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The Possibility of Functioning at Maximum Power for Solar Photovoltaic - Electric Battery Systems

The paper presents the functioning of a solar photovoltaic module (PVM) that debits direct to on electric battery (EB). By a good adapting of PVM to EB, so that the no load voltage of the two components (PVM and EB) are well suited, during a day the energy value can be reached near to the maximum possible value, when the PVM functions in the maximum power point (MPP). The proposed solution is much more economic than the classical: PVM + DC – DC + EB because the direct current - direct current power converter, is not necessary (DC - DC).

Keywords: *solar photovoltaic module, maximum power point*

1. Introduction

From the renewable energy category, the solar electro energetic systems are more and more used to obtain electric energy.[1, 5, 6].

In the papers that considers the electric energy obtained from solar energy based on photovoltaic effect [3, 4, 9, 10] it is expected that the system with PVM functions in the maximum power points-MPP [11, 12]. To obtain this operating mode, a DC-DC converter between PVM and EB is necessary and so the system becomes expensive and unprofitable economic.

Through the modification of the equivalent resistance load at the solar battery terminals, the operation of the system is trying to be as near to the maximum power point, but this point being unknown, the operating power of the system is done below the maximum [9, 11]. All this methods for modification of the equivalent load resistance, assume high cost for complex electronic equipment's particularly the DC-DC converters [16] and in many applications, the investments become unprofitable.

The power obtained from the sun continues changes and the system (PVM+DC-DC+EB), figure 1, must be so arranged that is has to function near to the maximum power point.

To reduce the costs of solar energetic installations, cheap and effective equipment's have to be manufactured as proposed in this paper.

By mathematical modeling of voltage-current characteristics, through computing of the obtained energy, an estimation of the profitability of the functioning of the system PVM + EB, is proposed.

The coordinates of the maximum power point P_{OPTIM} (voltage: U_{OPTIM}, current: I_{OPTIM}) are changing in time, depending on the meteorological conditions (the intensity of solar radiation P_S) and from this reason, the equivalent load at the terminals of solar module (PVM) has to be correlated with the value of the solar radiation intensity [15, 17].

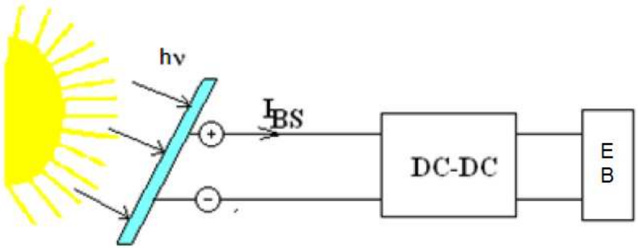

Figure 1. The system PVM+DC-DC+EB

Through measuring the power of the solar radiation P_S the fundamental parameters that describes the functioning of PVM in the maximum power points MPP, can be determinate, namely:

- the optimal load resistance R_{optim}, with the mathematical model of the PVM, or, in a simplified variant, through the ratio of the no load voltages to the short-circuit current (fig. 2) [4];
- the useful maxim electric power: P_{OPTIM};
- the I_{OPTIM} current and the U_{OPTIM} voltage corresponding to the maximum power point.

The determination of the coordinates of the maximum power point (MPP or P_{OPTIM}), are based on the *external characteristics –U = f(I)* (fig. 2) of the solar modules (PVS), characteristics that changes in depending of the nebulosity in the atmosphere.

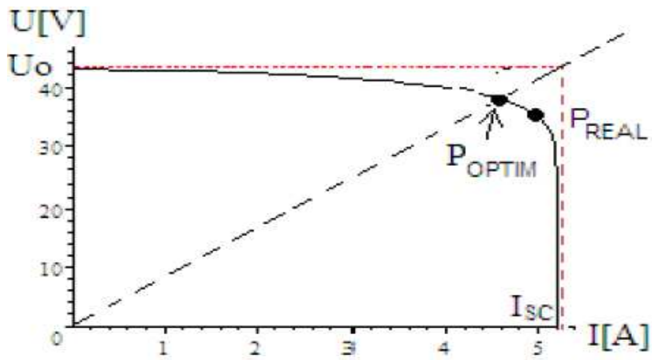

Figure 2. External characteristics *U = f(I)*

In the following, we calculated the difference between the obtained energy with PVM directly debiting on the EB and the maximum possible. In this respect, it is necessary that the external characteristics *U = f(I)* of the solar module PVM, has to be mathematically modeled.

