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Conception of the Solar Regulator for Renewable Energy

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ABSTRACT

In this work, we are interested in conducting a technological research on the use of the renewable energy, particularly the "photovoltaic" to achieve a complete system for the controlled production of energy. In fact, we talked about the different types of renewable energy and their importance to the economic sector; photovoltaic cells and its operating principle, modeling, current-voltage characteristics and the influence of parameters on the performance of energy that makes us think to make followers continued to enjoy the maximum of energy. The integration of regulator renewable energy in the embedded system by using a microcontroller.

Keywords: Modeling; Solar; Storage; Energy efficiency; Converter DC/DC; Battery Accumulator; Regulator

1. Introduction

The energy is the capacity of a system that modifies its state, to produce a work pulling a movement, of the light or the heat, on the other hand its energies do not run out, that is the speed of formation must be bigger than its speed of use.

Concerning the exhaustion of the known world reserves (oil, coal, gas…), economic crises (sharp rise in prices of the oil), the accidents of nuclear power plants such as those of Three Mile Island (USA, 1979) or of Chernobyl (USSR, 1986) have been increasing as well. The concern of pollution, the need is ceaselessly growing in energy, all these perspectives strengthened the interest of the general public to the renewable energies, in particular the photovoltaic energy, which stands out as one of the most promising renewable sources of energy [1].

The renewable domain of energies is an innovative alternative with regard to the ancient systems which bases themselves on the principles of energies not renewable ones to produce a source of energy; it is for that reason these types of energy are objects of research activity.

2. Different Types of Renewable Energies

2.1. Wind Energy

Concerning the windmill, helixes turn to pull a rotor coupled with a generator, which converts the mechanical energy in electrical energy. Whether it is on earth (fields, farms, parks, power plants of wind turbines) or offshore little deep, off northern coasts, (off shoring), all the winds are exploitable [2].

Wind turbine is reliable and profitable; it represents the source of ideal electricity for numerous applications. Wind turbines come in many sizes, Microsystems mounted on a mast at the 5-megawatt turbines powering the electricity grid [3].

2.2. Hydro-Electric Power

It acts according to the movement of the water, smooth or in waterfall. In order to be exploited, it is often necessary to concentrate it, either by taking advantage of natural falls, or by the arrangement of a dam, so as to obtain a height of fall and a debit sufficient to install a hydroelectric power plant [2]. The water is so channeled towards a turbine which pulls an electric generator.

2.3. Biomass

The bioenergy consists in transforming the renewable raw materials of vegetable origin or animal (biomass) in energy; it allows diversity of the agricultural sector and to value the waste. There are various possible ways to produce heat, electricity or fuel, each is taking place by different energy intermediaries [2] (combustion, pyrolysis, and gasification).

2.4. Geothermal Energy

This type of energy is obtained by getting back the heat of the basement. Two techniques can be used. The geothermal science low temperature allows, by injecting some cold water in the basement into big depth (from 500 to 1500 m), to get back it warmed. The geothermal science high temperature consists in getting the very warm water springing in the volcanic zones to transform it into electricity.

2.5. Solar Energy

The solar energy arrives to the atmosphere under the shape of an electromagnetic radiation, leading light and heat. Photovoltaic panels allow converting it directly to electricity, and for this energy we distinguish two deferential types [2].

2.5.1. Solar Thermal Energy

There are two types of solar panels: the sensors to water and air collector:

- In the temperature sensors “water”, water or more often a heat transfer liquid, flows through tubes with fins in a closed circuit. For best performance, the assembly is placed in a glass box in order to obtain an insulating greenhouse. With lots of sunshine, and if the hot water needs are moderate, a simple network of finned tubes may suffice. The fins, which form what is called the absorber, are heated by solar radiation and transfer their heat to the coolant flowing through the tubes. The solar water is used to produce hot water and hot water for heating the dwelling involved.
- In the thermal sensors “air”, air circulates and is heated in contact with absorbers. The air is then heated and ventilated in habitats for heating or in sheds for drying agricultural production.

2.5.2. Photovoltaic Solar Energy

The photovoltaic energy bases itself on the photoelectric effect to create a continuous electric current from an electromagnetic radiation. This light source can be natural (sun) or very artificial (a lamp).

The photovoltaic cells are constituents “optoélectroniques” which transform directly the solar light into electricity by a process called photovoltaic effect, it was discovered by E. Becquerel in 1839 [4]. They are realized by means of semiconducting materials, that is having intermediate properties between the drivers and the insulations.

