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POWER CONTROL ENERGY OF A PUMPING SYSTEM (PHOTOVOLTAIC- DIESEL)

Abdelhamid ksentini[1], Zakaria Hadef [2],W Bougheloum[3] ,E-B Azzag[1],S Maarouf[1], R Kebbache[1]

[1] Electrotechnical laboratory, Faculty of technology, Badji- Mokhtar University, Annaba 23000, Algeria
[2]Department of Physics, Faculty of Sciences, University 20 Aout 1955, BP 26, 21000, Skikda, Algeria.
[3] Laboratory of Automation and Signals, Faculty of technology, Badji- Mokhtar University, Annaba23000, Algeria
e-mail(1): hksentini86@gmail.com ,email(2) : abdelhamid.ksentini@univ-annaba.dz

Abstract— Future Algerian agricultural projects are oriented to the Sahara. Knowing that generally electrical energy is supplied largely by Generator Diesel (DGs). Due to the difficulty and lack of land roads for these desert areas, which creates fluctuations in the fuel supply process for farmers. In order to find a solution to mitigate this fluctuation requires the use of modern technology such as the hybridization of local renewable energy such as solar energy. Our system consists of the integration of a photogenerator (PVG) with a DG to feed a synchronous motor coupled to a central water pump controlled by means of transformers. This work presents an intelligent approach for improving and optimizing the control performance of a system using the Fuzzy Logic Control (FLC) based maximum power point tracking (MPPT) method. In this article, we will analyze a contribution to the use of a hybrid energy system (PVG-DG) according to a management strategy whose purpose is to reduce energy costs and reduce the emission of greenhouse gases (CO_2). Our simulation results presented at the end of the article have demonstrated the efficiency and flexibility of the Matlab simulated techniques system based on the actual geographic information of the study area to validate the performance of the proposed system. Which can be used in other practical studies in the future.

Keywords: Photovoltaic array, Diesel generator, Water pumping, Command, CO_2 emission, Cost analysis

1. INTRODUCTION

The electrical network in Algeria consists of an interconnected network in the northern states and isolated networks in the far south(Generator set). Spread out across more than 23 sites in the southern part of the country, the diesel production fleet has resulted in a high rate of CO2 greenhouse gas emissions and substantial fuel consumption. In 2017, the report predicted a decrease in carbon emissions by 12% compared to 1990. The objective of negotiating a new climate regime at the World Climate Change Conference (COP25) is to put a stop to carbon emissions by 40-70% by 2050 and achieve a 100% reduction by 2100. In order to meet future energy demands, it is essential to diversify our resources. An energy transition is required that includes both a reduction in the consumption of fossil fuels and a significant integration of renewable energies into our energy mix. Renewable energies will play a crucial role in ensuring a reliable and sustainable energy supply in the future. Among the various renewable energy sources, photovoltaic solar energy has gained increasing attention as a viable alternative [1]. Algeria's geographical location makes it an ideal place for the development and utilization of solar energy. With high levels of radiation intensity and sunshine lasting over ten hours a day for several months [2], our country has the potential to meet a significant portion of its energy needs through solar power. This advantage is particularly beneficial for remote regions, especially for photovoltaic pumping applications. A number of pumping systems have already been installed in Algeria to supply drinking water, as researchers such as EL Haines and Djamila Rekioua have contributed to the socio-economic development of these regions through their work.The importance of this research lies in the integration of the two sources and the improvement of the efficiency of the photovoltaic pumping system using a five-level inverter, and to conduct an economic analysis comparing two systems: a PVG system only and a hybrid (PVG-DG) system. The paper outlines the modeling of the PVG and photovoltaic pumping subsystem components, including converters and machine. To track the maximum power point for this system we used Fuzzy Logic Control (FLC) technology and a simulation program of the pumping system is developed using Matlab/simulink. The results of the simulation are presented in the article, which is organized as follows. The introduction was discussed in the first part, followed by the presentation of data specific to the Becher region in Algeria in the second part. The third section is a definition of a system and analysis in the modeling of its components, while the fourth section explains the techniques and technologies of controlling the components of the system. The penultimate part deals with the results obtained from this research, followed by a conclusion.

