THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2021

ANALYSIS OF A POWER SUPPLY SOLUTION USING RENEWABLE SOURCES

Assoc. Prof. Ioana DIACONESCU, PhD
“Dunarea de Jos” University of Galati,
S.I.M. Department

ABSTRACT

This paper aims to determine a solution for the power supply (off-grid solution) using a photovoltaic cell equipment designed based on the analysis of the factors that influence the annual performance of the photovoltaic modules.
The solution is based on the advantage in making solar panels that can be sized according to the application, to provide the values imposed by voltage and current. In this application, there will be used cell panels with 24V voltage in vacuum and 4A current in short circuit, that is, 96W theoretical power. The connection of the cells will be done following an efficiency analysis.

KEYWORDS: PV system, energy balance, solar cell, thin-film technology, solar panel

1. INTRODUCTION

The case study of this article examines the theoretical way of power supplying using solar energy to an isolated household consumer, who cannot be connected to the electrical grid, so that it must produce its own power consumption. In the case of autonomous photovoltaic systems with energy storage with DC receivers, the system is additionally equipped with charge controller and electrochemical batteries that allow storing and using surpluses of electricity at a different time when solar radiation is insufficient to produce the necessary energy or when there is no radiation. The system is additionally equipped with the DC/AC inverter that allows power to AC installations, such as those in the classical electrical grid.

For system sizing, the following should be considered [1]:

(a) the energy consumption of all receivers, depending on the need for consumption, over the period of one day (24 hours). The number of batteries will be chosen so as to meet the energy requirements with a small margin of safety.

b) once this stage is completed, the photovoltaic system can be dimensioned. Thus, the consumption and also the charging of batteries, must be taken into account to ensure continuity in the energy supply of consumers.

The identification of a solution that takes into account the afore mentioned aspects lead to the dimensioning of the photovoltaic system.

2. FACTORS THAT INFLUENCE PV ENERGY PRODUCTION

2.1. Operating characteristics of solar cells

Numerous laboratory tests have led to the measurement of the performance of the solar cell. In this respect, for the standard test conditions (TSc), the following industrial standard parameters are used:

- temperature = 24,8 °C

- lighting = 1,000 W/m^2
- air density = AM 1,51

Also, the amount of current produced by photovoltaic cells is calculated according to voltage, the current-voltage variation curves (I-V) of the solar cell show the dependence between them.

The power produced by the cell is almost directly proportional to the intensity of sunlight. An important property of the photovoltaic cell is that the voltage does not depend on the size of the cell and remains constant when the light intensity changes. The current through such a device is approximately directly proportional to the light intensity and the size of the cell.

The power produced by a solar cell can be effectively increased using a tracking mechanism, which maintains the photovoltaic cell directly oriented towards the sun or concentrating sunlight with lenses and mirrors.

Thus, the amount of power supplied by a photovoltaic device is (except for the temperature dependence) determined mainly by:

- type and surface of the material
- solar light intensity;
- wavelength of sunlight.

Factors that may influence the competitiveness of solar-based applications are:

- Price on installed power;
- The amount of investment taxes;
- Financial support provided by the state in order to reduce the price of the installed system;
- Other support to attract customers (for example lower interest rates on loans);
- Tariffs for electricity obtained in photovoltaic systems, which is injected into the grid;
- System life and degradation over time;
- Solar resource (duration of sunny day);
- Availability and cost of space required for the installation;
- Price or cost of alternative energy;
- Interest rate.

Factors involving major risks and unforeseen situations for creditors and investors are technological and operational risks and financial risks.

2.2. Solar energy production

Solar radiation releases an impressive amount of energy, and the Earth receives virtually all this energy in the form of electromagnetic radiation (Fig.1). Incident radiation at a distance equal to the average solar distance at the end of the atmosphere on a normal plane is the solar constant 1360 W/m^2 [1]. Solar radiation is a function of the orbital position of the earth.