3. The Photovoltaic Solar Energy

In this part, we are interested in the photovoltaic solar energy and the description of the elements of a system of photovoltaic harnessing.

The development, the optimization and the characterization of photovoltaic cells imply certain knowledge of the used source of energy: The sun. The surface of this one behaves as a black body in the temperature about 5800 K. This leads to a peak of broadcast emission, situated in a wavelength of 0.5 µm for a power about 60 MW/m^2 that is a total of 9.5×10^{25} W [5]. By taking into account the visible surface of the sun and the distance between this one and the earth, it leads to an average illumination in the year of 1.36 kW/m^2 except atmosphere.

This irradiance is balanced by different factors on the surface of the earth: absorption by the molecules of the various coats of the atmosphere, the climatic conditions and the latitude of the place of observation and season. Gases as ozone (O_3), for wavelengths lower than 0.3 µm, carbon dioxide (CO_2) and steam (H_2O), for infrared above 2 µm, absorb the energies close to their energy of connection, what leads to “hole” in the visible solar spectrum on the ground. Besides, dusts and present sprays in the atmosphere lead to an absorption distributed almost on all the spectral range, what leads to a global decline of the incidental power. To compare and unify the performances of the photovoltaic cells elaborated in the various laboratories of the world, it established the notion of Air Mass (AM). It quantifies the amount of power absorbed by the atmosphere as a function of the angle θ of the sun from the zenith:

$$\mathrm{AM} = \frac{1}{\cos(\theta)} \qquad (1)$$

If the sun is at the zenith of the place of observation, $\theta = 0^\circ$, AM = 1: The notation used is AM1. AM0 is the irradiance outside the atmosphere, and is mainly used to predict the behavior of cells for space applications. The standard spectrum is the most studied AM1.5G, G global meaning because it takes into account both direct and diffuse radiation, as opposed to AM1.5D which considers only the direct.

A photovoltaic system linked with the network includes the following components:

- **A photovoltaic generator:** which must be exposed as much as possible so as to collect the maximum of period of sunshine over the year.
- **An inverter:** its role is to transform the direct current supplied by the PV array into alternating current with all of the alternating current delivered by the grid.
- **Organs of security and connecting:** to the network which assures functions of protection and persons and the properties face to face of the user and the network and the control of production and consumption.
- **A means of electricity storage:** potential composed of batteries (lithium-ion…).

4. Semiconductors and Principle of Functioning of a Cell PV

Semiconductors are bodies, the resistivity of which is intermediate between that of the drivers and that some insulations. As an example: the silicon.

The photovoltaic effect is used in solar cells to convert light energy directly from sunlight into electricity through the production and transport; this can happen due to a semiconductor material of positive and negative electrical charges as a result of light.

The photovoltaic effect is the appearance of a potential difference between the two sides of a semiconductor junction under the action of light radiation.

The photovoltaic conversion is performed by using photovoltaic cells generally produced crystalline silicon (**Figure 1**). If a load is placed across the cell, the electrons of the N zone joining the holes in the P zone via the external connection, creating a potential difference and an electric current flows [6].

4.1. Parameters of Solar Radiation Governing the Functioning of Cells

The sun is a star among many others. It has a diameter of 1,390,000 km, or about 50 times that of Earth. In every slowness of wave, λ can be associated with a photon of energy $E_{ph} = hv$ Where h is the constant of Planck (h = 6.62 × 10^{-34} Js) and v the frequency corresponding to the wavelength ($\lambda = \frac{c}{n}$, where c =3 × 10^8 m·s^{-1} speed of light in the space and n indication of the considered environment).

E_{ph} is the energy that removes electrons. It is inversely proportional to the wavelength of the photon.

For an electron bound to the atom (valence band) to become free in a semiconductor and participates in the conduction current, you must provide a minimum energy for it to reach higher energy levels (conduction band). It is the energy of the "band gap" E_g in electron volts (eV) (1 eV = 160.217 × 10^{-21} Joule = 44.505 × 10^{-24} Wh).

Each photon must have an energy greater than the energy E_g (*Gap* $E_g = E_C - E_V$, with E_C and E_V are respectively the energies of bungs conduction and valence).

4.2. Photovoltaic Cells

Photovoltaic cells are made of "silica". The latter can be defined as follows: Silica is found in nature in compact form (pebbles, quartz vein, for example), or as more or less fine sand. We also obtained industrially in powder form.

