branch independently.



2.1-21

Grid tie power inverter DL 9013G contains:

1) island protection indicator
2) output power indicators
3) PV panel input terminals
4) PE terminal
5) mains terminals



2.1-22

MICRO grid power inverter circuit diagram

- **DL 9013G** (figure 2.1-21) is a grid tie power inverter. The main difference between a standard power inverter and a grid tie power inverter is that the latter also ensures that the power supplied will be in phase with the grid power. This allows individuals with surplus power (wind, solar, etc.) to sell the power back to the utility in the form of net metering or the arrangement that local power utility offers.

The traditional grid tie inverters are in the high output, about 1-10 kW, they are very heavy and expensive. Therefore, most people interested in green energy generation cannot afford it. DL 9013G micro grid tie inverter is very economical, easy to install, convenient and reliable.

MICRO grid tie inverter's advantages compared to the traditional grid tie inverters are:

1. Easy to install, low cost per unit power, low cost of maintenance, as well as an extremely low power consumption. As the equipped micro solar grid tie inverter is made with digital logic components and low consumption.
2. The combination can be made according to user's needs while the number of combination is not limited by the system itself, which means one can add or reduce the number of system according to one's needs. But the traditional inverter is very expensive, if an additional solar panel is needed, one has to add an expensive inverter too.
3. Not interactive between the units of the combination system. The traditional grid inverter system just combines the solar panels for higher output to the grid system, if there is one of the solar panels that has some problems due to failing leaves, bird drops, dust, etc, the whole system performance would be affected. However, our micro system has solved the above problem. If poor performance occurs in one of the solar panels, then its poor performance would not affect the performance of the other units in the whole system.

As shown in figure 2.1-21, DL 9013G module has 12 V solar panel input, ground terminal and AC terminals. Power grid voltage should be connected to "Mains" terminals to ensure that power supplied will be in phase with grid power. "Mains" terminals should also be connected to the load (lamp for example) that is supposed to be powered from solar panel connected to the PV input. Power inverter in module DL 9013G is programmed to supply load from PV source and surplus energy is sent to the mains grid. If PV source cannot produce enough energy for the load, then mains grid supplies the load. The result is that the load is always supplied with electrical energy. If "Mains" terminals are disconnected from power grid then Island Protection LED glows red. Figure 2.1-22 shows circuit diagram with proper connections.

Specifications:

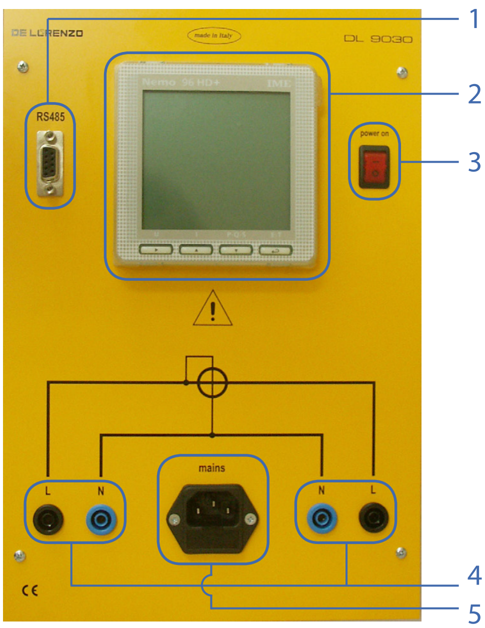
Model	GT-360 W
Normal AC Output Power	300 W
Maximum AC Output Power	360 W
AC Output Voltage Rang	190 V ~ 260 V
AC Output Frequency Range	46 Hz ~ 65 Hz
Total Harmonic Distortion(THD)	< 5%
Power Factor	0.99
DC Input Voltage Range	14 V ~ 28 V
Peak Inverter Efficiency	95%
Standby Power consumption	< 0.5 W
Output Current Waveform	Pure sine-wave
MPPT Function	Yes
Over Current Protection	Yes
Over Temperature Protection	Yes
Reverse Polarity Protection	Yes
Island Protection	Yes
Stackable	Yes
Operating Temperature Range	–10 °C ~ 45 °C
Net weight	1 kg
Gross weight	1.5 kg
Dimension	240 mm × 185 mm × 95 mm

Features:

- Generates pure Sine Wave
- Plug and Play Design, simply plug into an outlet (GFI), no hard-wiring
- Maximum Power Point Tracking (MPPT) - optimize power output
- Stackable (connect in parallel for higher output)
- Island protection: Inverter will shut down during black outs.
- Simple and safe installation
- Reverse polarity protection
- Constant power output
- Low distortion output on all ranges
- Allows different power factor from loads
- Does not require rewiring of existing electronics
- LED indicators to reflect power output rate
- Compact and light-weight design

Note

Generally 24 V solar panel rated voltage is 36 V, so please DO NOT connect 24 V solar panel to this inverter, because the inverter input is 14-28 V, otherwise the inverter will be burnt.



