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Study of System Model Optimized of Photovoltaic Pumping

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Abstract – ***Solar photovoltaic water pumping (SPVWP) is a cost-effective application in remote locations in developed countries. The economy and reliability of solar electric power made it an excellent choice for remote water pumping. This paper concern a techniques of research of for the maximum power point tracking (MPPT) by methods of photovoltaic system optimization. First, for the purpose of comparison and because of its proven and good performances, the system was used without MPPT. 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.***

Keyword: **photovoltaic, pumping, optimization, SPVWP, point of maximum power MPPT.**

I. INTRODUCTION

The output characteristics of photovoltaic arrays are nonlinear and change with the cell's temperature and solar irradiance. For a given conditions there is a unique point in which the array produces maximum output power. This point is called maximum power point (MPP) which varies depending of cell temperature and present irradiation level. To obtain the maximum power from a photovoltaic array, a maximum power point tracker (MPPT) is used. We study three methods of search for MPP: P&O, INC and fuzzy logic. [1] [2]. We will discuss a method of tracking the maximum power. We then present the appropriate control technology for the DC motor.

II. MODEL OF A PHOTOVOLTAIC CELL

Figure (1) shows the diagram of a photovoltaic cell:

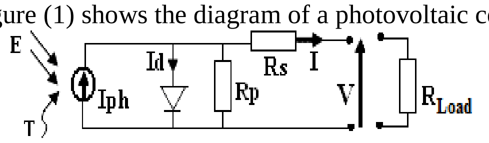

Fig.1. Circuit diagram of a photovoltaic cell

The term of current I generated by the cell and supplied to the load is given by:

$$I = I_{SC}\left[1 - C_1\left[\exp\left(\frac{V}{C_2 V_{OC}}\right) - 1\right]\right] \quad (1)$$

$$C_2 = \frac{\frac{V_m}{V_{OC}} - 1}{\ln\left(1 - \frac{I_m}{I_{SC}}\right)} \quad (2)$$

With: C_1 and C_2: Constants calculated for each simulation.

V_{OC} The open circuit voltage of PVG

I_{SC}: the current generated by solar rays.

I_m, V_m and P_m current, voltage and maximum power, respectively.

The expression (1) 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 photovoltaic generator: [3] [4]

$$I = I_{ref} + \Delta I \quad (3)$$

$$V = V_{ref} + \Delta V \quad (4)$$

$$\Delta T = (T - T_{ref}) \quad (5)$$

$$\Delta I = \alpha_T \left(\frac{E}{E_{ref}}\right) + \left(\frac{E}{E_{ref}} - 1\right) I_{SC} \quad (6)$$

$$\Delta V = -\beta_T - R_S \Delta I \quad (7)$$

$$T = T_a + \frac{E}{E_{ref}}\left(NOCT - T_{a,ref}\right) \quad (8)$$

With: Eref: The illuminance of reference

αT and βT: 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.

III. SYSTEM OF PV PUMPING

The system of pumping consists of a photovoltaic generator, a BLDCM motor and centrifugal pump.

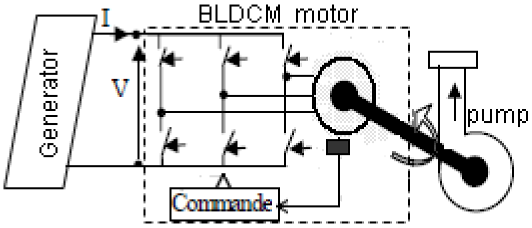

Fig.2. Structure of PV pumping system. [5] [6]

IV. OPTIMIZATION OF PHOTOVOLTAIC PUMPING SYSTEM

When the PV generator receives a need of too strong current it may deliver its maximum current corresponding to a running in short-circuited. This is the case of a direct connect of the PV generator to a load. Note that in certain situations, there are charges that can't be defeated because the transitional regimes are important [7]. For our study, the pump can't provide water because power consumption is not sufficient to raise the water at the desired height. This is due to the problem of remoteness of the operating point of solar generator compared to the optimal operating point [8].