As a semiconductor, silicon is the main element used in the manufacture of photovoltaic solar cells.

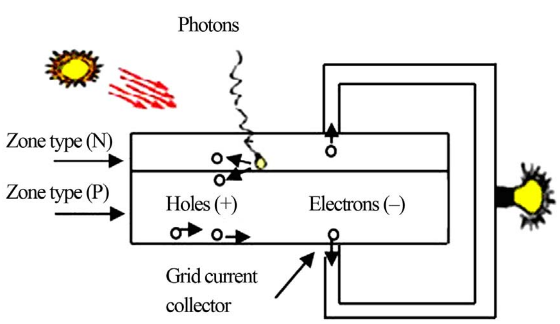

Figure 1. Principle of operation of a photovoltaic cell.

When a photon with enough energy is absorbed by the semiconductor, it produces a broken valence bond and frees an electron creating a "hole" positive [7].

In the darkness, the PV cell operates like a diode. It does not produce current. However, if connected to an external source of tension, a current flows I_D [8]. A cell is often modeled by the circuit diagram shown in **Figure 2**.

$$I = I_{ph} - I_D - \frac{V + I \cdot R_s}{R_{sh}} \quad (2)$$

$$I_D = I_S \left(\exp\left(q \frac{V + I \cdot R_s}{A \cdot K \cdot T} \right) - 1 \right) \quad (3)$$

4.3. Voltage-Current Electrical Characteristics of a Photovoltaic Panel

The characteristic curve of a PV cell is the variation of the current it produces according to the voltage across it. From the short circuit (zero voltage corresponding to the maximum current product) to open circuit (zero current for a maximum voltage across the cell). This characteristic $I = f(v)$ turns on the mathematical form from the two Equations (1) and (2) above as follows:

$$I = I_{ph} - I_S \left[\exp\left(q \frac{V + I \cdot R_s}{A \cdot K \cdot T} \right) - 1 - \frac{V + I \cdot R_s}{R_{sh}} \right] \quad (4)$$

From Equation (3) we draw the variation of the current I as a function of voltage V, with very high. R_{sh} is illustrated in **Figure 3**, for a given irradiance and temperature.

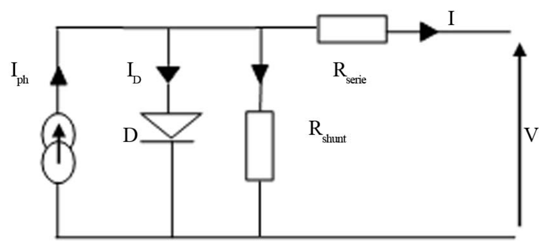

Figure 2. Equivalent circuit of a PV cell.

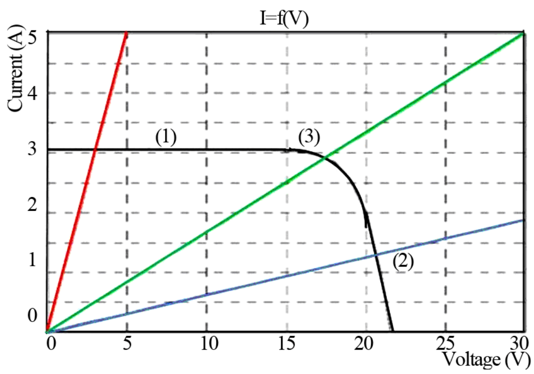

Figure 3. Current-voltage characteristics of photovoltaic modules E = 1000 W/m^2, T = 25˚C.

- The area (1) is characterized by the current that remains constant regardless of voltage. In this area, the PV array operates as a current generator.
- The area (2) is characterized by a variation of the current corresponding to a nearly constant voltage, and in this region, the generator is similar to a voltage generator.
- The area (3) corresponds to the bend of the characteristic. This is the intermediate region between the two areas above, and represents the preferred region for the operation (the optimal point can be determined).

Figure 4 shows the influence of light on the characteristic current—voltage of a photovoltaic module at a constant temperature.

Note that the voltage V_{CO} varies very slightly depending on the light, in contrast to the short-circuit I_{CC} increases strongly with light.

Figure 5 shows the influence of temperature on the current-voltage characteristic of the photovoltaic module for a given illumination. Note that when the temperature increases, the open circuit voltage V_{CO} down, while the short-circuit I_{CC} increases [9].