2. DATA OF SOLAR EMISSION

This system was studied on a desert area located in southern Algeria (Becher) [3], [4]. Real radiation data were taken from the location of the system. The resulting values are presented in the table1.

Table 1 Average measured monthly solar energy intensity in Becher, Algeria, year 2020.

Month	Irradiation (kWh/m²/day)
January	4.200
February	5.330
March	6.220
April	7.270
May	7.600
June	7.540
July	7.420
August	7.080
September	6.470
October	5.370
November	4.380
December	3.880
Irradiation moy/year	**6.063**

3. REPRESENTATION AND MODELING OF SYSTEM COMPONENTS

Figure 1 represents the main constituent elements of the proposal system with its various parts for a good understanding of the overall system.

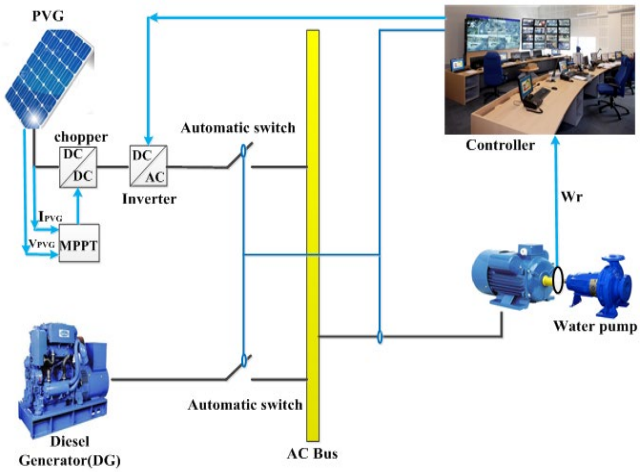


Figure.1 Schematic of the (PVG - DG) pumping system

After presenting the system in general, we will discuss in the following section the electrical modeling of each element of the pumping system.

3.1. Modeling of the photovoltaic production system (PVG)

The mathematical modeling literature differs from one researcher to another according to the efficiency and accuracy given by the photoelectric generator [5]. In this research, we tried to give the best and most accurate modeling of the solar panel to give an excellent current-voltage characteristic (I-V), [6].

Figure 2 highlights the equivalent electrical circuit for the PVG module comprising multiple PV cells. The unit usually contains a current generator (Iph), Resistors placed in series (Rs) and branch on parallel (Rp) [7],[8],[9].

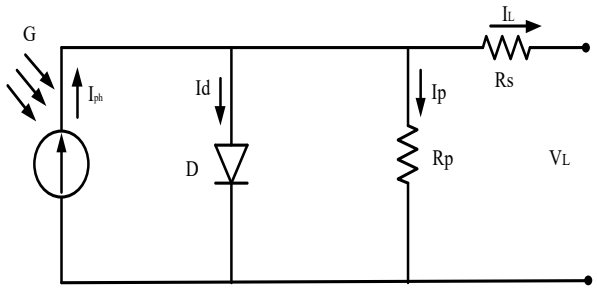


Figure.2 Electrical equivalent circuit of PVG cell.

Equation (1) represents the application of Kirchhoff's law for the (PVG-DG) system shown in Figure 1:

$$I_P = \frac{I_L R_s + V_L}{R_P} \quad (1)$$

Equation (2) expresses the diode current [8],[10]:

$$I_d = I_o \left\{ e^{\left(\frac{qV_d}{mN_S KT}\right)} - 1 \right\} \quad (2)$$

The load current (IL) can be determined using the following Eq. (3) from these equations:

$$I_L = I_{Ph} - I_o \left\{ e^{\left(\frac{qV_d}{mN_S KT}\right)} - 1 \right\} - \frac{I_L R_S + V_L}{R_P} \quad (3)$$

Figure 3 represents the application of the previous equations for the PVG system in the MATLAB program. This masqueraded Simulink model provides a visual representation of the PVG system and its components.