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A. *Boost converter*

A boost converter is simply a particular type of power converter with an output DC. This type of circuit is used to 'step-up' a source voltage to a higher, regulated voltage, allowing one power supply to provide different driving voltages[9].The basic boost converter circuit consists of only a switch (typically a transistor), resistance, an inductor, and a capacitor.

The specific connections are shown in figure 3.

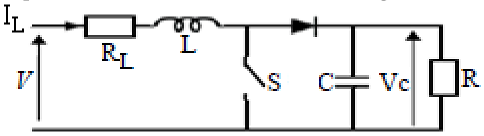

Fig.3. Boost converter

Applying Kirchhoff's rules around the loops, it can obtain the ideal mathematical model of this circuit: [10]

$$\begin{cases} L\dfrac{dI_L}{dt} = V - V_C(1-D) - R_L I_L \\ C\dfrac{dV_C}{dt} = -I_L(1-D) - \dfrac{V_C}{R} \end{cases} \quad (9)$$

Where: I_L: is the current across the inductor

Vc: voltage in the capacitor Parameters.

R_L , L , and C are supposed to be known constants.

D: is the switch position

V: is voltage supplied by PV photovoltaic array.

The gain from the boost converter is directly proportional to the duty cycle (D), or the time the switch is 'on' each cycle.

$$\frac{V_C}{V} = \frac{1}{1-D} \quad (10)$$

B. Group Motor-pump of PV pumping system:

We will concede a motor DC to constant flux, while disregarding the reaction of induced and the phenomenon of commutation, the tension of the motor will be equal to:

$$Va = R_a I_a + L_a.\frac{dI_a}{dt} + k_e\omega \quad (11)$$

and the couple of the motor $C_e = k_t I_a$ (12)

The centrifugal pump opposes a resistant couple:

$$C_r = k_r w^2 + C_s \quad (13)$$

$K_e(V/rad.s^{-1})$, $k_t(Nm/Ampère)$ et $kr(Nm/rad.s^{-1})$ are coefficients of proportionality.

On the other hand we have the mechanical equation:

$$J_m \frac{d\omega}{dt} = C_e - C_r \quad (14)$$

With Jm: the moment of inertia of the group. [11]

The model of the centrifugal pump used is identified by the expression of Peleinder and Petermain

$$H_m = k_0\omega^2 - k_1\omega Q - k_2 Q^2 \quad (15)$$

With: Hm: Height manometric; ω: Speed (rad/sec).

k_0, $k_1$and k_2: Constant clean of the pump.

The characteristic of the pipeline is given by the equation: [12].

$$H_p = H_g + k_h Q^2 \quad (16)$$

With: Hg: height geometric

k_h: constant given of the pump.

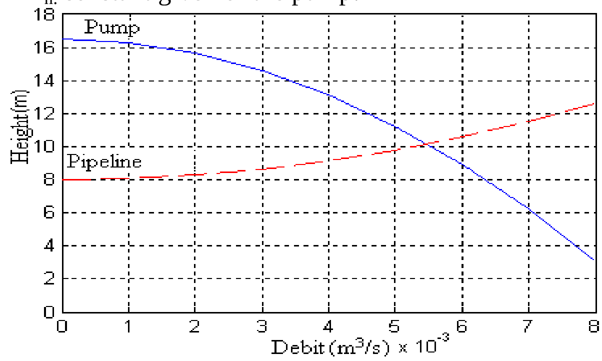

Fig.4. Characteristic Hm (Q) of the pump And the pipeline

C. Techniques of research of point of power maximal (MPPT):

During the operation of a panel statement adapted by converters of energy, the point of maximum power PPM can be degraded following the variations of the meteorological conditions or the load. The adaptation between the source and the load actually takes place by varying duty cycle *G*, the search for this point of maximum power must be carried out automatically. This is completely possible by adopting one of the approaches of adaptation known under the name of the orders MPPTs (Maximum Power Point Tracking).