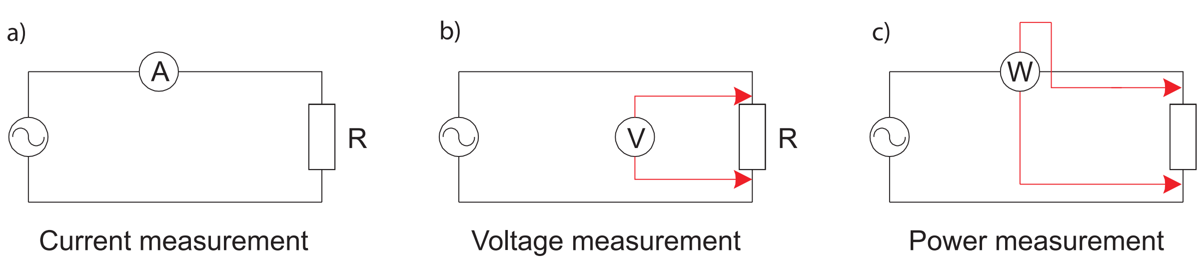
2.1-23

Measurement module DL 9030 contains:
1) RS485 communication port
2) display with navigation buttons
3) on/off switch
4) terminals
5) mains socket

User guide:

1. Connect the solar panel's DC supply cables to the DC input terminal of the inverter; be sure that the polarity is correct. Recommended DC input cable size for maximum output is 10 A or cables that can handle more than 30 A. Optimal length would be less than 8 m, longer cables will experience higher voltage drop. The range of output power of Solar Panel is 20 W ~ 300 W.
2. Put the AC output voltage switch on the inverter to the correct position (115 V or 230 V) according to your location home grid AC voltage.
3. Connect the supplied AC power cord to the inverter and plug it to a home wall socket.
4. The 3 green LED indicators will start to cycle from left to right when the grid and DC supply is detected. This indicates the inverter is operating under normal condition. The rate of the cycling is according to how much power is being output from the solar panels or the wind turbine. The greater the power output, the faster the rate. If there is no AC grid detected, the red LED will be on, the inverter will not provide power, this is called the "Island Protection".

- **DL 9030** (figure 2.1-23) is measurement module. The main part of the module is Nemo 96HD+ network monitor. It measures current and voltage in electrical circuit and from obtained values calculates various parameters like frequency, power, energy etc. Current is measured with element that has almost zero resistance, and voltage is measured with element that has huge resistance. It can be imagined that resistance of voltage measuring device is equal to infinity. Nemo 96HD+ must measure current that flows through phase and voltage between phase and neutral line. Figure 2.1-24a shows current measurement, figure 2.1-24b shows voltage measurement and figure 2.1-24c shows what it looks like when two measurements are combined.