If Ss is total solar radiation on all emitted frequencies, at a distance R from the centre of the sun the radiation flow is the same in all directions, then a radiation flow can be defined at a distance R from the sun Q(R).

$$Q(R) = \frac{S_S}{4 \cdot \pi \cdot R^2} \quad (1)$$

The Earth intercepts from the sun a radiation disk with the area $\pi \cdot r^2$, where r is the earth's radius. Thus:

$$\frac{\pi \cdot r^2 \cdot Q(R)}{4 \cdot \pi \cdot r^2} = \frac{Q(R)}{4} \quad (2)$$

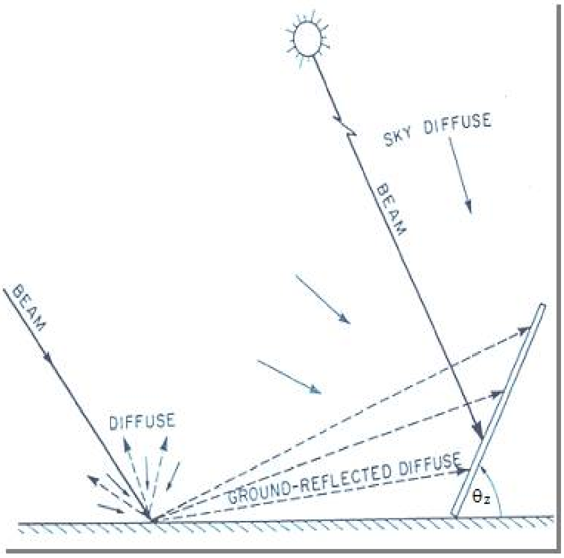


Fig.1 Global solar radiation

The above calculations are valid if the earth is spherical, without atmosphere, and its orbit perfectly spherical.

Absorption of visible solar radiation on short waves is balanced by infrared radiation emission, long waves. The calculation of the emission and radiation absorption by the earth leads to a body temperature of 253 K. The difference of approximately 30 K to the average temperature of the earth's surface is given by the greenhouse effect [2].

2.2.1. Solar radiation at ground level

When solar radiation enters the atmosphere, part of its energy is consumed by scattering and another by absorption. The part of the radiation scattered in the atmosphere is called diffuse solar radiation. Part of the diffuse radiation returns to the alien environment, and the other part reaches ground level (Fig.1).

Solar radiation that reaches directly from the solar disk on the earth's surface is called direct solar radiation. The total amount of energy transmitted, on all wavelengths, by direct or diffuse radiation is called global solar radiation.

2.2.2. Incident solar radiation on sloping solar panels

In order to increase the amount of energy received by the vast majority of solar installations, they are not placed horizontally, but on an inclined plane. The optimal angle for the placement of solar panels is often equal to the latitude at which the solar installation is placed. Because the panels are not placed horizontally, in addition to direct and diffuse solar radiation, a component of solar radiation can also appear, the one reflected by the ground (Fig.1).

2.2.3. Solar radiation measurement

Global solar radiation can be estimated according to the equation:

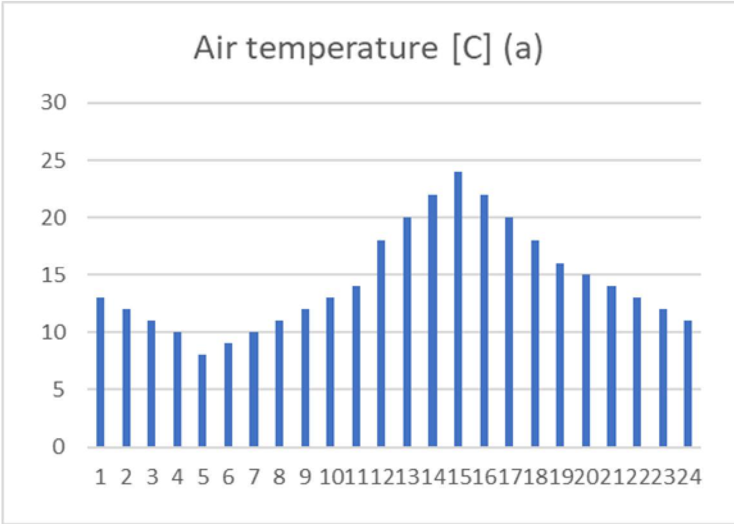
$$I = I_b \cos\theta_z + I_d \quad (3)$$