1. Method of perturbation and observation:

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 indicates it, the P&O method functions with the disruption of tension and the observation of the impact of this change on the power of exit of the photovoltaic panel. The algorithm of the P & O method is represented by figure (5). [13]

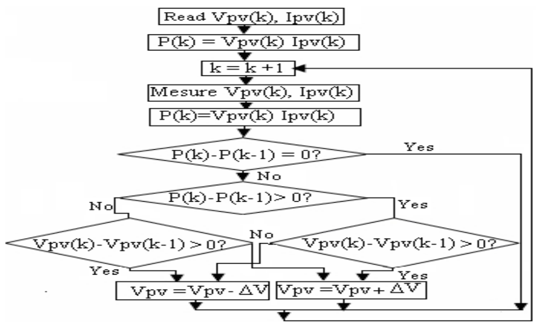

Fig.5. Organization chart of method the perturbation and observation

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 precedent cycle. If the power of exit increased, is adjusted in the same direction that in the precedent cycle. If the power of exit decreased is adjusted in the opposite direction than in the precedent cycle. V_{PV} is disrupted thus to every cycle of MPPT. When the point of maximal power is reached, V_{PV} oscillate around the optimal value V_{PVmppt}. This causes a loss of power that increases with the step of the incrémentation of the perturbation. If this step of the incrémentation is large, the MPPT algorithm responds quickly to sudden changes in operating conditions. On the other hand, if the step is small, the losses, at the time of the conditions of slow or steady atmospheric changes, will be lower but the system won't be able to respond the fast changes of the temperature or the irradiation quickly. [8] The inconvenience of the technique of P&O is the one in case of fast atmospheric condition change, as a mobile cloud, this method can displace the operating point in the false direction as shown in Figure (6).

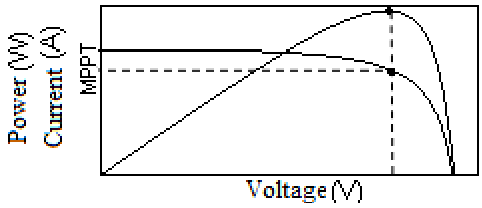

Fig.6. Point of function maximum

At the beginning, the operating voltage of the converter is to the point (1) that is the point of maximal power as represented on the figure (7). To suppose that a perturbation displaces the operating point toward point (2). During this period of perturbation, the illumination increased from E1 to E2. This leads to an increase of the measure of power of exit of the converter of Ppv1 to Ppv2. However, the point of maximal power to this illumination is to the point (4) that corresponds to a maximal power P_{PV}max, E2. In the following perturbation, the algorithm of P&O will increment the operating tension of the converter (MPPT) well farther the right toward point (3), and again an increase of the converter's power will be measured if the illumination increased of E2 to E3 with the new point of maximal power to the point (5). In this way, the algorithm of P&O will continue to displace the operating point of the converter more far from the real maximum point of power, and again more of power will be lost. This incorrect adjustment will continue until the change of the illumination slowed down or stabilize. The first solution to this problem is to increase execution speed by using a micro-controller faster. The second solution is to verify any rapid change of irradiation while verifying the value of dI_{pv}/dt and while neutralizing the adjustment of tension if the change of dI_{pv}/dt exceeds a limit. [8]

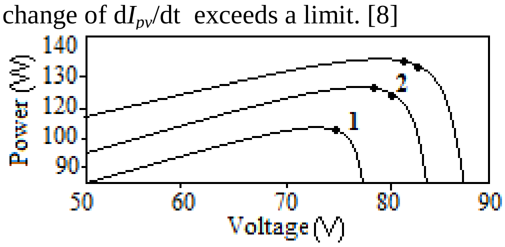

Fig.7. Divergence of the method *P&O*

2. Method of Conductance incremental

This method is more efficient and complex compared to other methods such as perturbation and observation. It is based on the fact that the derivative of the exit power P_{PV} in relation to the tension of panel V_{PV} is equal to zero to the maximum point of power. The characteristic P(V) of PV panel shows that this derivative is positive to the left of the maximum power point and negative to the right of the maximum power point. Figure (8)

