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OPTIMIZATION METHODS FOR REGENERATIVE CONVERSION SYSTEMS: SOLAR PHOTOVOLTAIC AND WIND

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Abstract *- The paper proposes optimization methods for the obtained power in photovoltaic and wind energy conversion systems. Both cases, aims obtaining the maximum output power, from the solar radiation respective wind, in the locations of conversion, namely the solar photovoltaic plants and wind parks. The obtained power and the energy production will be optimized based on the mathematical models for solar photovoltaic and wind systems, obtained from experimental characteristics.*
Keywords*: mathematical model, optimization, photovoltaic module PV, wind turbine*

I INTRODUCTION

As known, the last years, but especially in perspective, the renewable energy sources, in special the solar photovoltaic power and wind systems, used in obtaining electric energy, are increasing. Next, it will examine, in order, the solar photovoltaic conversion and then the wind conversion system, and this because of their complementarity, too.

It is known that the solar photovoltaic conversion must operate in the maximum power point, named MPP.

The coordinates of this point, the voltage Uop and the current Iop, are changing over time, depending on meteorological conditions (solar radiation intensity) and so the equivalent load from PV modules must be correlated with the solar radiation intensity [1].

The PV module external characteristics U=f(I) varies with weather conditions. The power provided by PV module, varies significantly in function of the current load and has a maximum value for the current I^*[4]:

$$P_{\max} = U^* \cdot I^* \tag{1}$$

The coordinates (U^* and I^*) of the MPP depends on the solar radiation intensity [7].

The PV control system must ensure the functioning at P_{max}, even if this values are changing, depending of the natural conditions (fog, pollution, clouds). The power received from the sun changes permanently, but the energetically system composed from PV module, power converter and the storage battery must operate in the MPP. The most effective solution is that based on maximum power point coordinates: voltage U_{op} and current I_{op}. The external characteristic of the modules must be modeled, in accordance with above mentioned goals.

Regarding to the energetic wind system it is know that the exploitable wind speed it lies in the field between 4 - 25 m/s, with the best results in the interval 12-15 m/s. Because of the high inertial moments of the wind machine rotor, the changing of the rotation speed of the synchronous generator is slow, and because of this, it will not track fast the wind speed, what would be necessary to function in the maximum power points [6]. Because the wind speeds are variable in time, it is necessary to determinate the RPM at the synchronous generator, so that the captured energy from the wind, will be maximum.

II MATHEMATICAL MODELS FOR SOLAR PHOTOVOLTAIC AND WIND SYSTEMS

Based on the external characteristic, experimental determinate [8] presented in figure 1, it can be found on mathematical expression which approximated best the dependence U(I).

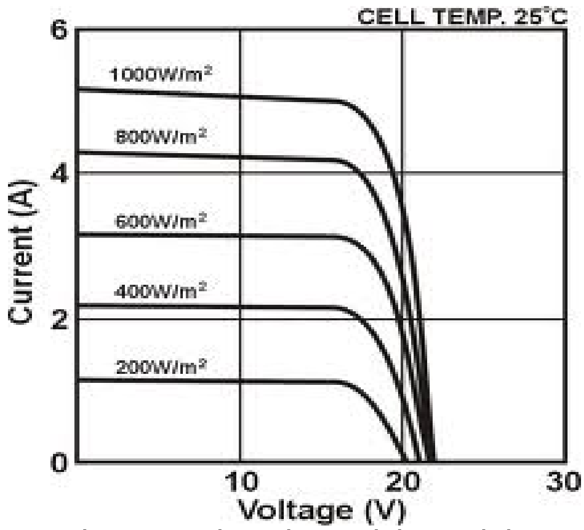

Figure 1 Experimental external characteristic

So the proposed mathematical model for these external characteristics, in general case, for a solar radiation power P_s and a temperature T of PV module is:

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

where a, b, c, d, f and g are constructive constants and I is the output current. The factors a, b, c, d and f are determinate from the experimental extern characteristics [5].
The coordinates of the voltage U_{op} and current I_{op} of the maximum power point P_{op} presented in figure 2, can be obtained from the derivate power:

$$\frac{d}{dt}P = \frac{d}{dt}(UI) = 0 \qquad (3)$$

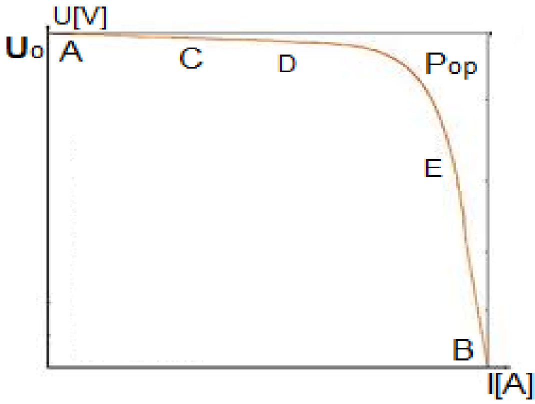

Figure 2 Determination of the external experimental characteristics

Substituting relation (2) in (3), results:

$$\frac{d}{dt}\left((d - Tf)\cdot\left(\cos\left(\frac{aI - gT}{P_s^b}\right)\right)^c \cdot I\right) = 0 \qquad (4)$$

From (4) results the optimal current I_{op} and accordingly the optimal voltage U_{op}, the optimal power P_{op} and the optimal resistance load R_{op}:

$$U_{op} = (d - Tf)\cdot\left(\cos\left(\frac{aI_{op} - gT}{P_s^b}\right)\right)^c \; P_{op} = U_{op}\cdot I_{op}\,;\; R_{op} = \frac{U_{op}}{I_{op}} \qquad (5)$$

The periodical determination of the characteristic U(I), allows to know the maximum power in any moments, being possible to adjust the load so that the captured solar energy by PV module, will be maximum. Using this control method, a maximum energy is achieved, at low cost. The external characteristics depend of the location, considering the weather changes and pollution degree during the day.

Knowing the dependence between voltage U and current I, the maximum power point can be determinate. The experimental determination is possible to be done with mounting scheme, depicted in figure 3.

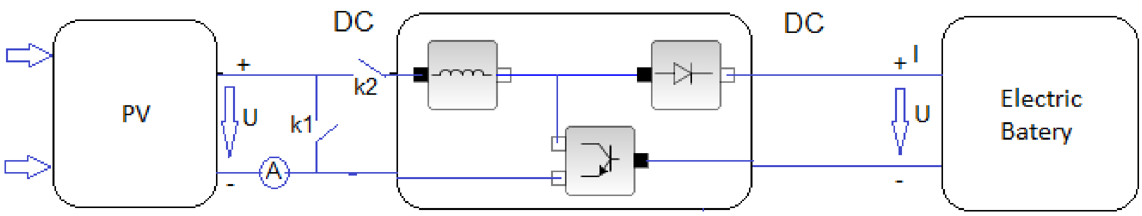

Figure 3 Montage scheme

Two extremely points are determinate:
- Unload (point A), by opening the switches k_1 and k_2, results $U_A = U_0$ and I = 0;
- Short circuit (point B), by closing the switches k_1 and k_2, results $I_{sc} = I_B$ and U= 0.

Other points are need to complete the external characteristic determination, for example C, D and E. These operating points can be found by measuring the voltage and current at tree values of the conduction angle of the converter switching elements α_1, α_2, α_3. All the measurements have to be performed considering the temperature T of the PV module and a solar radiation power P_s.
This determinations of PV characteristics for different solar radiant power and temperature values, several times during the day, allow precisely to know the dependence U (I). In this way, the maximum power point $P_{op,}$ with the coordinates (voltage U_{op}, current I_{op} and resistance R_{op}) are fully determinate. The time required for experimental measurement is low and the energy loss due this interruption is insignificant.

At wind electro energetic systems, it is necessary to stabilized the mathematical models of the wind turbine WT and the generator GS. The wind turbine WT takes the wind energy in a time interval, in conditions in that the speed rotation of the generator is constant and has on certain value, and the wind speed had some time variation.
In according with the value of generator load, the speed rotation increase or decrease and by comparison with the reference value, it modifies the generators load. The turbine model will permit to estimate the reference angular speed ω_{ref}. Considering a linear mechanical characteristic, figure 4, operating in the stable operating area of the wind turbine, the depending of torque according to the wind speed, can be expressed in form:

$$M_{WT} = a \cdot v^b \omega + cv^d \quad (6)$$

where a, b, c, d are factors that depends of the turbines geometric and that can be computed from catalogue dates.