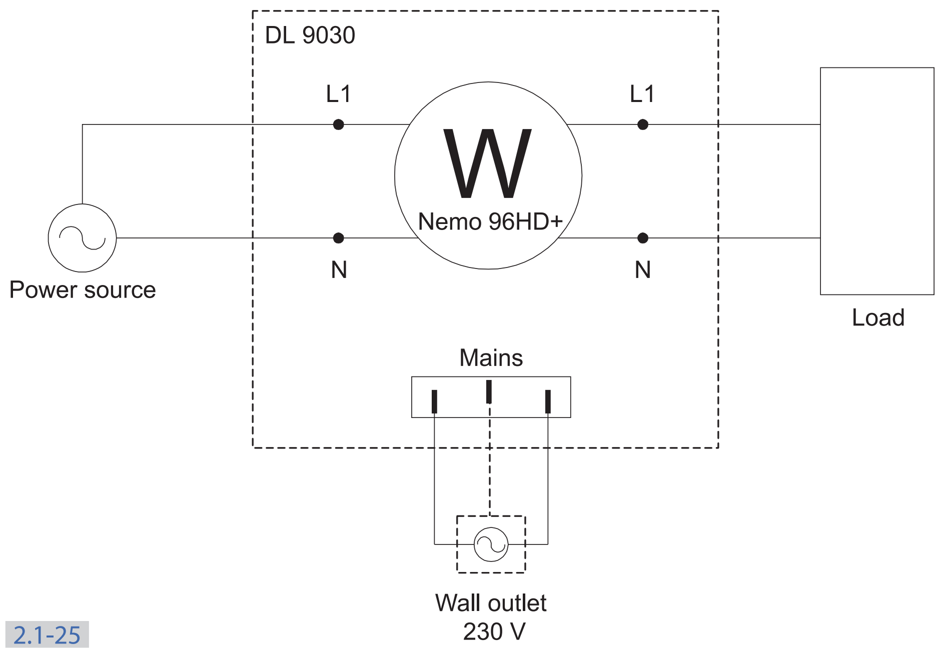
2.1-24

Current, voltage and power measurements

That is exactly the way Nemo 96HD+ is connected which means that it measures current and voltage at the same time. That is Watt meter connection because if power calculation is needed then current and voltage values must be obtained. Why? Because for load *R* power is obtained through following equitation:

$$P = U \cdot I$$

Nemo 96HD+ also needs power to operate. “Mains” plug should be connected with power cord, and power cord should be connected to wall outlet. After connection “Power on” switch should be turned to ON state for Nemo to operate. Module 9030 also has RS 485 port which can be used to connect Nemo 96HD+ to computer. Figure 2.1-25 shows how to connect DL9030 module.



2.1-25
DL 9030 connection scheme

Note

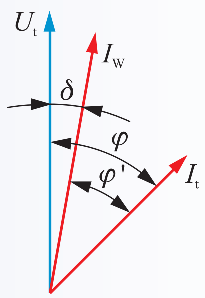


figure 1
Phase shift problem

AC power measurement using wattmeter

If there is a small phase shift between the voltage U_t and current I_w (both in the voltage branch), the wattmeter will not measure the actual power of the load $P = U_t \cdot I_t \cdot \cos\varphi$, but $P_w = U_t \cdot I_t \cdot \cos(\varphi - \delta)$. This causes the error:

$$P_{\cdot\%} = \frac{P_W - P}{P} \cdot 100\% = \frac{\cancel{U_t} \cdot \cancel{I_t} \cdot \cos(\varphi - \delta) - \cancel{U_t} \cdot \cancel{I_t} \cdot \cos\varphi}{\cancel{U_t} \cdot \cancel{I_t} \cdot \cos\varphi} \cdot 100\% .$$

Since $\cos(\varphi - \delta) = \cos\varphi \cos\delta + \sin\varphi \sin\delta$, and $\delta << \varphi$ and δ is a small angle, we have $\sin\delta \approx \delta$ and $\sin\varphi \approx \varphi$, which gives us:

$$P_{\cdot\%} = \frac{\cos\varphi + \delta \sin\varphi - \cos\varphi}{\cos\varphi} \cdot 100\% = \delta \tan\varphi \cdot 100\% .$$

Measuring current, voltage and power P_w provides data for calculation of φ'. By definition $\left(\cos\varphi' = \frac{P_W}{U}\right)$. According to figure 1 $\varphi = \varphi' + \delta$, which results in:

$$P_{\cdot\%} = \delta \frac{\tan\varphi' + \tan\delta}{1 - \tan\varphi' \tan\delta} \cdot 100\% \approx \delta \frac{\tan\varphi'}{1 - \delta \tan\varphi' \delta} \cdot 100\% .$$