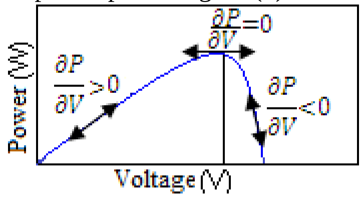

Fig.8. Characteristic power

This leads to the following set of equations: [14, 15, 16]

-In MPPT: $\frac{dp_{pv}}{dV_{pv}} = \frac{d(I_{pv}V_{pv})}{dV_{pv}} = I_{PV} + V_{pv}\frac{dI_{pv}}{dV_{pv}} = 0$ (17)

-A Left MPPT: $\frac{dp_{pv}}{dV_{pv}} = \frac{d(I_{pv}V_{pv})}{dV_{pv}} = I_{PV} + V_{pv}\frac{dI_{pv}}{dV_{pv}} > 0$ (18)

-A right MPPT: $\frac{dp_{pv}}{dV_{pv}} = \frac{d(I_{pv}V_{pv})}{dV_{pv}} = I_{PV} + V_{pv}\frac{dI_{pv}}{dV_{pv}} > 0$ (19)

These equations can be written as:

$\frac{dI_{pv}}{dV_{pv}} = -\frac{I_{pv}}{V_{pv}}$ Au MPPT

$\frac{dI_{pv}}{dV_{pv}} > -\frac{I_{pv}}{V_{pv}}$ A Left MPPT

$\frac{dI_{pv}}{dV_{pv}} < -\frac{I_{pv}}{V_{pv}}$ A right MPPT

The equations can be used above as algorithm of control to order the operating point of the converter while measuring the growth of conductance and the converter's instantaneous conductance dI_{PV} / dV_{PV} and I_{PV} / V_{PV} respectively. [15]. the organization chart of the control algorithm is shown on the figure (9).

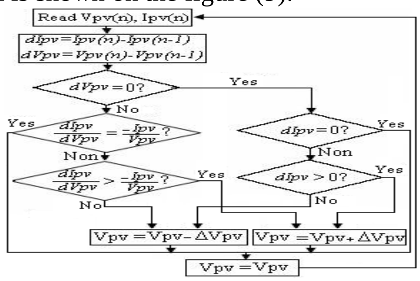

Fig.9. Organization chart of the method INC

3. Fuzzy Logic Controller Method

Fuzzy logic controllers (FLC) have the advantages of working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity.

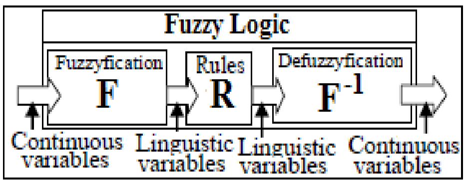

Fig.10. General synoptic diagram of (FLC)

The inputs to a MPPT fuzzy logic controller are usually an error *E* and a change in error C*E*. The user has the flexibility of choosing how to compute *E* and C*E* [17]

$$\begin{cases} E(k) = \dfrac{P(k)-P(k-1)}{V(k)-V(k-1)} \\ CE(k) = E(k) - E(k-1) \end{cases} \qquad (20)$$

Fuzzy logic controller is composed of three parts: fuzzification, inference engine and defuzzification as described below (Figure10). During fuzzification, numerical input variables are converted into linguistic variables based on a membership function similar to figure 11.

