Improvement of Efficiency of Thermal Photovoltaic Pumping System

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Abstract:- The photovoltaic (PV) efficiency of solar cells is inversely proportional to their operating temperature. The temperature distribution in a PV module will also give rise to thermal stresses within the module. Hence it is important to determine the operating temperature of solar cells accurately.

Much effort has been spent on the research and development of hybrid PVT, in order to improve the efficiency of thermal and electricity. The efficiency of the thermal and electricity is known as total efficiency of the PVT is affected by many system design parameters and operating conditions. Due to that, seven new design configurations of collectors has been designed, investigated and compared.

The objective of this work concerns the photovoltaic pumping system improvement by the insertion of a thermal photovoltaic collector (PVT) to increase the efficiency of this system.

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

1. INTRODUCTION:

The solar energy remains a significant source of energy savings, especially for conditions where sunlight is abundant and conventional energy is more expensive. This energy becomes more competitive if it improves the performance of thermal conversion systems [1]. For solar collectors, thermal efficiency can be improved by promoting the exchange of heat between the plate and the coolant, the PVT collector can simultaneously produce heat and electricity. It is composed of a flat plate water heating collector inserted into a photovoltaic module. [2]

2.ELEMENTS OF CONSTRUCTION OF PVT COLLECTOR:

The studied system consists of three main components, namely, (Fig. 1):
- A transparent cover allowing sunlight to pass towards the absorber and to create an effect of greenhouse. It is composed by one or more panes.
- A photovoltaic cell for the production of electricity.
- A plate absorbing for transfers from energy collected to a coolant.
-A box ensuring the protection of the whole of these elements.
- A heat insulator allowing limiting the losses by conduction through the walls back and side.

The schematics of the PV/T collector are shown in Figure1; the upper cover is represented by a glass sandwich that includes PV cells. The cell area can cover the entire glazed surface or can be distributed in a grid where the spacing between adjacent columns and rows can allow a direct gain of solar radiation to the backward absorber plate. The glass sandwich looks like a chess board composed of squares with or without PV cells embedded. Different configurations of PV/T collector can be created changing the cell area density in order to balance electricity and thermal energy output of the system. [2]

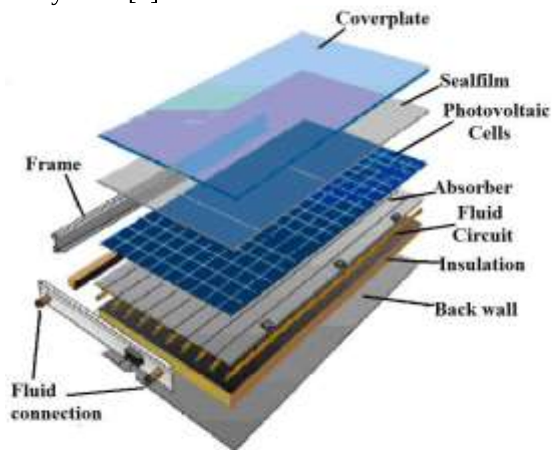

Fig.1: Elements of construction of PVT collector

3. MODEL OF A PHOTOVOLTAIC CELL:

Figure (2) shows the diagram of a photovoltaic cell:

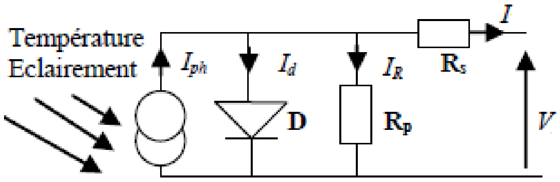

Fig. 2: Circuit diagram of a photovoltaic cell

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: C1 and C2: Constants calculated for each simulation.

VOC The open circuit voltage of PVG

ISC: the current generated by solar rays.

Im, Vm and Pm current, voltage and maximum power, respectively.

The expression (1) generates the characteristicI(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.