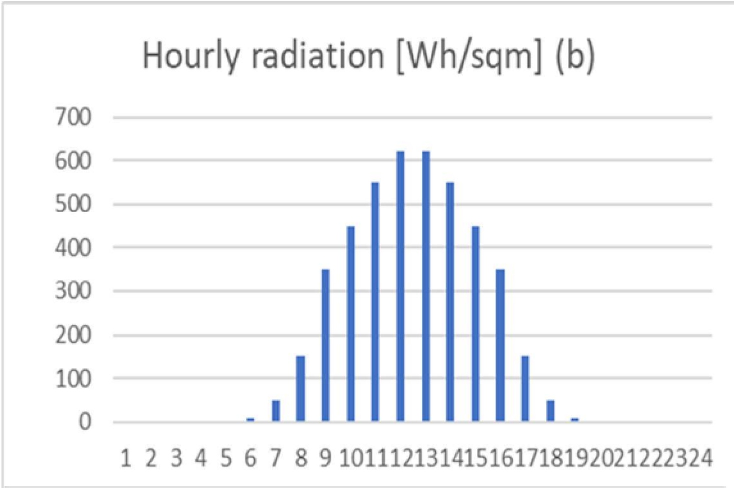
Where: I - global radiation, I_b - direct radiation, θ_z - the angle of incidence of radiation on the panel, and Id - diffuse radiation. It is observed that by knowing two components the third can be calculated.
Direct solar radiation is measured with a pyrheliometer and, from a constructive point of view, pyrheliometers can be: with water column, with silver disk, with Angstrom electrical effect and radiometers.
Global and diffuse solar radiation is measured with pyranometer, which is the device that measures direct and diffuse solar radiation from the entire hemisphere.

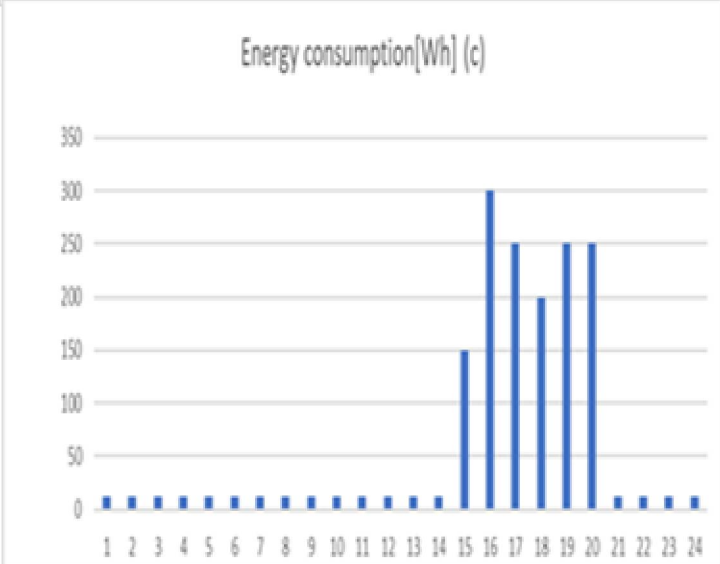
3. DAILY ENERGY BALANCE – CASE STUDY

The case study consists in determining the consumption characteristics of a household consumer and analysing the production of necessary solar energy, which take into account the external temperature and the urban solar radiation (Fig.2). Based on the analysis of energy demand as well as the distribution of solar radiation is determined by the energy balance curve and also by the total energy balance.

The energy must be supplied to the load in accordance with the application's consumption needs, and the energy need may occur at different times than when the energy flow from







the photovoltaic network is achieved. This creates a mismatch between switching energy from the photovoltaic system to the load [2].

