Modelling and simulation of photovoltaic pumping system optimized

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Abstract:
The photovoltaic systems do not require any outside contribution of fuel; besides the generator it self does neither contain any mobile piece nor require maintenance practically. Therefore, the recurrent costs of operation and maintenance are relatively weak.

The proposed study aims to optimize the power of the photovoltaic systems, with an aim of increasing the efficiency of these systems. An adequate adaptation between the solar generator and the load makes it possible to reduce the cost of the installation of such systems unclear.

Follows a general presentation on the photovoltaic systems, the comparison between the direct coupling and the technique of the maximum power point tracking (MPPT), proves to be necessary. Finally the use of this technique to supply a converter, while showing the influence of the climatic parameters around this point. The results gotten extended were promising and remain to validate practically.

Keywords:
Photovoltaic systems, pumping, optimization, point of maximum power MPPT.

1. Introduction:
The high cost of photovoltaic generator imposes an optimal and rational use of the latter to achieve economical operation. We used the photovoltaic generator in the region where it delivers its maximum power.

We translated the optimization of photovoltaic pumping system by the maximum power point tracking (MPPT), supplied by the photovoltaic generator. We will discuss a method of the maximum power point tracking (MPPT). We then present the appropriate control technology for the continuous current motor.

2. Model of a photovoltaic cell:
Figure (1) represents the diagram of a photovoltaic cell.

\[ I = I_{ph} - I_S \left[ \exp\left(\frac{V + R_l I}{AU_T}\right) - 1 - \frac{V + R_l I}{R_{sh}} \right] \] (1)

\[ I_{ph} = I_{ph} \left( T_1 \right) \left[ 1 + K_0 \left( T - T_1 \right) \right] \] (2)

and \[ U_T = \frac{k \cdot T}{q} \] (3)

With \[ I_{ph} \left( T_1 \right) = I_{SC} \left( T_{1,nom} \right) \frac{E}{E_{nom}} \] (4)

and \[ K_0 = \frac{I_{SC} \left( T_2 \right) - I_{SC} \left( T_1 \right)}{I_{SC} \left( T_1 \right) \frac{1}{T_1 - T} - 1} \] (5)

\[ I_S = I_S \left( T_1 \right) \left( \frac{T}{T_1} \right)^{3/4} \exp \left( \frac{-V_g}{A U_T \left( 1 - \frac{1}{T} \frac{1}{T_1} \right)} \right) \] (6)

3. Optimization of photovoltaic pumping system:
3.1. The techniques further maximum power:
The operating point of the PV system, situated to the intersection of the IV characteristics of the generator and the motor-pump, moves in the value of sunlight.

For high values of sunshine, the characteristics intersect in the area where the power delivered by the generator is optimal. By cons, for low values of the sunlight, the operating point moves away from this area. In other words, during the morning and evening, system performance is poor and the generator is in use.

A question arises, can we force the system to operate in the area where the power delivered by the generator is optimal, more precisely, can we force the generator to charge the maximum power regardless of the weather?

3.2. Base impedance matching by a DC-DC:
We concede a continuous current motor with constant flux, neglecting the armature reaction and the phenomenon of switching the motor voltage is equal to:

\[ V_{ch} = R_{a} I_{ch} + L_{a} \frac{dI_{ch}}{dt} + k_s \omega \] (8)

and the couple of the motor \[ C_r = k_r \omega^2 + C_S \] (9)

The centrifugal pump is between a couple resisting.
The coefficients of proportionality are 

\[ K_r(Nm/\text{rad.s}^{-1}), k_m(Nm/Ampère) \text{ and } kr(Nm/\text{rad.s}^{-1}) \]

On the other hand we have the mechanical equation:

\[ J_m \frac{d\omega}{dt} = C_e - C_r \tag{11} \]

With \( J_m \) the moment of inertia of the group. [2]

3.3. Technical research point of maximum power MPPT:

In general the operating point is not MPP photovoltaic panel. Then in the direct coupling of loads, solar panels are often oversized to ensure sufficient power to supply the load, this leads to an overly expensive. To overcome this problem, tracking the maximum power can be used for continued operation of the solar panel at its maximum power. For this we use methods of research MPPT among methods are:

3.3.1. Perturbation and observation (P & O):

The perturbation and observation (P & O) is an approach widely used in research because of MPPT is an iterative and requires only simple measures \( V_{pv} \) and \( I_{pv} \), it can detect the point of maximum power even when variations sudden radiation and temperature.