4. MODEL OF THERMAL SYSTEM:

The power recovered by the heat transfer fluid is defined as the difference between the incident solar energy and the heat losses. It is given by: [5]

$$Qu = AcFr[(\tau\alpha)_{eff}\, E - U_L\, (Te - Ta)] \quad (1)$$

The average temperature of the plate is given by

$$T = Te + \frac{Qu}{(AcU_L Fr)}(Te - Ta) \quad (9)$$

$$\text{With } Fr = \frac{MC_P}{U_L}[1 - \exp(\frac{-Ac.U_L}{MC_P}) Fc)] \quad (10)$$

$$Fc = \frac{1/WU_L}{\frac{1}{U_L[(W - d)F + d] + \frac{1}{W.h_{PVA}}} + \frac{1}{\pi dih_f}} \quad (11)$$

$$F = \frac{\tanh\left[\frac{m}{2}(W - di)\right]}{\frac{m}{2}(W - di)} \quad (12)$$

$$m = \sqrt{\frac{U_L}{K_{abc}L_{abc} + K_{pv}L_{pv}}} \quad (13)$$

Ac: Collector Area (m2)

Fr: Collector heat removal factor
(τα)eff: Effective transmissivity-absorptivity product.
E: Global radiation received by an inclined surface.
UL: Coefficient of heat loss, W/m2 ° C.
Te: Fluid temperature at the collector input.
Ta: Ambient temperature.
Qu: Useful energy recovered by the fluid

M:Mass of absorber.
Cp: Specific heat of absorber.
Fc: Collector efficiency factor.
W: Distance between the tubes.
d: Diameter pipe hydraulics.
F: Effectiveness coefficient.
hPVA: Coefficient of heat transfer from cell to absorb.
hf: Thermal coefficient of the fluid.
m: Surface flow, kg / s m2
Kabs: Conductivity Absorber.
Labs: Thickness Absorber.
KPV: PV Conductivity.
LPV : PV thickness.

5. Characteristic I(V) and P(V) of PV generator and PVT collector:
The power delivered by a photovoltaic generator depends on the irradiation what receives.

One notices that the maximum power for a system with a thermal photovoltaic collector (PVT) superior to the maximum power for a photovoltaic generator (GPV) system.

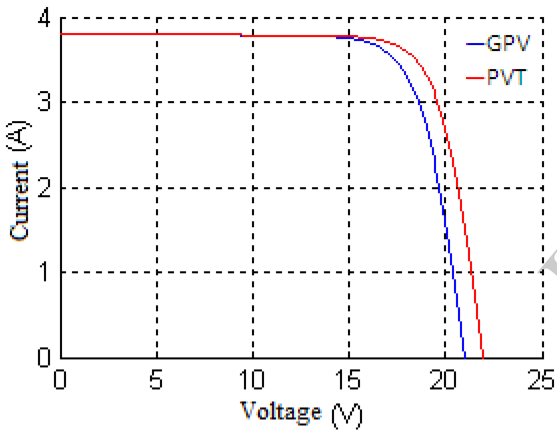

Fig. 3. Characteristic I (V) of GPV and PVT Collector

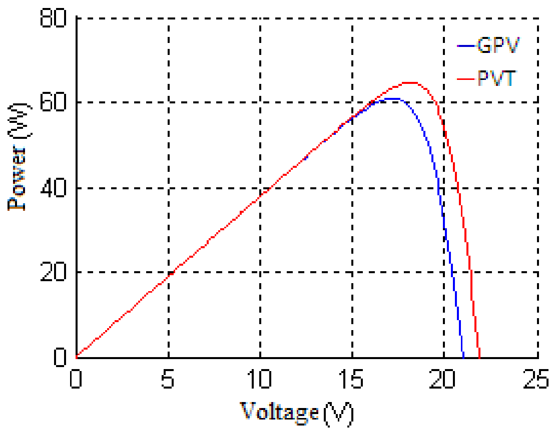

Fig.4. Characteristic P(V) of GPV and PVT Collector

6. SYSTEM OF PV PUMPING:

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

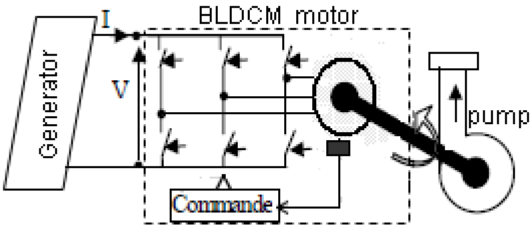

Fig.5. structure of PV pumping system. [6, 7]

7. Optimizations of PV 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 [8].

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 [9].