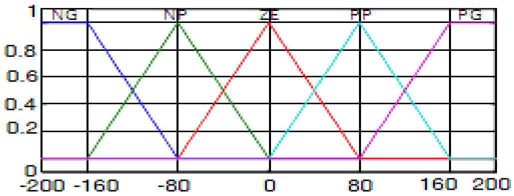

Fig.11. Membership function

In this case, five fuzzy levels are used: NB (Negative Big), NS (Negative Small), ZE (Zero), PS (Positive Small), and PB (Positive Big). The membership function is sometimes made less symmetric to give more importance to specific fuzzy levels [18] [19]. The kernel of FLC is the fuzzy inference system. Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made. The proposed Mamdani-type inference system endeavours to force the error function to zero. Two cases are to consider [20, 21, 22]:

•**First case:** *E* is positive; working point is on the left of the MPP. If the change of error CE is positive, then the working point converges toward the MPP. If CE is negative, the inverse that occurs.

•**Second case:** *E* is negative; working point is, therefore, on the right of the MPP. In this case if CE is positive, working point moves away of the MPP and vice versa if CE is negative

		CE				
		NG	NP	ZE	PP	PG
E	NG	ZE	ZE	PG	PG	PG
	NP	ZE	ZE	PP	PP	PP
	ZE	PP	ZE	ZE	ZE	NP
	PP	NP	NP	NP	ZE	ZE
	PG	NG	NG	NG	ZE	ZE

Group1
Group2
Group3
Group4

Table .1. Inference matrix

Finally, in the defuzzification stage, the fuzzy logic controller output is converted from a linguistic variable to a numerical variable still .This provides an analog signal that will control the power converter to the MPP.

V. RESULTS AND DISCUSSION

A. Comparison between optimized and non-optimized system

Whatever the nature of the couple of motor-pump group to the PV generator, with or without optimization criterion, the load characteristic, power, efficiency and the quantity of water provided by the pumping system are the main parameters permit the assessment and the validation of the exploitation of the photovoltaic pumping system.

B. Characteristic of load and power

The function of the system is improven by the use of the technical MPPT, where the motor to continuous current is supplied by nearer tensions to the face values , the effect of the technique compared to the direct coupling is very clear. For small values of the illuminance at 200W/m^2, the supply voltage is increased to a value as low as 80V for the direct coupling to a result value of 140V.

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

Figures (12) and (13) shows the large gap between the powers maximized and those of direct coupling.

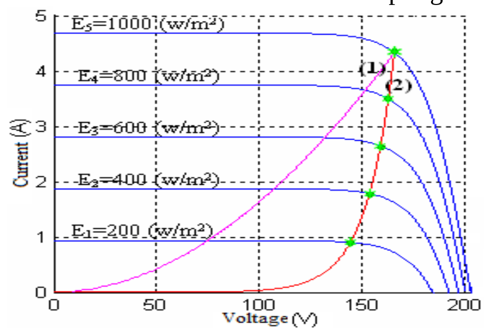

Fig.12. Characteristic I(V) of pumping system PVG
(1) Direct coupling, (2) Coupling with MPPT

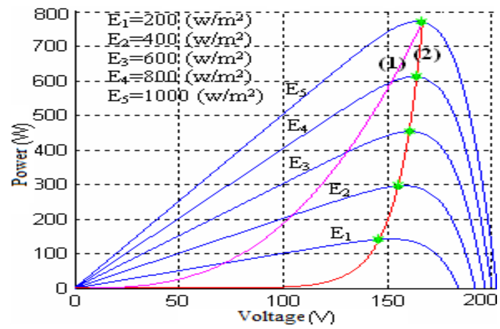

Fig.13. Characteristic I(V) of pumping system PVG
(1) Direct coupling, (2) Coupling with MPPT

C. Characteristic of efficiency and the debit of pumping system:

The efficiency of the system is defined by:

$$\eta_{PPV} = \frac{P_h}{P_e} = \frac{\rho.g.Q.H_m}{E.N_S.N_P.S} \qquad (21)$$

With Ph: hydraulic power,

Q: Quantity of given by: [23]

$$Q = \begin{cases} 0 & si\ E\langle E_t \\ -\dfrac{1}{2}\left[\dfrac{a_2}{a_1} - \left(\dfrac{a_2^{\,2} + 4a_1(E-a_3)}{a_1^2}\right)^{1/2}\right] & si\ E\rangle E_t \end{cases} \qquad (22)$$

E_t =270W/m^2 ; a_1, a_2 and a_3 are constants.

