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Photovoltaic energy used to supply water: environmental impact

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Abstract— **the stand alone photovoltaic pumping system (PVPS) is an appropriate solution to supply water for domestic, livestock and irrigation in remote locations. Also, supply water with solar panel allows reducing CO_2 emission and protecting environment. This paper presents a theoretical study of the effectiveness of water supply with photovoltaic panels, at the protection of environment compared with the pumping systems driven by diesel generator. The studied PV water pumping system consists of a photovoltaic generator, DC-DC boost converter, DC motor, centrifugal pump and a storage tank.**

***Keywords*—photovoltaique pumping system (PVPS), CO_2, water supply, photovoltaique generaor, diesel generator**

I. Introduction

The evolution of life has been possible due to the presence of water. However, although they exist in large quantities, only a small portion is actually available for human and animal consumption. The salt waters of the seas and oceans represent nearly 97% of the total volume of water on our planet, and many of the other 3% is blocked as snow, glaciers or deep groundwater. This resource is also not equitably distributed on earth, half of the surface water storage is in South America and another quarter in Asia.

About 65% of water continental rains evaporate and return to the atmosphere. The rest flows into rivers and lakes form on the surface or flows into the soil, where they may store in groundwater.

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To extract water from surface or underground, it is necessary to use pumps. The pumps need a source to be entrained. In this paper, we develop the water pumping systems driven by photovoltaic generator.

Solar energy is a source of energy available, clean and free, the photovoltaic pumping is one of the most important applications of this type of energy [1] [2], especially in rural areas that have a significant amount of solar radiation and do not have access to national grids.

In the absence of surface water, groundwater located in aquifers seems to be the only alternative to this problem, but difficult to access manually or with animal pumping. The mechanized pumping water becomes the only reliable alternative to extract water to a certain depth. PV pumping systems have enormous benefits: reliability, long-term profitability, non-polluting, simple operation etc…., can provide an appropriate solution to the water supply and to satisfy human and animal consumption, and irrigation in remote sites in arid regions.

In this paper, we present the different component of photovoltaic pumping system, a comparison study between the system entrained by photovoltaic generator and diesel generator.

II. Definition of PV pumping system

A PV pumping system consists of photovoltaic generator [3], a DC-DC converter (DC-AC inverter if we use AC motor), a motor-pump and a submersible storage tank.

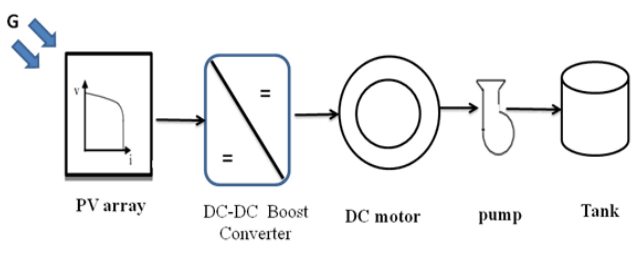

Figure 1. General Configuration of Photovoltaic Pumping System

A. *PV panel model*

Direct conversion of solar energy into electrical energy is provided by solar cells [4]. Figure 2 shows the equivalent circuit of a PV cell.

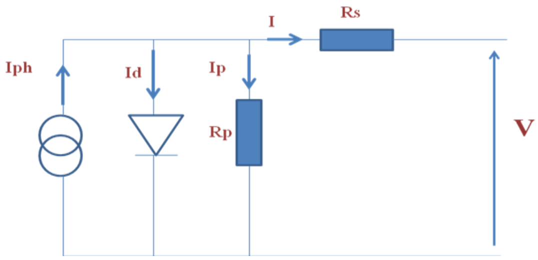

Figure 2. Equivalent circuit of solar cell

The general equation of the output current is:

$$I = I_{ph} - I_o(\exp(\frac{V_j q}{K_o T}) - 1) - \frac{V + R_s I}{R_p} \qquad (1)$$

where V is the PV output voltage, I is the PV output current, I_{ph} is the photocurrent, I_0 is the saturation current, R_s is the series resistance, R_p is the shunt resistance, and q is the electronic charge, n is the diode factor, K is the Boltzmann's constant, T is the junction temperature.