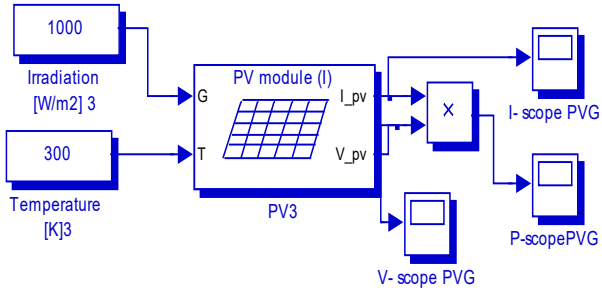


Figure.3 Simulation diagram of the PVG.

The ability of a photovoltaic generator (PVG) module to convert energy to solar irradiation and temperature conditions is described by its *I-V* curve [11],[12]. A change in the state of the PVG module can be expected to cause a change in this characteristic [13]. Figure 4 shows the current and Figure 5 shows the power energy of the PVG generator under standard conditions. The PVG consists of two parallel branches, with each branch comprising 24 series modules.

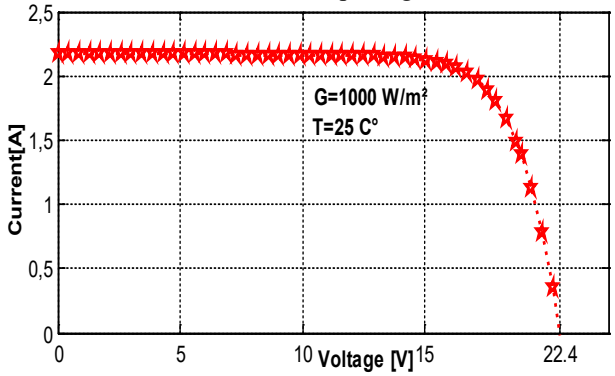


Figure.4 *I–V* curve of photovoltaic generator PVG.

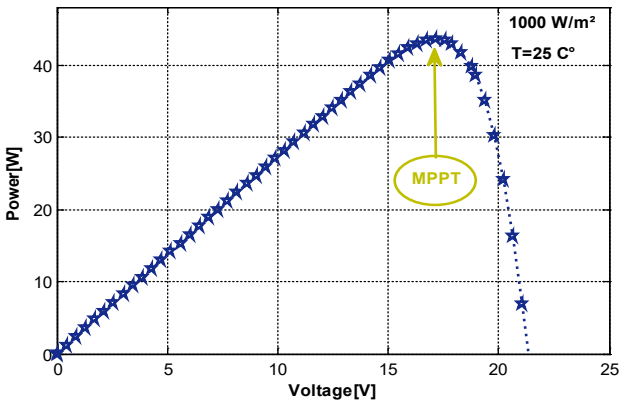


Figure.5 *P–V* curve of photovoltaic generator PVG.

Note in Figure 5 that the maximum voltage (V_{max}) corresponds to (P_{max}) which varies only slightly depending

on the illumination and unlike the current (I_{PVG}) which increases strongly with illumination.

3.2. Diesel Generator (DG)

DG is a dependable and viable alternative source of power for various applications such as residential and commercial use. It operates by utilizing an alternator and a diesel engine which uses diesel fuel as its energy source [14]. The DG consists of two parts [15]:

- The first part is a fuel-consuming diesel engine that produces rotary mechanical energy.
- The second part is a synchronous generator that produces electrical energy.

The equation below provides the instantaneous fuel consumption, $Consu_{fuel}$, of the generator [16].
The instantaneous fuel consumption $Consu_{fuel}$ can be represented by the following equation :

$$Consu_{fuel} = Consu_{0,fuel} + Consu_{speci,fuel}.P_{DG} \quad (5)$$

Where:
$Consu_{0,fuel}$: Empty fuel consumption of DG [L/h].
$Consu_{0,fuel}$ represents the vacuum fuel consumption of the DG in liters per hour (L/h).
$Consu_{speci,fuel}$: represents the specific fuel consumption of the generator in liters per kilowatt-hour [L/kWh].