4.4. Efficiency of Photovoltaic Cells

It characterizes the performance efficiency of a system. It is expressed as the ratio of the energy that the cell product, the energy that the panel receives, that is the report: $\eta = E_{\text{elecrical}} / E_{\text{light}}$.

In practice, solar cells convert only a portion of the incident energy into electricity.

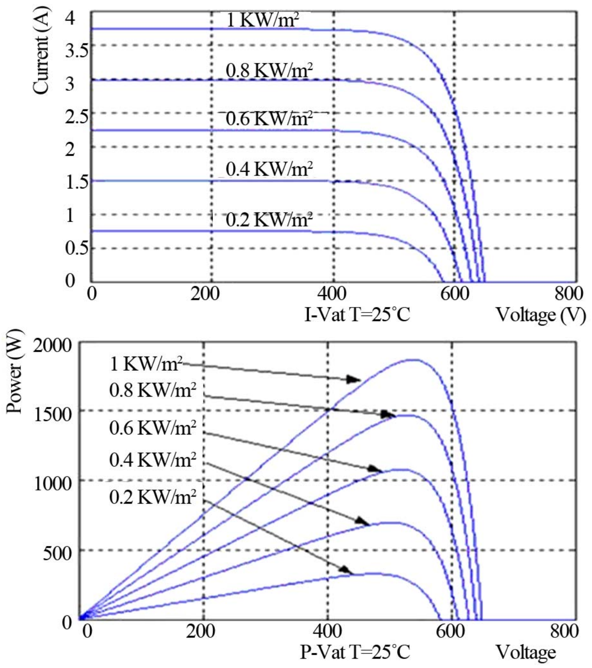

Figure 4. Influence of the illumination at *T* = 25˚C.

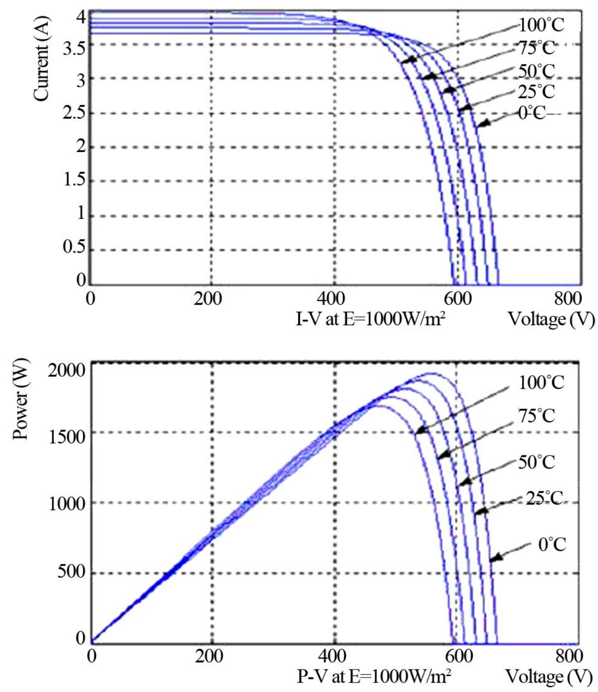

Figure 5. Influence of temperature for a light, *E* = 1000 W/m².

5. Association of PV Module

➢ **In series:**

By N identical modules in series, the current in the branch remains the same and the voltage across the branch is N times greater than that of a module. As shown in **Figure 6** that $U = \sum U_c$, U_c, the voltage across the cell index "*c*". In order to limit the reverse voltage across the terminals of a module, it is necessary to place a bypass diode across each module.

➢ **In parallel:**

By N identical modules in parallel, the voltage of the branch remains the same, and the total current is N times of the current of a module. In **Figure 7**, we represents the variation of $U = \sum I_c$, I_c, Ampere: current across the cell index "*c*". To avoid becoming a receiver module, there must be a diode in series in each branch.

6. Storage System of Solar Photovoltaic

In a PV system, storage is the conservation of energy produced by the PV generator, waiting for future use. Management of solar energy requires envisaged following of the conduction of storage and weather that will address two main functions [10]:

-Provides the installation of electricity when the PV generator does not produce (at night or in bad weather for example).

-Provides for the installation of powers greater than those provided by the PV generator.