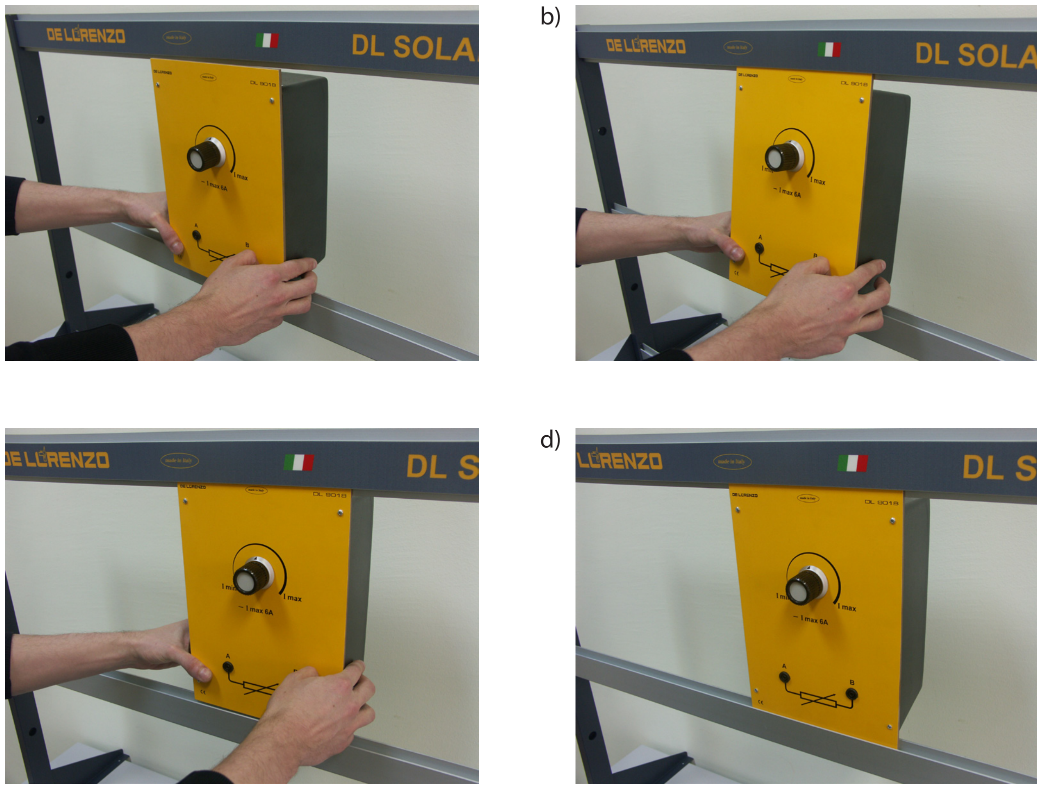
Greater δ and greater $\tan\varphi$ (lower power factor) cause greater error.

- **Frame for DL modules** (figure 2.1-26). Modules can be put in two rows. The order of the modules should be set in such a manner to provide as least cable crossing as possible. This way you will reduce the number of wrong connections.

2.1-26
Frame for DL modules

The procedure for installation of DL modules into the frame is provided in figure 2.1-27. First, it is necessary to insert the back of the module into the frame. After that, insert the upper part of the module into the rail. Finally, push the lower part of the module and let it slide into the lower rails.

a) b) c) d)



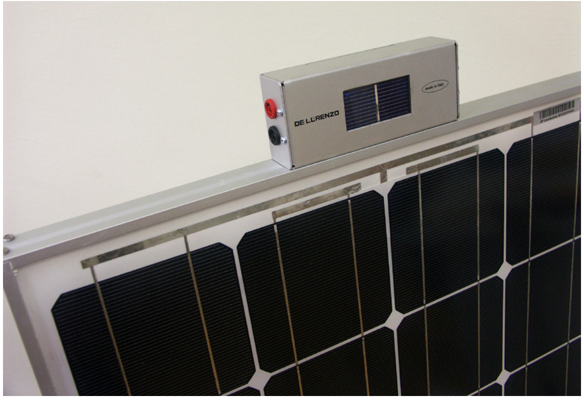
2.1-27

Installation of DL modules into the frame

• **Solar panel** (figure 2.1-28) incorporates a solar module (85 W, 12 V) and sensors for irradiation and temperature measurements (figure 2.1-29). Red and black terminals provide the solar panel power output, while 5-pin terminal provides irradiation and temperature data (figure 2.1-30). For easier handling, the light-weight solar module is placed on wheels. Side of the panel contains a meter for measuring the angle of the solar panel inclination towards the horizontal surface (figure 2.1-31).

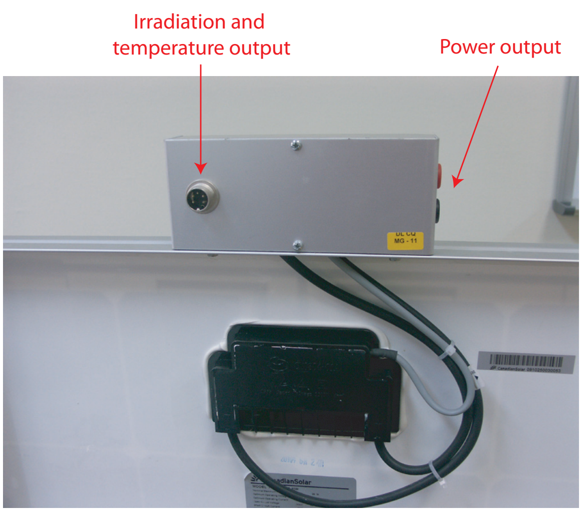
2.1-28

Solar panel



2.1-29

Sensors for irradiation and temperature measurements



2.1-30

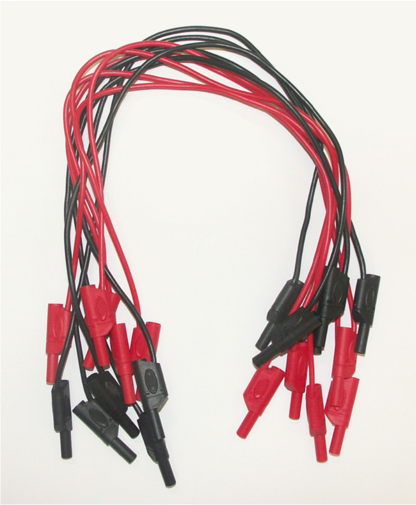
Solar panel outputs

2.1-31

Meter for measuring the angle of the solar panel inclination towards the horizontal surface