3.3. Chopper (DC/DC)

Adapting the solar panel with an inverter is very important
In order to achieve this adaptation, in this research, we added a DC-DC Boost converter that is controlled by MPPT technology[17]. This control works to set the duty cycle stably no matter the solar panel power output varies [18]. The Boost converter topology used in this study is illustrated in Figure 6:

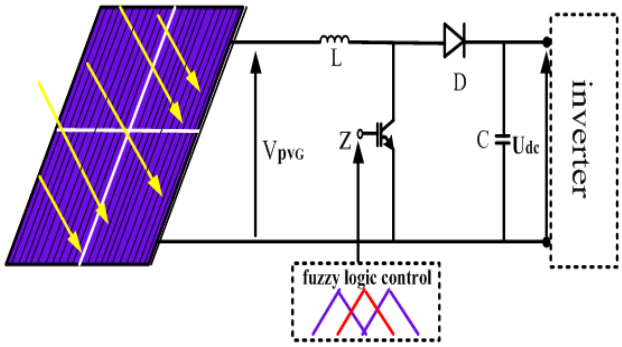


Figure.6 Boost converter circuit.

At a stable condition, the relation "6" [19],[20] can be utilized to express the output voltage of the chopper amplifier.

$$\frac{U_{dC}}{V_{PVG}} = \frac{I_{PVG}}{I_{dc}} = \frac{1}{(1-Z)} \quad (5)$$

Where:
$\mathbf{U_{dc}}$ is the voltage produced by the chopper, $\mathbf{V_{PVG}}$ is the voltage given to the chopper and **Z** is the duty cycle which is the ratio between the time within which the MOSFET.

3.4. Modeling of the synchronous motor

The equations presented in (Eq. 6), [21], [22] represent the mathematical model for a synchronous permanent magnet motor:

$$\begin{cases} U_{sd} = R_s i_{sd} + \dfrac{d\psi_{sd}}{dt} - \omega_r \psi_{sq} \\ U_{sq} = R_s i_{sd} + \dfrac{d\psi_{sd}}{dt} + \omega_r \psi_{sd} \end{cases} \quad \begin{cases} \psi_{sd} = L_d i_{sd} + \psi_f \\ \psi_{sq} = L_q i_{sq} \end{cases} \quad (6)$$

One can express the electromagnetic torque as follows:

$$C_e = \frac{3}{2} p((L_d - L_q).i_{sd}.i_{sq} + \psi_r.i_{sq}) \quad (7)$$

Where;
Usd*, *Usq and ***isd*, *isq*** : Stator voltages and currents,respectively.

The previous equations for the water pump motor can be embodied in the MATLAB / *simulink* program, as shown in the figure 7.

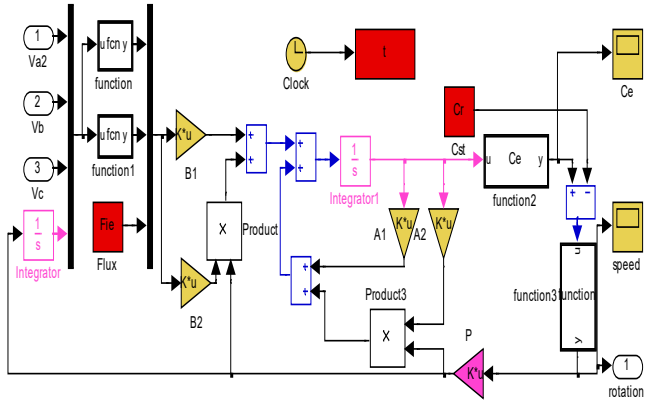


Figure.7 Block of permanent magnet synchronous motor.

3.5. Motor pump model

A centrifugal pump [23], is the most frequently utilized pump. For this search, we have opted for a centrifugal pump that is paired with an electric motor

$$Q' = Q\frac{N'}{N}, H' = H\left(\frac{N'}{N}\right)^2, P' = P\left(\frac{N'}{N}\right)^3 \quad (8)$$

With:
N',N: speed and reference speed.
Q', Q : flow and reference flow.
H', H : Height and total height.
The parameters synchronous magnet permanent motor is given in Table 2.

Table 2 Pumping motor data

R_s = 0.6 Ω	f = 50 Hz
L_d= 0.0012 H	L_q=0.0025 H
J=0.0011 kg.m²	P = 4
Ψ=0.12	ω_r= 2851 *tr/min*
Q_{max}=41 L/min	H_{max}=34 m

4. ALGORITHM AND TECHNIQUE CONTROL SYSTEM

After the initial knowledge of the system, the control unit shall be set into the system by means of an FLC. To illustrate the operation of this technique, four sections must be coordinated: fuzzification stage, inference stage, defuzzification stage and rule base. As depicted in Figure 8,

the modified values of the photovoltaic generator (ΔP_{PV}) and (ΔI_{PV}) serve as inputs, while (ΔV_{ref}) represents the output reference voltage.