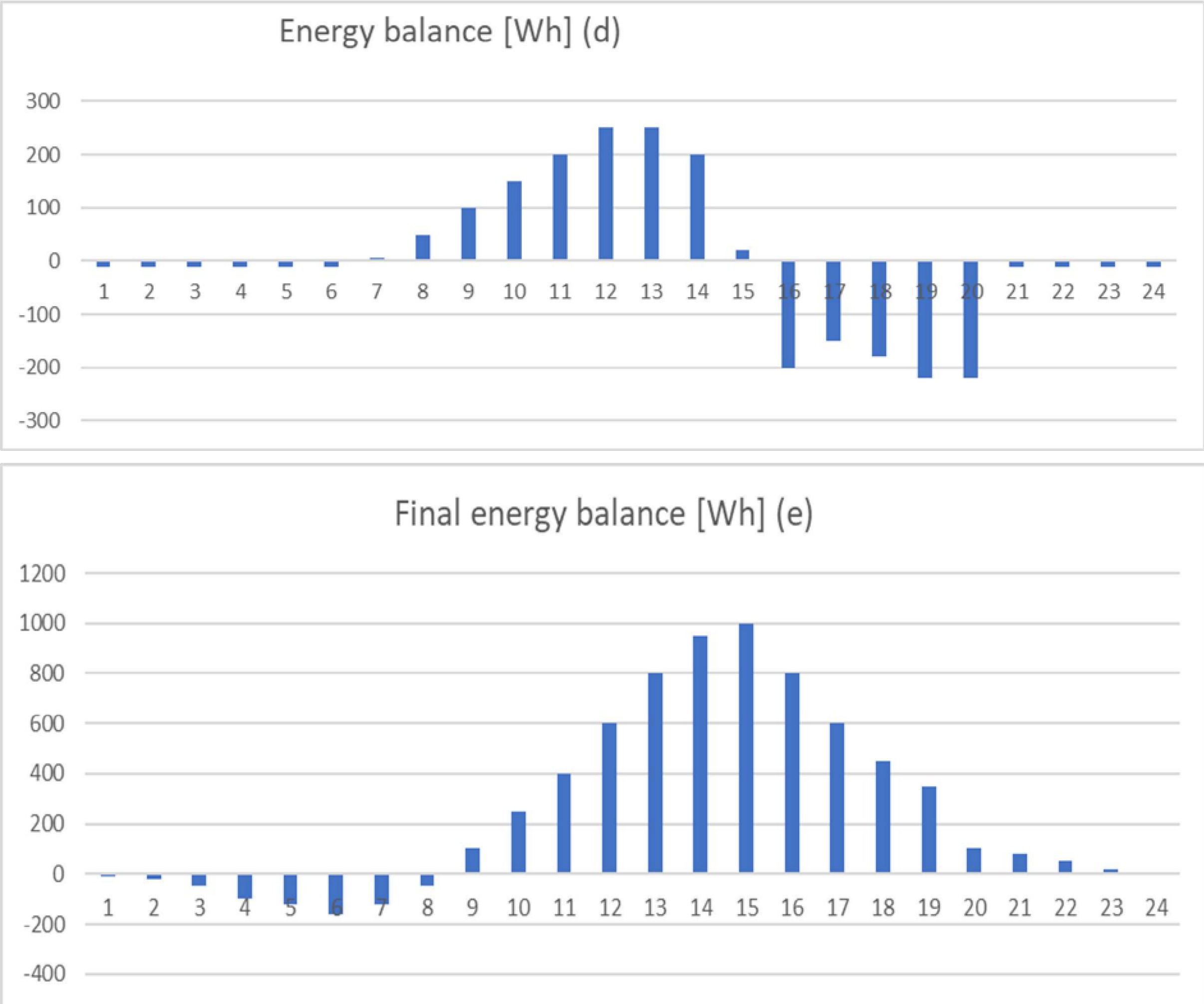


Fig.2 (a) temperature profile in day hours; (b) solar radiation for a typical day of the year; (c) a typical load profile at day hours level; (d) energy balance at day hours level; (e) cumulative energy balance/day

4. THE SUPPLY SOLUTION USING THIN-FILM TECHNOLOGY

For the design of the installation were used solar cells with 24V voltage at idle operation and 4A current at short circuit operation, with a theoretical power of 96W, which were tested under AM atmosphere conditions (Air Mass), where AM is the mass of air at midday sun, at sea level, when the sun is perpendicular to the surface of the Earth. The available power at the level of solar cells under AM1 conditions is equivalent to 1kW/m^2. The best time of the day when cell testing is done is around noon in the summer, near the solstice [3]. At that point it comes closest to the AM1 standard. Testing can be done at other times, but it should be taken into account that the output values are lower than the peak values, which are obtained under optimal irradiation conditions [4].