2.1-32
Single black cable

- **Single black cable, length = 160 cm** (figure 2.1-32)
- **5 black and 5 red cables, length = 60 cm** (figure 2.1-33)
- **4 black, 5 red and 5 blue cables, length = 110 cm** (figure 2.1-34)
- **Two mains power cables , length 200 cm** (figure 2.1-35). One is used to power the DL 9032, and the other to power the DL 9030 module.
- **Temperature and irradiation signal cable** (figure 2.1-36).

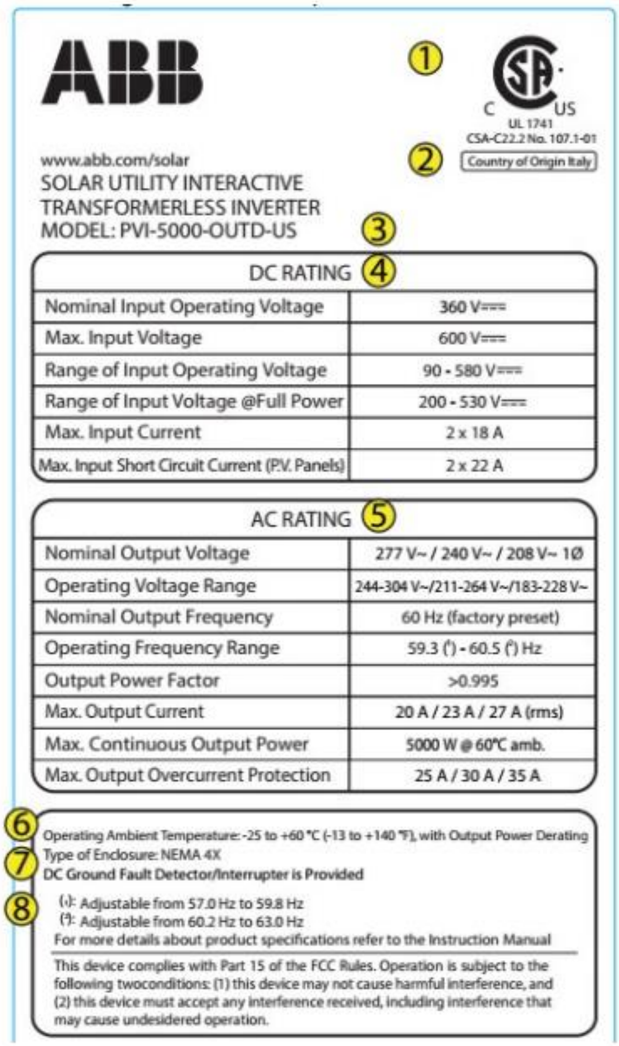


2.1-33
5 black and 5 red cables

2.1-34
4 black, 5 red and 5 blue cables

2.1-35
Two mains power cables

2.1-36
Temperature and irradiation signal cable



(1) الشهادات التي يملكها المنتج.

(2) بلد المنشأ الخاصة بالمنتج، وهي هنا إيطاليا.

(3) نوع العاكس، وهو من النوع الذي لا يحتوي على محول وأيضاً يوجد رقم المنتج.

(4) قيم التّيار المستمر الخاصة بهذا العاكس (سيتم شرحها بالتفصيل لاحقاً في هذا التّمرين).

(5) قيم التّيار المتردد الخاصة بهذا العاكس (سيتم شرحها بالتفصيل لاحقاً في هذا التّمرين).

(6) معلومات بيئة التركيب، حيث يستطيع هذا النوع من العواكس العمل من درجة حرارة −25 الى 60 سيليسوس.

(7) الحماية المرفقة بالعاكس، وهي هنا حماية ضد قصر الدائرة الأرضيّ.

(8) القيم التي يمكن تعديلها للتردد، حيث يمكن تعديل هذا المنتج ليعمل من تردد 57 الى 59.8 (هيرتزاً) ومن 60.2 إلى 63 (هيرتزاً).