As its name implies, the method P & O works with the disturbance voltage \( V_{pv} \) and observing the impact of this change on the output of the photovoltaic panel.

The algorithm of the P & O method is represented by figure (2). [3]

![Organizational chart of the perturbation and observation](image)

At each cycle, \( V_{pv} \) and \( I_{pv} \) were measured to calculate \( P_{pv}(k) \). This value \( P_{pv}(k) \) is compared to the value \( P_{pv}(k-1) \) calculated the previous cycle.

If the power output increased \( V_{pv} \) is adjusted in the same direction as in the previous cycle.

If the power output decreased \( V_{pv} \) is adjusted in the opposite direction than in the previous cycle. \( V_{pv} \) was so upset at each cycle MPPT.

When the maximum power point is reached, \( V_{pv} \) oscillates around the optimal value \( V_{pv,\text{mp}} \). This causes a power loss that increases with no increment of the disturbance. If this increment is not large, the MPPT algorithm responds quickly to sudden changes in operating conditions.

On the other hand, if the step is small, the losses in terms of atmospheric changes slow or stable, but will lower the system can not respond quickly to rapid changes in temperature or irradiation. [4]

The disadvantage of the technique of P & O is that in case of rapidly changing weather conditions, such as a moving cloud, this method can move the operating point in the wrong direction as shown in Figure (3).

![Maximal working point](image)

Initially, the operating voltage of the converter is in (1), which is the maximum power point.

Assume that a disturbance moves the operating point to point (2). During this period of disruption, the illumination was increased from \( E_1 \) to \( E_2 \). This leads to an increase in the extent of output power converter \( P_{pv1} \) to \( P_{pv2} \).

However, the maximum power point in this light is in (4), which corresponds to maximum power \( P_{pv,\text{max}} \), \( E_2 \).

In the disturbance following the algorithm of P & O increment the operating voltage of the converter (MPPT) much further right to the point (3), and even an increase of power converter will be measured if the illumination was increased \( E_2 \) to \( E_3 \) with the new point of maximum power point (5).

In this way, the algorithm of P & O will continue to move the operating point of the converter below the maximum point of real power and more power will be lost. This incorrect adjustment will continue until the change of illumination slows or stabilizes.

The first solution to this problem is to increase execution speed by using a micro-controller faster.

The second option is to check any rapid change in radiation checking the value of \( \frac{dI_{pv}}{dt} \) and neutralizing the tension adjustment if the change of \( \frac{dI_{pv}}{dt} \) exceeds a limit.
3.3.2. Method of a model parasitic capacity (PC):

The algorithm of the parasitic capacitance (Parasitic Capacitance MPPT) is similar to the increment of the conductivity (INC-MPPT) except that the effect of parasitic capacitance (CP) which models the storage charges in the junction’s p-n solar cells is included.

By adding this capability to our model by representing it as I(t) = C_dV/dt, the new model is expressed by[5,6]:

\[ I = I_{ph} - I_{s} \left[ \exp \left( \frac{V + R_{s}I}{A_{T}} \right) - 1 \right] \left( - \frac{V + R_{s}I}{R_{sh}} \right) + C_{p} \frac{dV}{dt} \]

\[ = F(V) + C_{p} \frac{dV}{dt} \] (12)

Equation (12) shows the two components (I) is a function of the voltage E (V) and the second relates to the current in the stray capacitance. Using this notation, the increment of the conductivity of the solar panel can be defined as the ratio dF(V)/dV and the instantaneous conductivity can be defined as the ratio-F (V) / V. The MPP is obtained when dP / dV = 0.