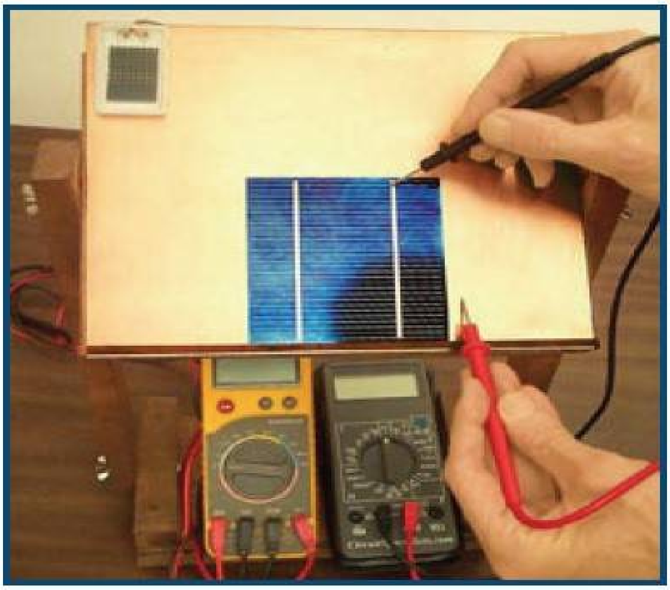


Fig. 3 - Solar cell testing stand

For testing the solar cells, a stand was used to keep the cells at the same level and position at the time of testing (Figure 3).

The stand on which the cell is placed is recommended to be made of copper, so the measurement is made easier, because the contact between the positive electrodes and the stand is made. It is recommended that the test of the photovoltaic cells that make up a module be performed on the same day to maintain the same test conditions for each cell.

4.1. Solar panels

One of the important advantages of designing solar panels is that they can be sized according to the application, to provide what voltage and current we want. In this application were made panels with 48 cells to have a flow of 24V in vacuum and 4A in short circuit, resulting in panels with a theoretical flow of 96W. A simple example of connecting cells is shown in Figure 4.

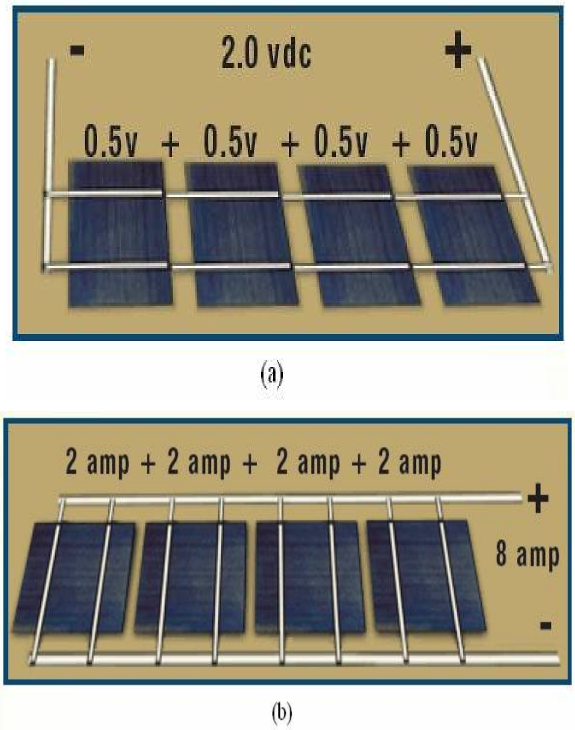


Fig. 4 - (a) string of connected solar cells in series (to increase the voltage); (b) string of cells connected in parallel (to increase the output current).

Also, the panels can be connected in series, parallel or mixed depending on the need. The connection is as in Figure 5.