ب) قيم التّيار المستمر.

DC RATING		
Nominal Input Operating Voltage	1	360 V===
Max. Input Voltage	2	600 V===
Range of Input Operating Voltage	3	90 - 580 V===
Range of Input Voltage @Full Power	4	200 - 530 V===
Max. Input Current	5	2 x 18 A
Max. Input Short Circuit Current (P.V. Panels)	6	2 x 22 A

انظر إلى الجزء الخاص من المعلومات الفنية الخاصة بقيم التّيار المستمر للعاكس المستعمل في الأعلى

1) قيمة الجهد المعياريّ للعاكس، وهي هنا 360 (فولتاً) مستمراً.
2) أقصى قيمة فرق جهد مستمر يمكن أن يدخل إلى العاكس وهي 600 (فولت) مستمر.
3) قيم الجهود التي يمكن أن يعمل عليها هذا العاكس في حالة الحمل الذي لم يبلغ الحمل الأقصى وهي 90−580 (فولتاً) مستمراً.
4) قيم الجهود التي يمكن أن يعمل عليها هذا العاكس في حالة الحمل الأقصى، وهي 200−530 (فولت) مستمر.
5) أقصى قيمة تيار يمكن أن يتحملها على مدخله وهي 18 (أمبير) تيار مستمر لكلّ مدخل (عدد المداخل اثنان).
6) أقصى قيمة تيار قصر وهو 22 (أمبيراً) تيار مستمر لكلّ مدخل (عدد المداخل اثنان).

ت) قيم التّيار المتردد

AC RATING		
Nominal Output Voltage	1	277 V~ / 240 V~ / 208 V~ 1Ø
Operating Voltage Range	2	244-304 V~ / 211-264 V~ / 183-228 V~
Nominal Output Frequency	3	60 Hz (factory preset)
Operating Frequency Range	4	59.3 (1) - 60.5 (2) Hz
Output Power Factor	5	>0.995
Max. Output Current	6	20 A / 23 A / 27 A (rms)
Max. Continuous Output Power	7	5000 W @ 60°C amb.
Max. Output Overcurrent Protection	8	25 A / 30 A / 35 A

انظر إلى الجزء الخاص من المعلومات الفنية ذات العلاقة بقيم التّيار المستمر للعاكس المستعمل في الأعلى:

1. قيمة الجهد المعياريّ لهذا النوع هي 240 (فولتاً) متردداً احادي الطور.
2. مدى الجهود الذي يخرج من هذا العاكس هو 211− 264 (فولتاً) متردداً.
3. التردد الخارج وهو 60 (هيرتزاً) تم إعداده مسبقاً للعمل على هذا التّردد من المصنع.
4. القيم التي يمكن تعديلها للتردد، حيث يمكن تعديل هذا المنتج ليعمل من تردد 57 الى 59.8 (هيرتزاً) ومن 60.2 إلى 63 (هيرتزاً)، (رجوعاً إلى النقطة التاسعة من المواصفات الفنية العامة في الأعلى).
5. قيمة معامل القدرة وهي أكبر من 0.995
6. أقصى قيمة تيار خارج وهي 23 (أمبير) تيار متردد.
7. أقصى قيمة قدرة خارجة من العاكس وهي 5000 (واط) عند درجة حرارة 60 سيليوسيس محيطة بالعاكس.
8. قيمة جهاز حماية يركب على المخرج هي 30 (أمبيراً) متردداً.

تختلف أنواع العواكس المنفصلة المتوفرة في السوق عن الشّبكة في الشكل والقدرة...، وفي معظمها تكون مشتركة في المعلومات الفنية، وسنختار أحد هذه العواكس لدراسة نشرة البيانات الخاصة به، والتي يمكن الاستفادة منها لقراءة أيّ نشرة بيانات أخرى لأيّ عاكس معزول عن الشّبكة.

يتم البحث عن المعلومات الفنية المرفقة مع نشرة بيانات العاكس المتوفر لديك في المشغل، وستجد المعلومات الفنية كما في الشّكل الآتي:

Technical Data

1	Rated power	1500 W
2	Surge power	1650 - 1750 W, 180 s; 1750 - 3000 W, 6 s
3	Input	48 Vdc
4	Operating voltage	41.2 to 61.2 Vdc
5	Shut down low battery	41.2 Vdc
6	Battery low voltage alarm	42.0 Vdc
7	Overvoltage shut down	61.2 Vdc
8	No load current draw	< 0.4 Adc
9	Save mode max. current draw	< 0.09 Adc
10	Output	230 Vac
11	Efficiency at rated Vdc, full load	93%
12	Dimensions	16.5 x 8 x 3.5 in (420 x 205 x 90 mm)
13	Weight	10.6 lbs (4.8 kg)

1 القدرة الاسمية للعاكس، وهي 1.5 كيلوواط.