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 [10].

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 6.

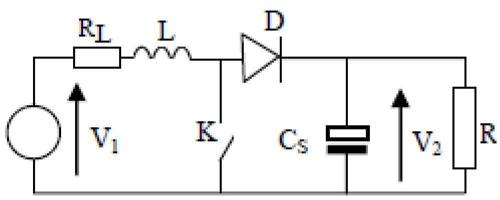

Fig.6. Boost Converter

Applying Kirchhoff's rules around the loops, it can obtain the ideal mathematical model of this circuit: [11]

$$\begin{cases} L\dfrac{dI_L}{dt} = V_1 - V_2(1-D) - R_L I_L \\ C_S\dfrac{dV_2}{dt} = -I_L(1-D) - \dfrac{V_2}{R} \end{cases} \quad (14)$$

Where:
IL: is the current across the inductor
Vc: voltage in the capacitor Parameters.
RL , 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.

$$\frac{V_C}{V} = \frac{1}{1-D} \quad (15)$$

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:

$$Va = R_a I_a + L_a.\frac{dI_a}{dt} + k_e\omega \quad (16)$$

and the couple of the motor

$$C_e = k_t I_a \quad (17)$$

The centrifugal pump opposes a resistant couple:

$$C_r = k_r w^2 + C_s \quad (18)$$

Ke(V/rad.s-1)
kt(Nm/Ampère)
kr(Nm/rad.s-1) are coefficients of proportionality.
On the other hand we have the mechanical equation:

$$J_m \frac{d\omega}{dt} = C_e - C_r \quad (19)$$

With Jm: the moment of inertia of the group. [12]

7. Results and discussion:
A. Characteristic of load and power:
The function of the system is improven by the use PVT collector system, where the motor to continuous current is supplied by nearer tensions to the face values.

- GPV system:
For small values of the luminance at 200W/m2, the supply voltage is increased to a value as low as 75V during this luminance, to a value of 110V by continuation (600 W/m2).

- PVT collector system:
For small values of the luminance at 200W/m2, the supply voltage is increased to a value as low as 80V during this luminance, to a value of 130V by continuation (600 W/m2).

The powers obtained by the use PVT collector system are the highest possible values. Thus, the overall power of PVT collector is used.

Figures (7) and (8) watch the big gap between the powers maximized for system of GPV and system of PVT.

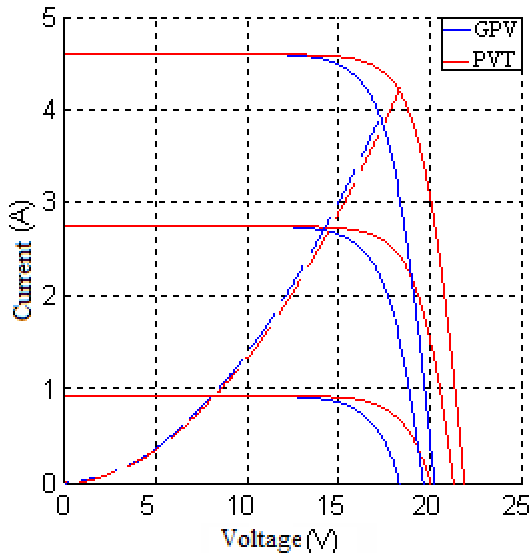

Fig.7. Characteristic I(V) of pumping system

GPV and PVT

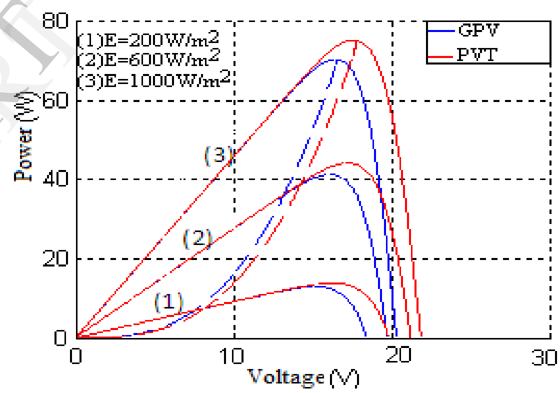

Fig.8. Characteristic P (V) of pumping system

By GPV and PVT.