The figure (14) represents the efficiency, which is 100%, begins of luminance 825W/m2 for the MPPT technique, against the direct coupling is characterized by a low yield, especially for low luminance values. But from E=900W/m2 and the values of the efficiency will be

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close, reconciliation proves the good matching between the motor-pump group and the generator for the direct coupling of strong illumination

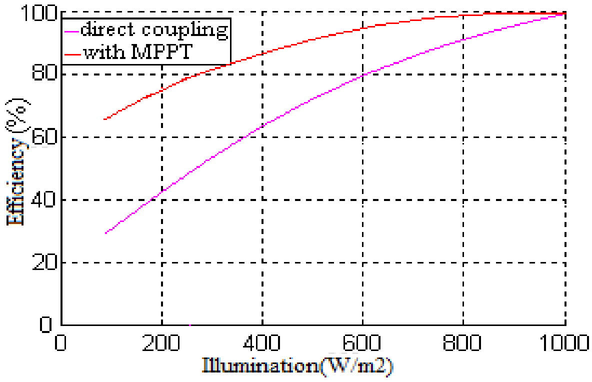

Fig.14. Efficiency of pumping system PVG

The figures (15) represent the paces of the debits, to the direct coupling and with the technique of MPPT according to the luminance.

In the case of the direct coupling system begins to supply water at a luminance of 280W/m2, thus maximizing power strength of the pump supplying water to from 175W/m2. [23]

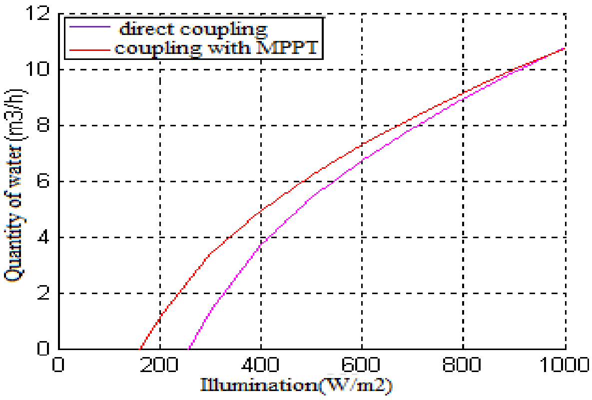

Fig.15. Quantities of water of Pumping system by PVG

IV. CONCLUSION

This paper presents a techniques of research of point of power maximal MPPT, this techniques based on the simplest system consisting of a direct coupling of motor-pump group to the photovoltaic generator. For an ideal optimization of the energy delivered by the generator. The technique of MPPT is used. But this technique present some inconveniences as the complexity of implantation and the elevated price. The direct coupling of generator motor-pump group has been studied as a baseline; it represents the type of connection the easiest and of course cheaper. But this coupling is only acceptable in very specific conditions where the load is adapted appropriately to the generator and offers an acceptable efficiency.

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M.MARIR BENABBAS he received the DES degree in physic energetic, from the university of Constantine in 1981, and the magister photovoltaic from the university of Constantine with associated of university of Belgium, Leuven 1984, her dissertation research is concerned with the breakdown phenomena in solar cells, from 1984 she joined the electronically institute of Constantine university, where she served successively as instructor, assistant master. In 1993, where she was obtained her doctorate as sciences of microelectronic from the university of Constantine with collaboration from Institute national Polytechnic (INP, ENSEEIHT) of Toulouse his dissertation is concerned with the physics and modeling quantum compound semiconductor devices such as high electron mobility transistors (HEMTS).Since 1993, she served as associate professor in the electronically department. She is now an associate research scientist in the material and electronically compound laboratory of engineering science faculty where she has been engaged in research on heterostructure quantum well devices and physics, and photovoltaic system, working on OPVC cells until a few years. She works in several scientific projects with the different institution of ministry.