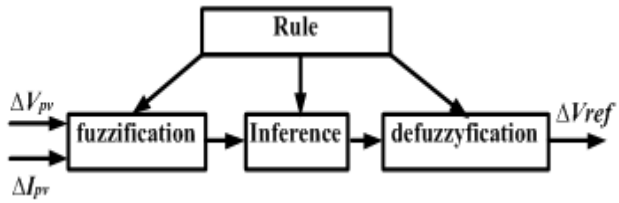


Figure.8 Illustration of FLC technology controller.

The equations used to calculate the input variables, ΔPPV, ΔIPV, and the output variable, ΔVref, for the proposed fuzzy logic controller are as follows:

$$\Delta V_{pv}(k) = V_{pv}(k) - V_{pv}(k-1) \quad (9)$$

$$\Delta I_{pv}(k) = I_{pv}(k) - I_{pv}(k-1) \quad (10)$$

$$VP_{Pv}(k) = \Delta V_{pv}(k) \times \Delta I_{pv}(k) \quad (11)$$

Ultimately, during the defuzzification process, the fuzzy subsets of the output are transformed into numerical values.

5. RESULTS AND DISCUSSIONS

The simulation scheme shown in Figure 1 was implemented using Matlab-Simulink software to simulate the operation of a motor pump (see Figure 9).

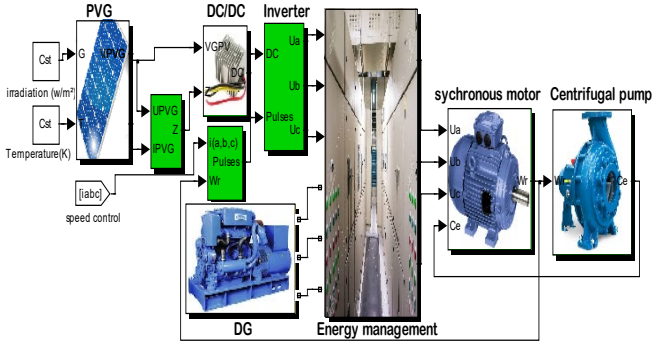


Figure.9 Structure of proposed hybrid system (PVG-DG).

5.4. Electrical interpretations

In this section we present the variations versus the time of the voltage PVG, the power of the PVG , current DG, voltage DG and the speed of the engine rotation illustrated respectively by Figures 10to14.

Under constant conditions (1000W/m², T = 25°C), Figure 10 displays the current of the PV generator, which exhibits a small disturbance at t = 0.15s, resulting in a transient regime in the studied system.

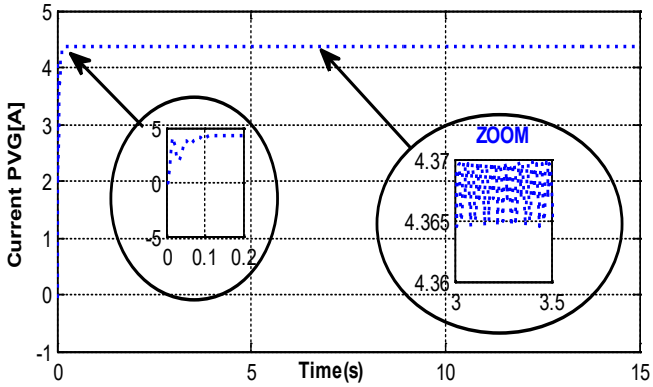


Figure.10 Current generated by the PVG.