B. Characteristic of efficiency and the debit of pumping system:
The efficiency of the system is defined by:

$$\eta_{PPV} = \frac{P_S}{P_e} = \frac{\rho.g.Q.H_m}{E.N_S.N_P.S} \quad (20)$$

With PS: hydraulic power,

Q: Quantity of water, given by: [13]

$$Q = \begin{cases} 0 & si\, E\langle E_t \\ \frac{1}{2}\frac{C_2}{C_1}\left[\left(1+4(E-C_3)\left(\frac{C_1}{C_2}\right)\right)^{0.5} - 1\right] & si\, E\rangle E_t \end{cases} \quad (21)$$

Et = 180W/m2, a, b and c are constant.
The figure (9) illustrious gait efficiency.

- PVT collector system: The efficiency is 45% for the luminance of 50W/m2 and 85% for the luminance of 600W/m2.

- GPV system: On the other hand GPV is characterized by the efficiency is 30% for the luminance of 80W/m2 and 75% for the luminance of 600W/m2.

But from E = 900W/m2 and the values of the efficiency will be close, reconciliation proves the good matching between the motor-pump group and the generator for the strong illumination.

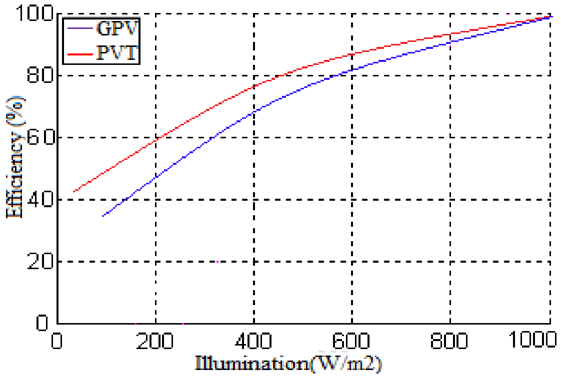

Fig.9. Efficiency of pumping system

By the GPV and PVT

The figure (10) represent the paces of the debits, to the GPV and with PVT according to the illuminance.

- In the case of the GPV system begins to supply water at an illuminance of 280W/m2. But for PVT system, the maximizing power strength of the pump supplying water to from 175W/m2.

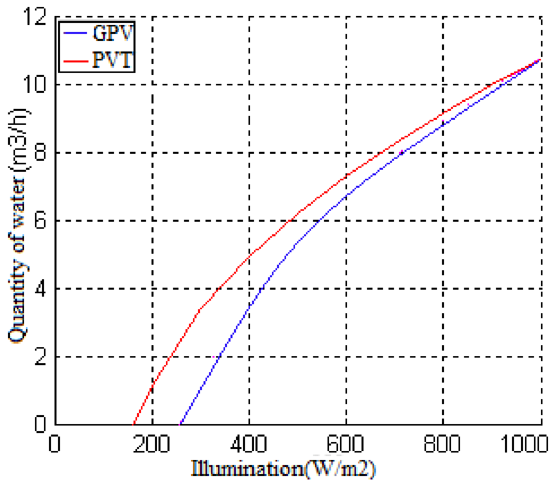

Fig.10. Quantities of water of pumping system

By GPV and PVT

8. CONCLUSION:

In the photovoltaic conversion in the solar collector, a heat is generated, thereby increasing the temperature at the photovoltaic cell and causing a drop in performance. This phenomenon is due to the part of not absorbed by the cells and solar radiation will cause its warming-up. On the other hand, this part of the absorbed radiation is lost as heat. The objective of this work is twofold, increase the electrical efficiency of the collector, that is to say the electrical efficiency by reducing the operating temperature and using the same heat for heating water or the surrounding space.

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