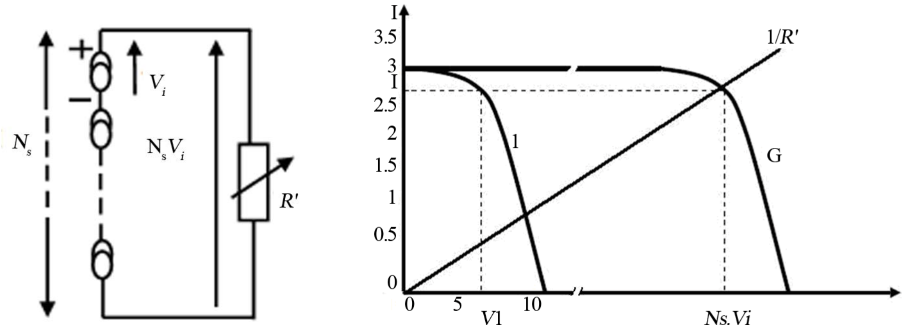

Figure 6. Group of cells in series.

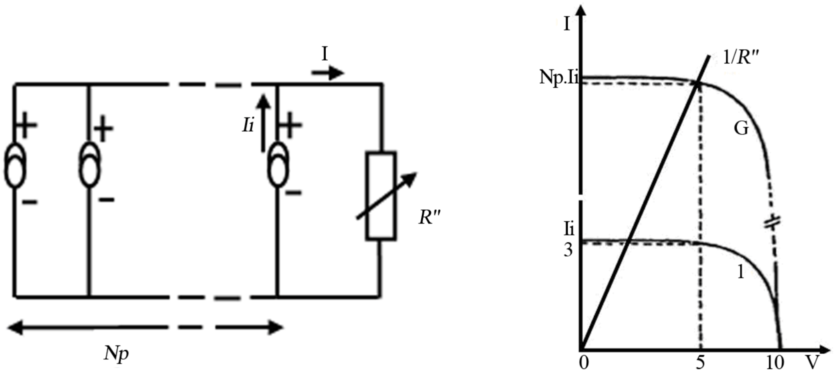

Figure 7. Group of cells in parallel [11].

7. Solar Panels and Profitability

A solar panel is a device designed to recover some energy from sunlight to convert it into a form of energy (electric or thermal) used by man.

The yields of the solar panels vary depending on many factors:

- Influence of the angle of incidence.
- Interest in photovoltaic solar panels movable relative to the fixed panels.
- Influence of the angle of inclination.

7.1. Influence of the Angle of Incidence

The angle of incidence is the angle formed by the rays of the sun and the plane of the panel. The angle of incidence plays a major role in the yields of the panel.

Thus, the yield is at the maximum when the rays come perpendicular to the panel. While for an angle of 45˚ for example, the yield is only 70%. The **Figure 8** presents the performance of panels according to the angle of incidence.

7.2. Interest of Photovoltaic Solar Panels Movable Relative to the Fixed Panels

During the day, the sun moves continuously, while a photovoltaic array is fixed in its positioning, losing a considerable amount of energy that could be available.

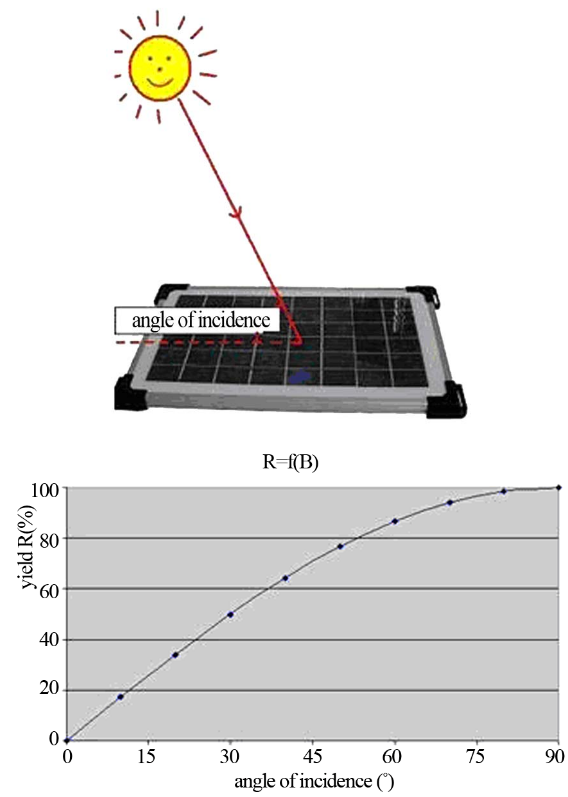

Figure 8. Graph representing the performance against the angle of incidence.