2 القدرة الاندفاعية للعاكس مع الفترة الزمنية المسموحة لكلّ قدرة.

3 قيمة جهد المدخل، وهنا قيمته 48 فولتاً، وهناك عواكس أُخرى تكون قيم جهود أُخرى مثل 24 أو 96، كما يوجد مفتاح اختيار فلتية التّشغيل أو اختيار تشغيل تلقائيّ حسب نوع العاكس.

4 فترة الجهد التي يعمل عندها دون عطل.

5 قيمة الجهد الثابت لمدخل العاكس (جهد البطارية) الأدنى الذي يعمل عنده العاكس قبل الفصل عن البطاريات بسبب انخفاض جهدها.

6 قيمة جهد البطارية التي يعمل عندها العاكس على إنذار المستخدم قبل الفصل والتوقف عن العمل.

7 قيمة جهد المدخل للعاكس (جهد البطارية) الأقصى الذي يعمل عنده العاكس قبل الفصل عن البطاريات بسبب الارتفاع في الجهد.

8 مقدار التيار المستهلك من قبل العاكس في حالة عدم وجود الحمل، ويجب أن تكون القيمة منخفضة.

9 قيمة التيار المستهلك من قبل العاكس في وضعية الاستعداد.

10 قيمة الجهد المتناوب الخارج من العاكس.

11 قيمة كفاءة العاكس عند الحمل الكليّ.

12 قيم أبعاد العاكس.

13 مقدار وزن العاكس.

علما بأن هناك مجموعة من المعلومات المهمة من ضمنها معلومات تتعلق بدرجة الحرارة والأمان والحماية للعاكس، وهي كما يلي:

1	AC regulation	+/- 3%
2	Frequency swith select.	50/60 Hz +/-0.1%
3	Protections	Overload, short circuit, DC over/under voltage, over temperature
4	Waveform	True sine wave
5	Power factor cos Ø	0.8 to 0.95
6	Operating temperature	-4 to 104 °F/-20° C to + 40° C
7	Max. humidity	90%
8	Safety standard	UL458
9	Cooling	Load/temperature controlled fan
10	Reverse polarity protection	No, will result in permanent damage
11	Remote control unit	Si-RSW

يمثّل الشكل الآتي جزءاً من المواصفات الفنية الخاصة ببطارية دورة عميقة، حيث تمثّل المعلومات الواضحة ما يلي:

MODEL	**27TMH with POD vent**	1
VOLTAGE	**12**	2
MATERIAL	**Polypropylene**	3
DIMENSIONS	**Inches (mm)**	4
BATTERY	**Deep-Cycle Flooded/Wet Lead-Acid Battery**	5
COLOR	**Maroon**	6
WATERING	**N/A**	7

حيث إن:

1 رقم النموذج الخاص بالبطارية.

2 فولتية البطارية وهي 12 (فولتاً).

3 نوع المادة المصنوع منها جسم البطارية وهو بولي بروبيلين.

4 مقاسات البطارية المُعطاة في المواصفات هي بالإنش والمليميتر.

5 البطارية من نوع الدورة العميقة، وهي بطارية رصاص مغمورة.

6 لون البطارية وهو اللون الأحمر الغامق.

7 البطارية غير قابلة لإضافة الماء المقطر.

ب) المواصفات الكهربائيّة.

Capacity [A] Minutes		Capacity [B] Amp-Hours (AH)				Energy (kWh)
@ 25 Amps	@ 75 Amps	5-Hr	10-Hr	20-Hr	100-Hr	100-Hr
200 1	51 2	95 3	106 4	115	128	1.54 5

1 البطارية قادرة على العمل 200 دقيقة إذا ما تم تفريغها بتيار ثابت يساوي 25 (أمبيراً).

2 البطارية قادرة على العمل 51 دقيقة إذا ما تم تفريغها بتيار ثابت يساوي 75 (أمبيراً).

3 البطارية إذا تم تفريغها خلال خمس ساعات فقط فإن سعتها ستكون في هذه الحالة 95(أمبيراً).ساعة.

4 البطارية إذا ما تم تفريغها خلال 10 ساعات فقط فإن سعتها ستكون في هذه الحالة 106 أمبير.ساعة.

5 سعة البطارية تساوي 1.54 كيلوواط. ساعة إذا ما تم استهلاك هذه الطّاقة في زمن مقداره 100 ساعة.

