

Sustainable energy solutions for the agricultural world

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Abstract

The majority of Algerian lands are arid and semi arid, containing an important number of agricultural farms that can be divided in two types; the first one is connected to grid and the second type is located in isolated zones. Both of these types of farms suffer of many problems due to lack of electrification. Firstly in the isolated sites, they use diesel engines which are limited principally to irrigation and house lighting for few hours a day because of high fuel costs and engine maintenance. Secondly for the farms connected to grid, they tend to suffer from the quality of electric energy due to very important voltage drops in the summer periods where the demand for electricity becomes high due to pumping water and air conditioning. This high energy consumption is reflected in the electricity bills which become a burden to the farmers. As Algeria is one of the countries that, has sunny days during all year, solar energy can contribute to solve these problems by feeding farms with electricity and giving them some advantages. To perform this study, we present the analysis of the farm's loads, followed by the development of sizing systems where two farms (isolated and grid connected) are chosen for this study. Finally an implementation of solar stations is proposed.

Keywords: Solar energy, Solar radiation, Photovoltaic systems, Sizing model, agricultural farms

1. Introduction

Solar energy is one of the most used applications of renewable energy especially in countries that are characterized by sunny days. The solar energy has an important advantage due to the fact that it is pollution free and requires low maintenance. Several researches are carried out on this field so as to better understand its behaviour and operation in order to develop an adequate management and exploitation of this energy[1-2].

Algeria is one of the countries that are characterized by sunny days due to its climate diversities. The sunshine duration can reach annually 3900 hours in the arid and semi arid areas and the energy received daily on a horizontal surface is approximately 5kWh/m² over most of the country. It varies from near 1700kWh/m²/year in the North to 2263 kWh/m²/year in the South[3-5]. These specifications make Algeria favourite to solar applications because most of its areas are arid and semi arid. An important number of agricultural farms are implemented in these areas. Some of them are connected to grid and others are in isolated sites. Both of them suffer of many problems due to lack of electrification. Solar energy can contribute to solve these problems by feeding farms with electricity and giving them some advantages such as:

- avoiding rural exodus by improving the lives of farmers;

- contributing to the reduction of the greenhouse gas emissions;
- preserving fossil fuels for future generations;

In this paper, we present a study of two farms one is connected to grid and the other is in isolated site. Starting by the analysis of the farm's loads, which are composed of two kinds of loads, domestic and pumping systems. The first one uses batteries storage and the second one is without storage batteries. Then the development of sizing systems (with and without storage) is analysed. Finally an implementation of solar stations is proposed for these two farms.

2. Sizing system

The general steps of sizing system are summarized as follow [6-12]:

- Step 1: estimation of solar energy.
- Step 2 : determination of consumer's loads
- Step 3 : calculation of the PV field power and choice of modules
- Step 4 : storage Batteries sizing in case of daily working system
- Step 5 : inverter sizing
- Step 6 : cables and wiring
- Step 7 : total cost of the system

3. Available solar energy

We start by some information about the used site which is Batna region, taken as an example of semi arid. Its geographical location is given in table 1. The monthly average daily radiation at the latitude angle is presented in Fig. 1 [3,12]. Value of irradiation worth month, for the low season, is 3.866kWh/m².d and for the high season is 5.5kWh/m².d.

Table 1 Geographical location

Latitude (deg)	35.33 N
Longitude (deg)	6.11 E
Altitude (m)	1040
Albedo	0.25

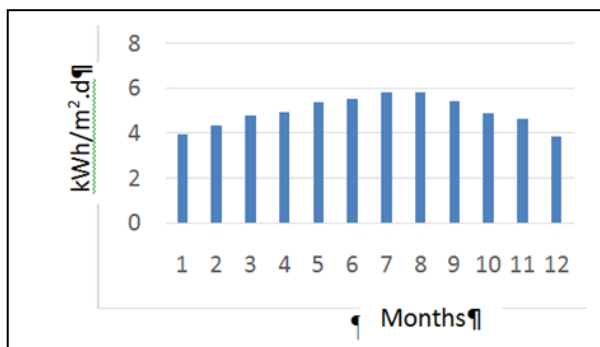


Figure 1. Monthly average daily radiation, at the latitude angle [12]

4. Farms loads

The farms are same loads and each of them is composed of three houses with 10 persons; they are used for cattle breeding (20 cows and 01 bull, 50 sheeps, 25 goats and 01 horse), equipped with 01 cowshed and 01sheepfold. The first one is located in area not connected to the conventional network and the second one is connected to grid. The forage crop is spread over 15 hectares. The loads can be divided in two types: domestic loads and water pumping. Due to the nature of these loads, two PV stations are envisaged. Table 2 and figure 2 give the domestic loads consumption and its repartition. In table 3 is shown the daily requirement water (peoples, animals and irrigation).it is assumed that 5ha can be daily irrigated.