Multiplying equation (12) by the voltage (V) panel for electric power, and then differentiating the result, the equation of electric power at MPP is obtained and can be expressed as [7]:

\[ \frac{dF(V)}{dV} + C_{p} \frac{dV}{V} \] (13)

The three terms of equation (13) represent the increase in conductivity, the wave induced by the parasitic capacitance and conductivity instant. The first and second derivatives of the voltage of the panel take into account the ripple effect generated by the alternative converter.

Note that if (CP) is zero, equation (13) simplifies and becomes the one used for the algorithm to increase the conductivity.

\[ I = I_{ref} + \Delta I \]

\[ V = V_{ref} + \Delta V \]

\[ \Delta T = (T - T_{ref}) \]

\[ \Delta I = \alpha \left( \frac{E}{E_{ref}} \right) - \beta \Delta I \]

\[ T = T_{a} + \frac{E}{E_{ref}} \left( NOCT - T_{a,ref} \right) \] (20)

With: Eref: The illuminance
\[ \alpha \] and \[ \beta \]: The coefficients of variation of the current and voltage with temperature.
\[ Ta \]: ambient temperature.
\[ Ta, ref \]: The ambient temperature reference.
\[ NOCT \]: Temperature normal cell function.

3.3.4. Method conductance increment:

This method is more efficient and more complex compared to other methods such as perturbation and observation.

It is based on the fact that the derivative of the output power \( P_{pv} \) versus voltage \( V_{pv} \) panel is equal to zero at the maximum point of power.

The \( P_{pv} \)-\( V_{pv} \) characteristic of PV panel in figure (5) shows that this derivative is positive to the left of the maximum power and negative to the right of maximum power.

\[
\frac{\partial P}{\partial V} > 0 \quad \text{for} \quad V < V_{MPP} \\
\frac{\partial P}{\partial V} < 0 \quad \text{for} \quad V > V_{MPP}
\]

Fig.5. Characteristic of the power

This leads to the following set of equations: [5, 6, 7]

\[
\frac{dP_{pv}}{dV_{pv}} = \frac{dI_{pv}V_{pv}}{dV_{pv}} = I_{pv}V_{pv} = 0 \quad \text{In MPPT} \quad (23)
\]

C2 = \frac{V_{m}}{V_{oc}} - 1 \ln \left( 1 - \frac{I_{m}}{I_{sc}} \right) \quad (16)

With: C1 and C2: Constants calculated for each simulation.

Voc The open circuit voltage of photovoltaic generator
\[ \text{Isc} \], \[ \text{Voc} \], and \[ \text{P}_{\text{max}} \]: current, voltage and maximum power, respectively, and \( \text{ISC} \): the current generated by solar rays.

The expression (14) generates the characteristic I (V) for illumination 100W/m2 and a temperature of 25 ° C.

For another value of the irradiance and temperature, the new values of current and voltage generator are PV [6]:

\[ I = I_{ref} + \Delta I \]

\[ V = V_{ref} + \Delta V \]

\[ \Delta T = (T - T_{ref}) \]

\[ \Delta I = \alpha \left( \frac{E}{E_{ref}} \right) - \beta \Delta I \]

\[ T = T_{a} + \frac{E}{E_{ref}} \left( NOCT - T_{a,ref} \right) \] (20)

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\[
\frac{dP_{pv}}{dV_{pv}} = \frac{dI_{pv}V_{pv}}{dV_{pv}} = I_{pv}V_{pv} = 0 \quad \text{In MPPT} \quad (23)
\]
\[ \frac{dp_{pv}}{dV_{pv}} = \frac{d(I_{pv}, V_{pv})}{dV_{pv}} = I_{pv} + V_{pv} \frac{dI_{pv}}{dV_{pv}} > 0 \quad (24) \]

To the left of the MPPT
\[ \frac{dp_{pv}}{dV_{pv}} = \frac{d(I_{pv}, V_{pv})}{dV_{pv}} = I_{pv} + V_{pv} \frac{dI_{pv}}{dV_{pv}} < 0 \quad (25) \]