Figure 11 showing the power generated by the PVG:

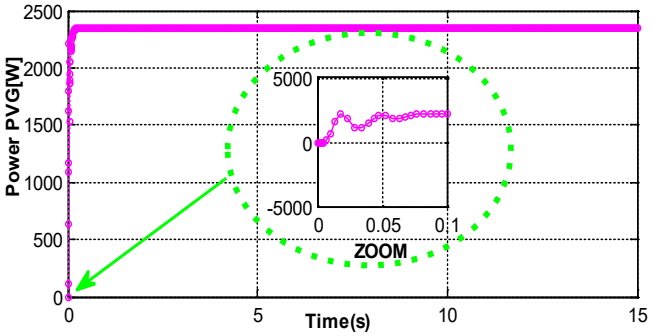


Figure.11 Power generated by the PVG.

From figure 11 it is recalled that the steady state of the output power does not change except during some disturbances at startup for 0.05s.

Figure 12 illustrates the three currents generated by the DG:

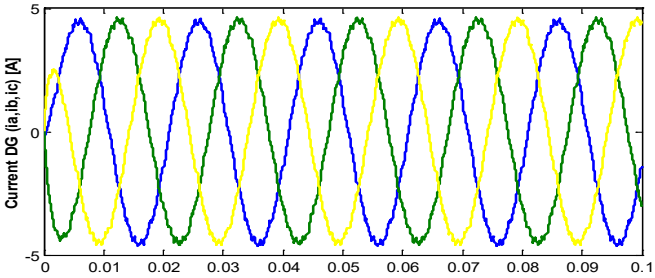


Figure.12 Currents generated by the DG.

Figure 13 shows the shape of voltage and current of a five-level inverter:

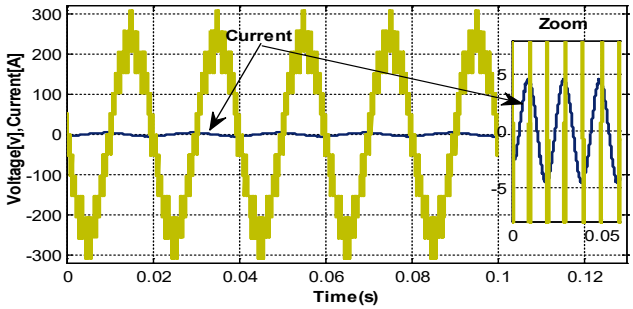


Figure.13 Three phase inverter voltage.

Figure.14 shows the speed of the engine rotation speed :

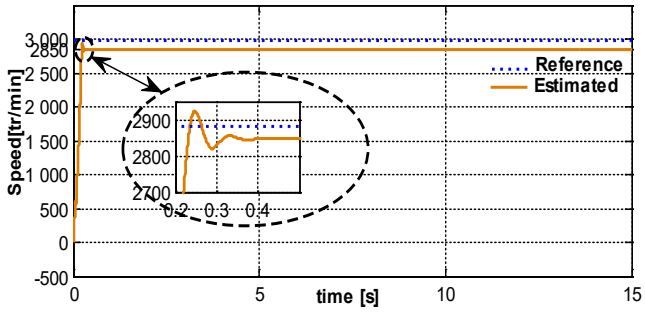


Figure. 14 Motor speed variation.

Note in figure.14 that the pace of the estimated rotational speed is kept constant and close to the reference rotational speed, regardless of the variations in sunshine and temperature.

5.5. Techno-economic interpretations

In this part of the results analysis, we can focus on the role of solar energy (PVG) in the operation of the diesel group for its role in reducing economic costs and emissions of greenhouse gases (CO2).

In this part, we have studied the comparison between two modes of operation of the same system (DG system) and (DG+PVG system).

Figure.15 shows the energy produced to the system according to the two proposed modes.

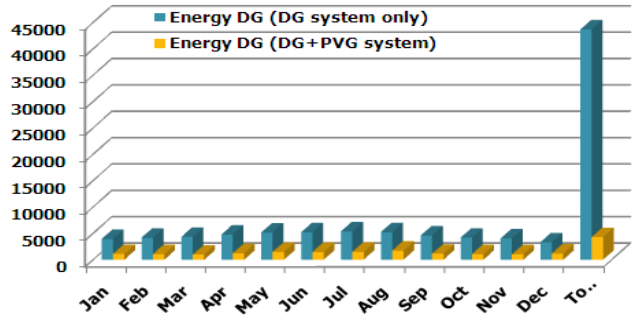


Figure.15 Comparison of Energy DG between two systems

From Figure.15, it is noted that during all months the energy generated by the diesel group in the hybrid system (DG + PVG) is lower than the DG only system, because of the hybridization with PVG which provided a amount of extra energy.