2. Modeling external characteristics

The proposed mathematical model for the external characteristics, *U=f(I)* have the form:

$$U(I)=(d-Tf)\left(\cos\left(\frac{aI-gT}{P_s^b}\right)\right)^c \tag{1}$$

where: *a*, *b*, *c* and *d* are constructive constants, P_S - the solar radiation power, I the obtained current. From the experimental external characteristics, the constants *a*, *b*, *c* and *d* will be determinate. [18]

The determination of the coordinates for the maximum electrical power points P_{OPTIM} (fig. 2), voltage: U_{OPTIM} and the current: I_{OPTIM} is done by cancelling the powers derivative: P=U·I, as follow:

$$\frac{d}{dt}\left((d-Tf)\left(\cos\left(\frac{aI-gT}{P_s^b}\right)\right)^c \cdot I\right)=0 \tag{2}$$

From the below equation, the current I_{OPTIM}, is obtained and so, the voltage U_{OPTIM} and the power P_{OPTIM} are determined:

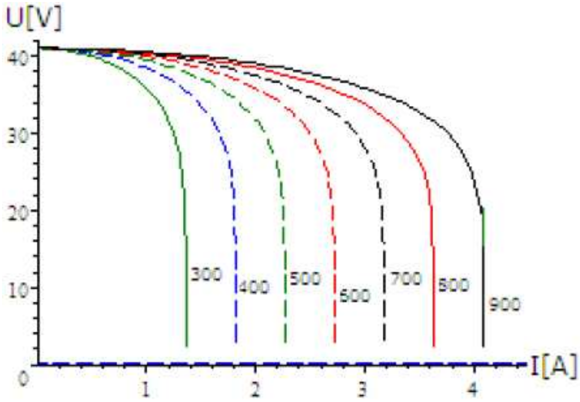

Figure 3. External characteristics with the radiant power as parameter

$$U_{OPTIM} = (d - Tf)\left(\cos\left(\frac{aI_{OPTIM} - gT}{P_s^b}\right)\right)^c \quad (3)$$

Case study

The external characteristics for one considered PVM, that functions at the temperature T = (273 + 25)K, are given by the functions [4]:

$$U(I) = 41\left(\cos\left(\frac{3.14}{8} I \frac{883}{(P_S)}\right)\right)^{0.15}, \quad (4)$$

with P_S – the radiant power, as parameter, fig. 3.

3. The solar module functions in the maximum power points

For a functioning in the maximum power points, characterized through the values U_{OPTIM} for voltage and I_{OPTIM} for current, it is necessary to use a DC-DC convertor between the PVM and EB. The coordinates of the maximum power point MPP are obtained by cancelling the derivate

$$\frac{dP}{dI} = \frac{d}{dI}\left(41\left(\cos\left(\frac{3.14}{8} I \frac{883}{(P_S)}\right)\right)^{0.15} \cdot I\right). \quad (5)$$

At P1 =900 [W], we obtain:

$$\frac{dP}{dI} = \frac{d}{dI}\left(41\left(\cos\left(\frac{3.14}{8} I \frac{883}{(900)}\right)\right)^{0.15} \cdot I\right) = 0, \quad (6)$$

from where I results to be 3.5533[A]. For the voltage U, we get then

$$U = 41\left(\cos\left(\frac{3.14}{8} 3.5533 \frac{883}{(900)}\right)\right)^{0.15} = 32.232[V] \quad (7)$$

The resulted power is: P = 114.52[W].

At P2 = 800[W], results P = 101.8 [W];
At P3 = 700[W], results P = 89.09 [W];
At P4 = 600[W], results P = 76.35 [W];
At P5 = 500[W], results P = 63.63 [W];
At P6 = 400[W], results P = 50.9 [W];
At P7 = 300[W], results P = 38.17 [W];
At P8 = 200[W], results P = 25.45 [W];
At P9 = 100[W], results P = 12.73 [W];
The value of the energy during one day:

$$W = \sum P_i \cdot t_i = 3.4587x10^6 [J] \tag{8}$$

4. The photovoltaic plant debitates on the electric batery

Usually the storage of solar energy is done in electric batteries (EB), fig.4.

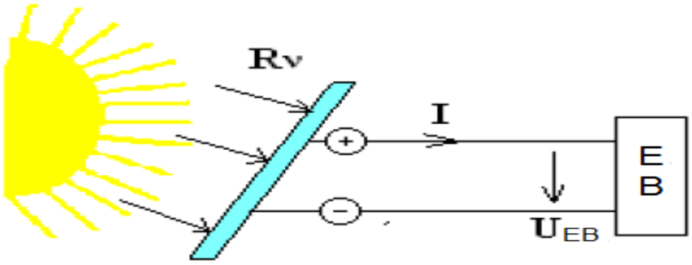

Figure 4. Photovoltaic modules and electric battery

In this case the voltage at the electric battery EB is given, for example: U=k·12[V], the systems (PVM + EB) functioning is far away from the maximum power points, as it can be seen in fig.5.