To the right of the MPPT

These equations can be written as:
\[ \frac{dI_{pv}}{dV_{pv}} = \frac{I_{pv}}{V_{pv}} \quad \text{To the MPPT} \]

\[ \frac{dI_{pv}}{dV_{pv}} > \frac{I_{pv}}{V_{pv}} \quad \text{On the left of the MPPT} \]

\[ \frac{dI_{pv}}{dV_{pv}} < \frac{I_{pv}}{V_{pv}} \quad \text{On the right of the MPPT} \]

The above equations can be used as a control algorithm for controlling the operating point of the converter by measuring the increase of the conductance and the conductance of the converter instantaneous \( \frac{dI_{pv}}{dV_{pv}} \) and \( \frac{I_{pv}}{V_{pv}} \) respectively. [6] The flowchart of the control algorithm is shown in Figure (6).

**Fig. 6.** Organization chart of the incremental conductance method

4. Results and discussion:

4.1. Comparison between non optimized system and optimized:

Whatever the nature of the coupling of motor-pump PV array, with or without optimization criterion, the characteristic load, power, performance and quantity of water supplied by the pumping system are the main parameters permit evaluation and validation of the operating system of photovoltaic.

4.1.1. Characteristic load and power:

The operating system is improved by the use of MPPT technology, where the DC motor is powered by voltages close to nominal values, the effect of the technique compared to direct coupling is very clear for low values of illumination at 200W/m², the voltage is increased to a value as low as 75V for the direct coupling to a value of 140V result.

The powers obtained by the MPPT technique are the highest values as possible; hence the operating system is ideal. Thus, the overall power of the photovoltaic generator is operated.

Figures (7) and (8) shows the large gap between the powers maximized and those of direct coupling.

**Fig. 7:** Characteristic P(V) of photovoltaic pumping system, optimized and non optimized, \( T=25^\circ\text{C} \)

**Fig. 8:** Characteristic P(V) of photovoltaic pumping system, optimized and non optimized, \( T=25^\circ\text{C} \)

4.2. Characteristic performance and speed of the pumping system:

The system performance is defined by:

\[ \eta_{ppv} = \frac{P_h}{P_e} = \frac{\rho \cdot g \cdot Q \cdot H_p}{E \cdot N \cdot N_p \cdot S} \quad (26) \]

With \( P_h \): hydraulic power

\( Q \): The amount of water and is given by [8] by the following relationship:

\[ Q = \begin{cases} 0 & \text{si } E(E_i) \\ -b + \sqrt{b^2 + 4a(E - c)} & \text{si } E \neq E_i \\ 2a & \text{si } E_i \end{cases} \quad (27) \]

\( E_i = 250 \text{W/m}^2 \); \( a, b \) and \( c \) are constants.
Figure (9) illustrates the shape of the yield, which is 100% for technical MPPT idealized cons by the direct coupling is characterized by low efficiency, especially for low values of illumination. But from E = 900W/m² the values of performance will be close, this approximation shows good fit between the motor-pump and generator for the direct coupling of a strong illumination.

Figure (10) represents the gait speeds, the direct coupling with MPPT technology according to the illumination. In the case of the coupled system begins to deliver water at an illuminance of 280W/m² thus maximizing power to force the pump supplying water from 175W/m². [8]

The direct coupling of the generator motor-pump has been studied as a baseline, it represents the type of connection the easiest and of course cheaper. But this pairing is acceptable only in very specific conditions where the load is properly adapted to the generator and provides an acceptable return. This is observed in this study for high illumination. By cons outside of that condition, the yield decreases and solar energy is converted poorly exploited. Thus it is necessary to recover this loss of energy. The MPPT provides an ideal solution to this problem and gives good results.

The disadvantage of this technique is the need to solve complicated nonlinear equations arising in the use of digital computers (microprocessor, DSP ...). This leads to a multi-layered complexity as the implementation, adaptation and course maintenance.

**Bibliographie**


[4] T.Esram, PL. Chapman *"Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques"* project was sponsored by the National Science Foundation ECS-01- 34208, Center for Electric Machinery and Electromechanics, University of Illinois at Urbana-Champaign.