This mathematic model of the wind turbine WT permits the determination of optimal functioning rotation speed, so that the captured energy will be maximum [2].

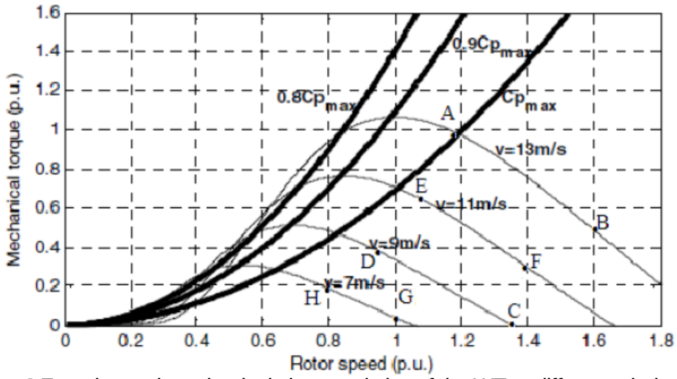

Figure 4 *Experimental mechanical characteristics of the WT at different wind speeds*

In dynamic regime, the synchronous generator GS with exciting in direct current is characterized in the orthogonal model, figure 5, by the equations [3]:

$$-U\sqrt{3}\sin\theta = R_d I_d + L_d \frac{dI_d}{dt} - \omega L_q I_q + M_E \frac{dI_E}{dt} + M_D \frac{dI_d}{dt} - \omega M_Q I_Q$$

$$U\sqrt{3}\cos\theta = \omega L_d I_d + R_q I_q + L_q \frac{dI_q}{dt} + \omega M_E I_E + \omega M_D I_D + M_Q \frac{dI_Q}{dt}$$

$$UE = M_E \frac{dI_d}{dt} + R_E I_E + LE \frac{dI_E}{dt} + M_{ED} \frac{dI_D}{dt}, \quad 0 = M_D \frac{dI_d}{dt} + M_{ED} \frac{dI_E}{dt} + R_D I_D + L_D \frac{dI_D}{dt}$$

$$0 = M_Q \frac{dI_q}{dt} + R_Q I_Q + L_Q \frac{dI_Q}{dt}, \qquad J\frac{d\omega}{dt} = p_1 \begin{bmatrix} (L_d - L_q) I_d I_q + M_E I_q I_E - \\ - M_Q I_d I_Q + M_D I_q I_D \end{bmatrix} - M_{motor} \quad (7)$$

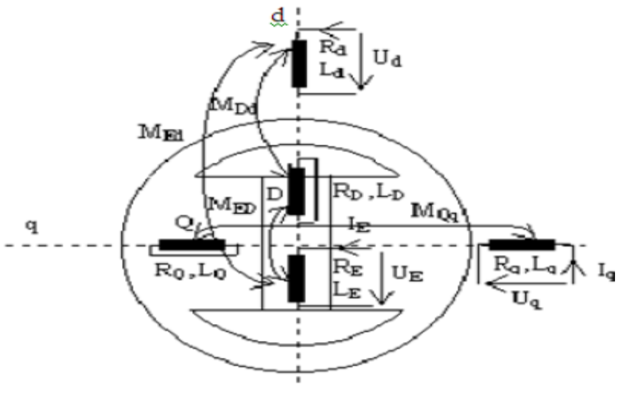

Figure 5 Orthogonal model of GS

From this system of equations , considering the simplified orthogonal model in stationary regime, results one algebraic system in which the generator moment is equal with that of the turbine, from which the solutions for the current, on the two axis and the generator torque (I_d, I_q and M_G), are obtained [3].

The control of the system (WT and GS) at maximum power, obtained from the electric generator, lead to break the turbine and inflating for the moment the electric power from the variation of the kinetic energy, but finally the obtained energy is lower.

The optimal control, assumes to obtain the maximum energy by a variable wind speed in time. This imposes the control of rotation speed by supplementary modification of the generators load and the turbines torque, by adapting the generator load to the wind speed. In these conditions, the wind system functions optimal at maximum energy.

III CONCLUSIONS

Based on the presented mathematical models, control algorithms that assure the functioning at maximum power of this systems, can be implemented.

In order to optimize these systems, it is necessary also to use optimal the surface, in the sense that, interior of wind park ,to install also the solar photovoltaic park, so that the supply energy will be more balanced through the complementary of those both regenerative sources.

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