B. *Motor-pump group*

Several types of AC and DC motors are available for PV pumping systems [5]. The choice of motor depends on many factors: the requirements of the size, efficiency, price, reliability and availability. Among the different kinds of DC motors existing, the permanent magnet motors (PMDC) are most commonly used in PV pumping systems. They provide a high torque at startup.

Depending on the application, and water sources (wells, drilling, pumping river, etc..) different types of pumps are used. In photovoltaic pump, the centrifugal pumps and the volumetric pumps are the most used [14]. The centrifugal pump studied applies a torque proportional to the square of the rotational speed of the motor [6]:

$$\Gamma_r = K_c \cdot \omega^2 \qquad (2)$$

Where K_c: the proportionality constant [(Nm/rad.s-1)²] and ω: the rotational speed of the motor (rad.s-1).
Any pump is characterized by its output power, which is given by:

$$P = \frac{P_u}{\eta} \qquad (3)$$

$$P_u = \rho \cdot g \cdot H \cdot Q \qquad (4)$$

where: η the total output; ρ the density of the fluid (Kg/m3); g acceleration of gravity (m²/s); H height of rise (m); Q water flow (m3/s).

III. Comparison study between PV and diesel generator

A. *Estimation of energy required to supply a quantity of water*

The energy required to extract a certain amount of water at a given height during a day energy, is calculated from the data flow and TMH (Total Manometric Head) required, and is expressed in watt-hours. This calculation is based on a constant hydraulic (Ch), and inversely proportional to the performance of motor pump used. The energy required to pump:

$$E_{ele} = \frac{Ch * \text{daily flow} * \text{TMH}}{\text{Effeciency of motor-pump}} \qquad (5)$$

$$E_{ele} = \frac{Ch * Q(m^3/d) * TMH(m)}{E_m} \qquad (6)$$

With: E_{ele} is usually expressed in kWh, and Ch = 2.725 kg.s.h /m ^{2} [7] .The water flow necessary for the consumption of 50 families, composed in average on 10 persons, with an average consumption of 20 liters per person is shown in the table below:

TABLE I. WATER REQUIEREMENT

Family	Person/family	Liter/pers	Total (m^3)
50	10	20	10

For a total manometric head TMH = 40 m, given that the effectiveness of the motor-pump unit (Em) determined by the curves provided by the manufacturer is 44%.

Then the electrical energy required to satisfy consumption is shown below:

$$E_{ele} = \frac{2.725 * Q(m^3/d) * TMH(m)}{E_m} \qquad (7)$$

$$E_{ele} = 2{,}663 \text{ KWh} \qquad (8)$$

B. *Dimensioning of PV Generator*

The power delivered by the PV generator, necessary to drive the motor-pump group, can be calculated by the following equation [7]:

$$W = \frac{E_{ele}}{\text{sunshine} * (1 - \text{losses})} \quad (9)$$

Sunshine can be estimated by region. Losses present different problems associated to global warming of PV cells and dusts. Studies have shown that a generator composed by 7 modules in series can satisfy this need by electricity. The lifetime of this generator is equivalent to 20 years.

C. Consumption of Diesel Generator

Knowing that a liter of diesel fuel = 40 MJ = 11.1 kWh [8]. In our case, to meet the water needs of these 50 families, a day of water pumping requires 0.24l diesel fuel, which corresponds to 86.4 l of fuel per year.

The emission diesel generators of CO_2 factor is given by: CEF = 0.9 kg CO_2 - e / kWh. The annual electrical energy consumption is 958.7 kWh, which corresponds to an emission of 863 kg CO_2.

IV. Conclusion

In this paper, a comparison study between PV water pumping system driven by PV generator and diesel generator is done, to show the advantage of these systems, and their impact in environment .The main concluding remarks are summarized as follows:

- the calculation has shown a reduction of emission of 863 kg CO_2/year. 17,244 tonnes of CO_2 in 20 years (equivalent of cycle life of PV generator),
- this technology, though still in constant development, work properly and give good results. There is a strong demand for new installations, and the production capacities seem to multiply,
- the costs of PV equipments and water pumps are expected to decrease more and more over the next few years, the demand for PV systems goes up worldwide. These factors will make PV pumping systems more economic in the near future.

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