Figure.16 shows the effect of the fuel consumption generated by the DG according to the two proposed modes of the system:

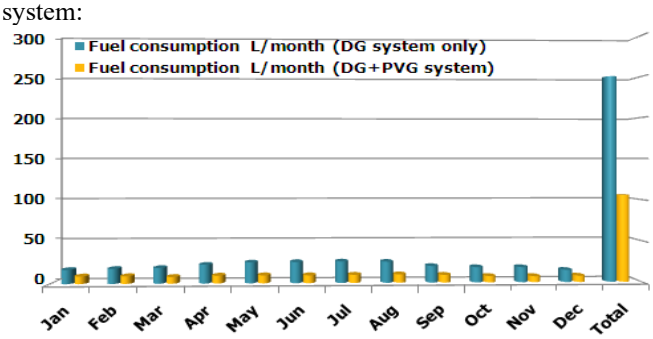


Figure.16 Comparison of fuel consumption generated by DG only and (PVG+DG) system.

According to the histogram in figure.16, it is noted that the fuel consumption provided by the (DG + PVG system) is lower than (DG system only), which corresponds to 105.5 (L/ year) for (DG + PVG system) and 250.2 (L / year) for (DG system only), this will have a direct influence on the CO_2 emission rate and climate change as shown in figure.17.

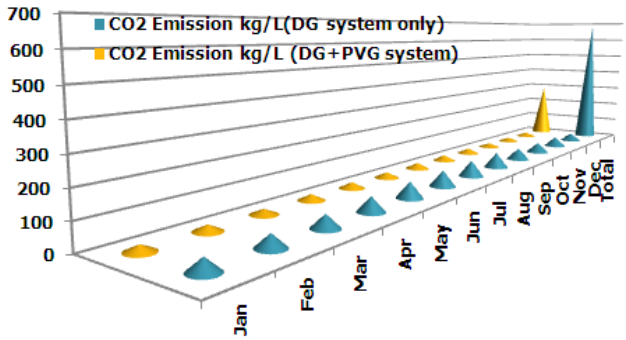


Figure.17 Comparison of emission CO_2 generated by DG only and (PVG+DG) system.

According to Figure.17, we have noted that this studied system is profitable whose goal is to reduce greenhouse gas (CO_2) emissions because the (CO_2) emission of (DG+ PVG system) is lower than the (DG system) corresponding to 288,015 (kg / L) for (DG + PVG system) and 683,046 (Kg / L) for the (DG system only).

Figure 18 gives us the profit from comparing the total *kWh* cost provided by the system.

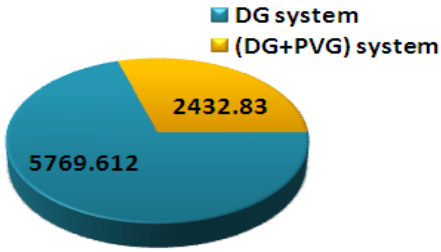


Figure.18 system economic gains.

These results demonstrate the enormous economic and environmental potential of the system (PVG-DG). The application of these results to large-scale consumption centers located at the various sites with a high solar energy potential whose average price of consumption of electric energy exceeding (6.125 DA / kWh) will be useful.

6. CONCLUSION

In our human society, we consume a very large amount of energy to cover our daily activities, this energy is necessary for man but our energy resources are not eternal (fuel). In this article, we have presented a technical-economic study for optimizing the performance of the pumping system (PVG-DG). In order to have the operation of the PVG, established to the techniques of the MPPT command to obtain the point of maximum power. The MPPT control, proposed in this paper, gives a fast response, reduces the power oscillations around the optimal and more efficient power point. The results of using this system showed the advantage of profit on the economic and environmental. This work has allowed us an economic and technical gain and

especially longevity of our system. In addition we have the assuran:ce of a continuity of service and a reduction of a part of the greenhouse gases (CO_2) during the operation of the PVG. In order to confirm the results obtained in this article, an experimental validation will be considered in future works.

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