Batteries are set up in the same logic. For 24 V systems, using 6V batteries and 225Ah capacity, we need to connect 4 batteries in series and 8 rows of 4 batteries in parallel. A total of 32 batteries. The possibilities to connect the batteries are shown in Figure 6.

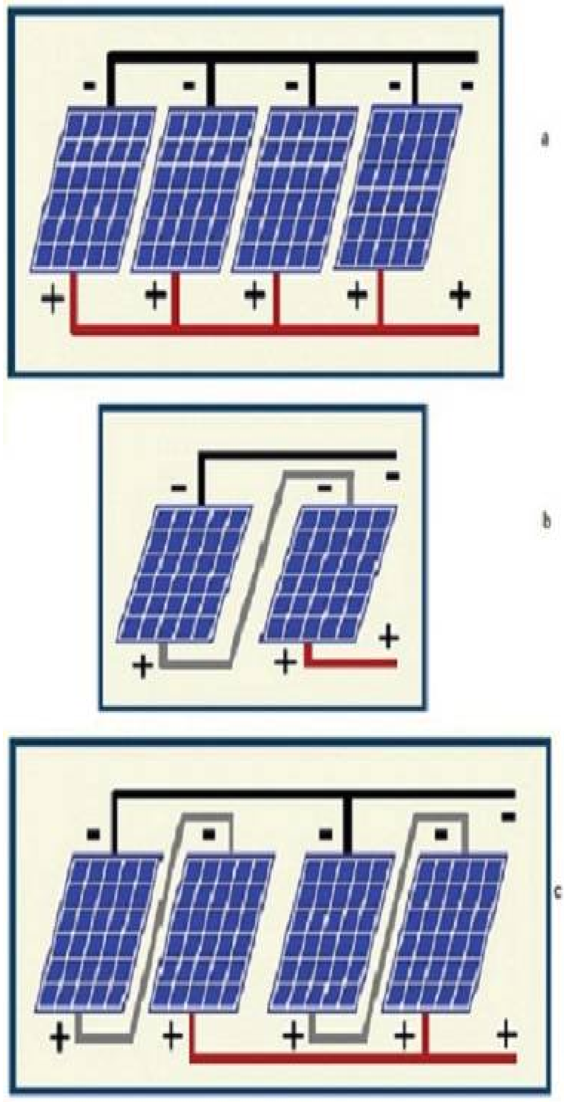
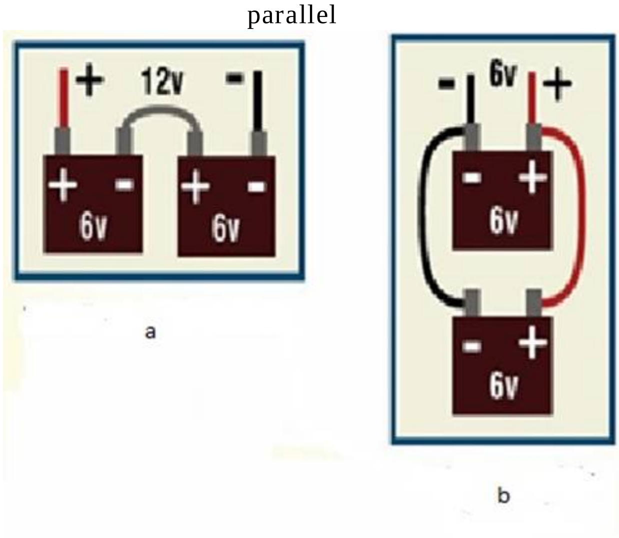


Fig. 5 Different ways of connecting photovoltaic panels: a. PV parallel, b. PV series, c. two pairs of PV series connected in parallel



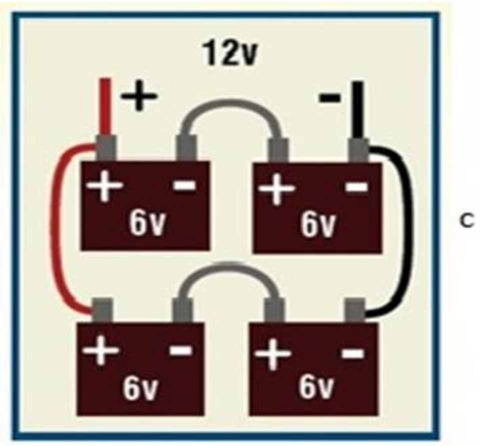


Fig. 6 Different ways to connect batteries:
a. series, b. parallel, c. mixt

4.2. Load regulator and inverter

The load regulators control the charging of the batteries from the solar panels. Their circuit is dedicated to keep the batteries fully charged and avoiding overcharging or undercharging.