Table2 : Domestic loads consumption

.Designation	Unit power(Watt)	Energy (Wh)
Lamps	15	1485
Street lights	75	3150

cowshed and 01sheepfold lights	50	600
televisions	100	900
refrigerators	4800	
Milking machine	750	3500
Domestic water pump	700	1400
washing machine	370	1110
Total	16945	

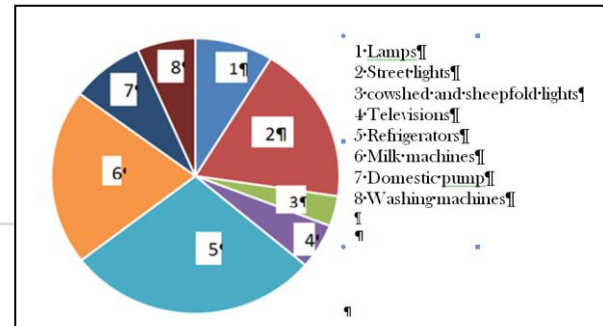


Figure 2. Loads repartition

Table3 : Daily water requirements

Designation	Number	Unit Consumption (liters)	Total consumption
Persons	10	150	1500
Cows and a bull	21	120	2520
Sheeps/ Goats	75	7	525
horse	01	60	60
Irrigation	05 ha	50000/ha	250000
Total	254605 litres = 254,605m ³		

5. Methodology

5.1. Hydraulic energy

It is given by [6]:

$$E_H = K_H \times Q_d \times HMT \quad (1)$$

Where

$K_H = \rho \times g = 2.725 \text{ kg.s.h/m}^2$ is the hydraulic constant, ρ water density (1000 kg/m³), g gravity, Q_d daily flow (m³/d) and HMT total head given by : $HMT = H_g + \Delta h$ With H_g geomtrici head and Δh the head losses.

5.2. PV power peak

The PV power peak (Pc) is given by [7]:

$$P_c = \frac{E_L}{N_{lmin} \times K} \quad (2)$$

Where

E_L is the daily consumed energy (Wh/d), N_{Imin} Equivalent number of hours corresponding to the worst daily for this period and K constant taking into account different losses in the system.

5.3. Battery capacity

The battery capacity is given by [7]:

$$\frac{N_d \times E_L}{U_b \times P_D \times R_T} \quad (3)$$

Where

N_d is the autonomy days, E_L daily loads, U_b Voltage battery, P_D Depth of discharge and R_T battery losses coefficient.

5.4 Inverter sizing

A) Inverter used in the principal system

The choice of inverter depends on the farm type. For systems on grid connexion, the inverter power must be between 0.9 to 0.95 of the peak PV power and for the off grid connexion, the inverter power must be greater than the daily peak power. For both systems their voltage range should be contains the PV voltage variation with temperature variations. In general, the inverter contains the regulator function and sometimes MPPT function

B) Inverter used in the pumping system

Its power must be less than the peak power of the PV generator. In general it is between 0.9 and 0.95 kWp.

5.5. Cables and Wiring

The wire sizing is chosen to limit the losses in different parts of the system. The drop voltage should be less than 2-3%.

6. Results and discuss

By applying the previous sizing model to the proposed farms, the following results are obtained:

6.1 Off-Grid solar electric farm

A) Principal generator

Results are shown in table 4.

Table 4: Principal system results

Designation	Value
PV peak power	6,08kWp (76 modules of 80Wp)
Nominal capacity (C100)	7845Ah with 4 autonomy days
Battery element chosen	2V, 4340Ah, Pd (25%)
Battery element connexion	2 parallel of 24 in series
Inverter power	1,6 kW

B) Pumping system

Table 5: It shows the obtained results.

Designation	Value
Hydraulic energy	114,4768 kWh/d
Pump efficiency (included motor and inverter efficiencies)	0,45
Electric energy	282,66kWh/d
PV power peak	57kWp (570 modules of 100Wp)
Pump	Submerged pump (with AC current motor and inverter)
Tank	Size of 4 autonomy days

6.2 On-Grid solar electric farm

A) Principal system

As loads are the same, then the previous obtained results are also the same. For this kind of farms, we suppose this load is supplied by PV system during a day and the grid supplies load during nights and in the cloddy periods. Consequently there is no storage battery.

B) Pumping system

The same results are obtained. The contribution of solar energy is in the quality of electrical energy (no power cut due to voltage drops) and also the reduction, or even total elimination, of the electricity bill.

7. Systems cost

Since cost of batteries is the most significant in photovoltaic systems then, we are limited to the cost of the main system for case of the isolated site. Figure 3 shows its distribution. It is clear that the cost of batteries is very high (usually it exceeds 80% of the total cost of the system). It is due to:

- autonomy which is 4 days;
- selected batteries with a life of 20 years

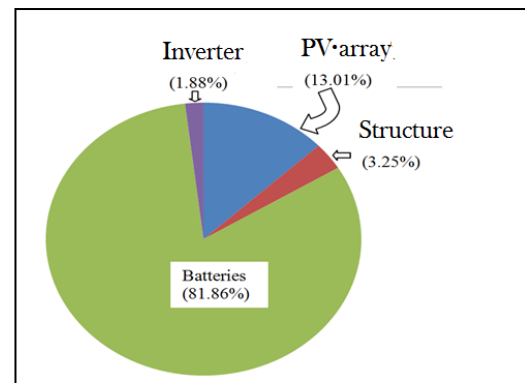


Figure 3. Cost repartition

8. Conclusion

Following this study, we are interested in the livestock sector which represents a high percentage of energy demand in the agricultural world. This analysis allowed us to determine the PV system to satisfy the loads and the water requirements. For domestic consumption we notice that the cost battery will be very high relatively to the other elements. This is due to the number of autonomous days which is 4.

Also we can notice the large water consummation for irrigation, which needs a very costly pumping system. Using PV system in on grid system has an important benefit in form of reducing the peak demand power during these high seasons periods.

In spite of this height cost we think that the solar energy is the key to the development of farms in these zones and solar energy is the future for our country despite the relatively high price of the components of the systems.

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