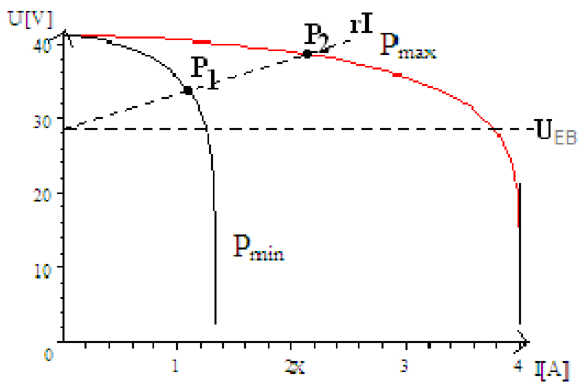

Figure 5. Operating points

The operating points P_1 (at minimum radiation power) and P_2 (at maximum radiation power) are obtained by the intersection of external characteristics *U = f(I)* of the PVM, with the voltage characteristics from EB: $U = U_{EB} + rI$, where *r* is the resistance of the EB circuit; U_{EB} the voltage at the EB terminal.

5. Determination of no load voltage by electric battery U_{eb}

The cells of the electric batteries have the no load voltage less than 2 [V].The corresponding voltage to the Maximum Power Point at P_S= 900[W], has the value: U_{OPTIM} = 32,232 [V] and therefore are chosen 32/2=16 cells for EB. At U_{EB} =32 [V] and an intern resistance for EB of value: r=0.1[Ω], the results, as in the same conditions by the functioning in MPP, are obtained.

The electric equivalent scheme in this case, is present in fig. 6.

The operating points P_1 at minimum radiation power P_{min} and P_2 at maximum radiant power P_{max}, can be determined on the external characteristics *U(I)* of the PVM at the voltage $U = rI + U_{EB} = 0.1 \cdot I + 32$ as reflected on the following:

At P1 = 900[W], results P = 112.11 [W];
At P2 = 800[W], results P = 101.8 [W];
At P3 = 700[W], results P = 89.079 [W];
At P4 = 600[W], results P = 76.353 [W];
At P5 = 500[W], results P = 63.628 [W];
At P6 = 400[W], results P = 50.901 [W];
At P7 = 300[W], results P = 38.175 [W];
At P8 = 200[W], results P = 25.449 [W];
At P9 = 100[W], results P = 12.724 [W];

The obtained energy has the value:

$$W = \sum P_i \cdot t_i = 3.4239x10^6 [J] = 0.95[kWh] \quad (9)$$

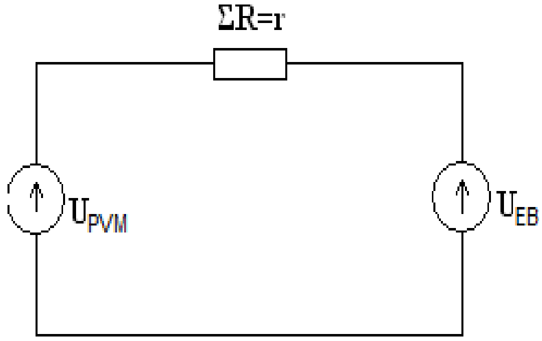

Figure 6. Electrical scheme PVM + EB

Through the operation of the system (PVM+DC-DC+EB) in the MPP zone, during one day, an energy of W = 3.4587[MJ] = 0,96[kWh] is produced. By direct functioning on the EB, in the same time period, the obtained energy is W = 3.4239 [MJ] = 095[kWh], so at a rate of less 1%.

The energy difference between the two situations is:

$$\Delta W = 3.4587 \times 10^{6} - 4.4239 \times 10^{6} [J] = 34800 [J] , \quad (10)$$

and represents 1%, a very small difference, in the usual application, insignificant, especially if we consider and the efficiency of DC-DC converters too, that can be greater than 1%.

The experimental results obtained with the solution (PVM + EB) confirmed through the above computations are just with 0.9% below the maximum possible energy, so this method is very simple and easy to apply in practice.

6. Conclusions

This paper analyzed the operation of one PVM that debitates the electric energy direct at an EB. In comparison with the operation in MPP, at maximum captured energy obtained and it can be concluded that, in this case, the system PVM + EB is more economic that the system PVM + DC-DC + EB, the difference of the stored energy, lays less than 1%. The possibility to eliminate the DC-DC converter has been shown, being cheaper, functioning in conditions of high energetic efficiency.

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