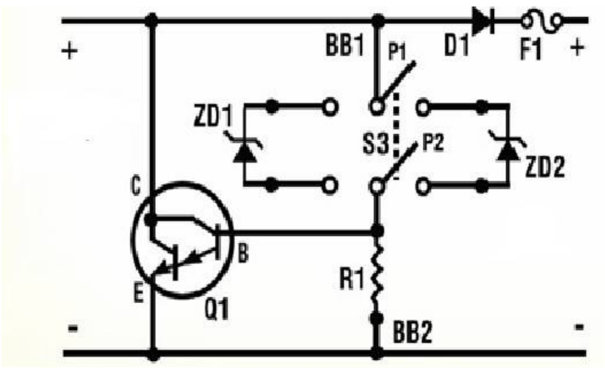


Fig.7 Electrical scheme of shunting load regulator

The chosen load regulator is of shunting type, which can disconnect from the batteries by deflecting the current through a shunt [5]. The scheme of the load regulator is shown in Figure 7.

5. CONCLUSIONS

In the case of serial connection of solar panels, the maximum discharge current and capacity do not change, so the serial connection of the elements is used in cases where a high electromotive voltage is required.

Rarely is the solution of parallel connection of photovoltaic panels used. When connecting the elements in parallel, the total electromotive voltage of the battery does not increase, but instead the maximum discharge capacity and current is increased. Therefore, parallel connection is used when a higher discharge current is required and a capacity greater than that of a single element.

Most of the time, the mixed connection solution is used, to which the electromotive voltage, capacity and maximum discharge current are increased. In this case, several groups of elements are usually connected in parallel, and in each group, there are connected in series as many elements as are needed to obtain the voltage required / required by the consumer.

The total number of parallel groups is determined by the required maximum discharge current.

Analysing the energy storage, it is good that the batteries are made up of series-bound elements and have a sufficient discharge current. Only when a higher current and capacity is needed is the use of mixed connection. In addition, the connection of additional elements, according to the principle of mixed connection, can be used in, raising the battery voltage, if the elements have discharged too much. The parallel connection of the batteries is chosen when increasing the battery amperage is desired, and the serial connection is chosen in the situation where the battery voltage is required to increase.

REFERENCES

1. **Diaconescu, I., Patrascu, R., Tutica, D., Ionescu, C.**, **Minciuc, E.**, *Influence of technical and economic factors in the assessment of energy efficiency projects in industry*, International Conference on ENERGY and ENVIRONMENT (CIEM), IEEE, Timisoara, October, 2019.
2. **Costinas, S., Diaconescu, I., Ioana Fagarasanu, I.,** *Wind power plant condition monitoring* , Proceedings of the 3rd WSEAS International Conference on Energy Planning, Energy Saving, Environmental Education (EPESE'09), Canary Islands, Spain, 2009.
3. **Pătraşcu, R., Bădicu, A., Minciuc, E., Diaconescu, I., Necula H.,** *Integration of renewable energy sources for industrial consumer,* U.P.B. Sci. Bull., Series C, Vol. 79, Iss. 3, 2017.
4. **Diaconescu, I., Grigorescu, L**., New Strategy for Energy Management Program, Calitatea-Acces la Succes, volumul I, Special issue, Yeear 9, No.93, 2008, pg. 221-225
5. **Diaconescu, I.,** *Analysis of Irreversible Thermodynamic Processes from Control Valves*, Proceedings of the 3rd WSEAS International Conference on Energy Planning, Energy Saving, Environmental Education (EPESE'09), Canary Islands, Spain, 2009.