In a fixed installation which, for optimal performance is exposed to the south, the energy delivered by PV modules is maximal only at noon for this if the PV modules are always oriented towards the sun, as if there the corresponding condition was constantly at noon, the power generated is always the maximum.

The photovoltaic modules placed on followers of the sun have an efficiency that increases significantly compared to fixed installations.

The followers of sun available in our range are monitoring the trajectory of the sun (which must be determined) along with an axis and the latter motorized seasonal manual. They thus generate an increase in the average output power of about 50% as shown in **Figure 9** by the PIC16F876.

7.3. Influence of the Inclination Angle

The "tilt angle" is the angle between the ground plane and the plane of the panel. However, according to the seasons, the tilt of the earth varies. To keep power panel as regular as possible throughout the year, we will keep the angle of 45˚ south.

8. Rregulators

The controller charge/discharge electronics is fully automatic which are connected to photovoltaic panel, battery, and the end devices of solar electricity.

Regulators can also include other functions such as:

- View or indication of battery voltage, state of charge and various currents.
- The alarm relays contacts for transmitting information indicating a malfunction.
- Thresholds of control used to start a rescue group.

➢ **Types of regulators**

Several types of controllers can be used in photovoltaic systems. The controller controls the flow of energy. It must protect the battery against overload (solar) and deep discharge (user). It must ensure the security and surveillance installation [12].

Charge controllers are characterized by three main groups:

Figure 9. Follower-based Microcontroller tracker.

-**Regulators series:** these are the controllers that incorporates a switch between the generator and the battery to stop charging.

The switch load is here in series with the battery as shown in **Figure 10**. It opens when the end load is reached.

-**Shunt regulators**, including the switch bypasses the solar array at the end of charge.

All the current passes through the panel battery, as shown in **Figure 11**. When the cut off is reached, all the current passes through the switch. It should be added imperative this switches a diode between the battery and not to short-circuit. This diode also acts as blocking current flowing from the night up to the battery panel.

-Regulators to search for maximum power point (MPPT or Maximum Power Point Tracking), which use a special electronic circuit to continuously extract the collector array maximum power [13].

➢ **Converters (inverters)**

Depending on the application, we will often use a converter to adapt the generated power to the load, since most of the machines used to operate AC where the need for an inverter in the PV system.

There are mainly the DC/DC converters that provide support to a DC voltage different from the voltage generated by the panels and DC/AC converters that produce an AC voltage for the corresponding expenses [14].

9. Conclusions

Over the study on photovoltaic, we have shown that the photovoltaic effect is the technology of solar panels constantly evolution of the construction to the installation

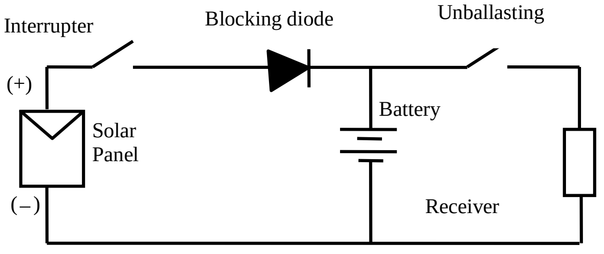

Figure 10. Diagram of a control series.

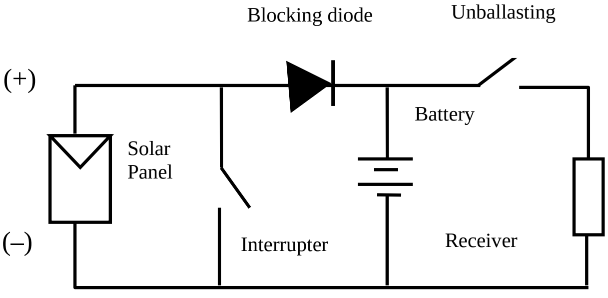

Figure 11. Diagram of a shunt regulator [12].

of a photovoltaic module, which responds to stress specific techniques, we found that photovoltaic energy renewable energy has advantages in terms of the environment, and operating costs very low is a free energy, generously and abundantly provided by the sun.

In order to implement the proposed solution in this paper, an energy storage system using photovoltaic grid inverters with the advanced modulation technique control such as modulation staircase, step leader, Delta or PMW (Pulse Width Modulation) which is developed in our laboratory. This system offers us the controller developed the internal components of the inverter controlled by a programmable memory and will be operated as an embedded system. The output voltage of the inverter varies between 180 and 380 volt. This principle will be the subject of the future publications and patents.

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