Charger Voltage Settings (at 77°F/25°C)	
System Voltage	12V
Bulk Charge 1	14.82
Float Charge 2	13.50
Equalize Charge 3	16.20

1 الجهد الموصى به في مرحلة الشّحن السّريع وهو 14.82

2 الجهد الموصى به في مرحلة شحن التعويم وهو 13.5

3 الجهد الموصى به في مرحلة شحن التّسوية وهو 16.2

البطارية الآتية من نوع flooded السّعة الأمبيرية معطاه بقيمة ثابتة 250 (أمبيراً) مثلا وليس بعلاقة غير خطية، كما في البطارية السابقة، علماً أن ذلك يعتمد على نوع البطارية المستخدمة في التصميم.

6V Deep Cycle Flooded Batteries										
Battery type	Box type, BCI	C20, Ah	C100,Ah	Reserve Capacity @ 25A, min	Dimensions, mm			Layout	Terminal Type	Lid
					L	W	H			
MP 6VUS	GC2	210	220	430	261	181	276	0	Dual	FLAT
MP6V	DIN	240	250	500	244	190	274	0	Dual	FLAT

ج) المواصفات الخاصة بالحرارة:

CHARGING TEMPERATURE COMPENSATION

Add 1	Subtract 2
0.005 volt per cell for every 1°C below 25°C **0.0028 volt per cell for every 1°F below 77°F**	**0.005 volt per cell for every 1°C above 25°C** **0.0028 volt per cell for every 1°F above 77°F**

1 يشير إلى أنه يجب إضافة 0.005 فولت لكلّ خلية لكلّ درجة حرارة تحت 25 درجة سيليسوس (هذه البطارية مكونة من 6 خلايا) ولمعرفة ذلك فكلّ خلية تعطي 2 (فولت) والبطارية 12 (فولتاً) لذلك عدد الخلايا 6 خلايا، ويفضل الرجوع إلى المواصفات الفنية للتأكد، ويمثّل السّطر الثّاني الكمية إذا ما أردت الحساب باستخدام درجة الحرارة بمقياس الفهرنهايت.

2 تمثّل المعلومات المُشار إليها بالرقم 2 بأنه يجب طرح 0.005 فولت لكلّ خلية لكلّ درجة حرارة فوق 25 درجة سيليسوس (هذه البطارية مكونة من 6 خلايا)، ولمعرفة ذلك فكلّ خلية تعطي 2 (فولت) والبطارية 12 (فولتاً) لذلك عدد الخلايا 6 خلايا، ويفضل الرجوع إلى المواصفات الفنية للتأكد. ويمثّل السطر الثاني الكمية إذا ما أردت الحساب باستخدام درجة الحرارة بمقياس الفهرنهايت.

د) المواصفات الخاصة بحالة الشّحن للبطارية

STATE OF CHARGE MEASURE OF OPEN-CIRCUIT VOLTAGE

1 Percentage Charge	2 Specific Gravity	3 Cell	4 12 Volt
100	1.277	2.122	12.73
90	1.258	2.103	12.62
80	1.238	2.083	12.50
70	1.217	2.062	12.37
60	1.195	2.040	12.24
50	1.172	2.017	12.10
40	1.148	1.993	11.96
30	1.124	1.969	11.81
20	1.098	1.943	11.66
10	1.073	1.918	11.51

1 نسبة الشّحن الخاصة بالبطارية.

2 كثافة المحلول الموجود داخل البطارية.

3 فولتية الخلية الواحدة.

4 فولتية البطارية.

إذا كانت فولتية البطارية 12.1 فولت، فإن فولتية الخلية الواحدة تكون 2.017 وكثافة السائل 1.172، وتكون نسبة الشحن الموجود فيها 50 %

الشكل المجاور يبيّن التفريغ الذاتي للبطارية، ويتراوح ما بين (5-15)% من قيمة الشّحن الكلية حسب ظروف التخزين ودرجة حرارته.

Self Discharge

5 – 15% per month depending on storage temperature conditions.

هـ- منحنى الأداء للبطارية

يمثّل الشكل المجاور العلاقة بين الفترة بالدقيقة التي يمكن أن تزودنا بها البطارية بالطاقة (المحور الأفقيّ) مع التيار الذي تغذيه البطارية للحمل أثناء التفريغ (المحور العموديّ)، فمثلاً هذه البطارية إذا تم تفريغها بسحب تيار 10 (أمبير) منها فبإمكانها تزويد هذا التيار لمدة 900 دقيقة تقريباً.