Sizing of a House Standalone Power System : Case of North Algeria

Sakina Atoui, N. Kellil, M. Hatti, B. Bouzidi, D. Ghribi Diaf

ABSTRACT--- This paper presents a study of sizing of standalone conventional photovoltaic system and tracking system designed for the electrification of a house located in Bou-Ismaïl Tipaza, northwest of Algeria. The system consists of conventional PV system or tracking system, electrical cabinet and batteries. Optimal sizing is carried out using the least-worst method to provide energy in winter. The results are presented to showthe effectiveness and the drawbacks of each systems, they also indicate that tracking system give better solution .

Keywords - Sizing; PV system; Irradiation; standalone PV system

I. INTRODUCTION

Renewable energy is the perfect alternative of the fossil energy. Its use is strongly recommended to save the environment from climate changes. Our country has a big potential of photovoltaic energy however, its use is very weak for several reasons. In this paper, we present a study for a standalone PV system to power a house located in the north of Algeria.

There are several studies for standalone PV system in the literature [1-3]. Sizing is the first step for making a standalone PV system. Several methods are used for sizing a standalone PV system and can be classified as intuitive[4] , numerical[5], analytical [6] and artificial intelligence methods[7]. In addition there are commercial software tools that are used for sizing a standalone photovoltaic system or other kind of renewable energy like wind energy , hybrid system [8], [9].

Reference [4] proposed an intuitive method for sizing a standalone PV system for residential buildings in Jordan. This method is based on the averages of daily meteorological and daily load demand. However, this sizing is not exact and may lead to oversizing which increase the cost of the energy or deficit of the energy in the cloudy days.

Reference [10] provide a review on sizing methodologies of photovoltaic array and storage battery in a standalone photovoltaic system. They summarize different techniques of sizing and present important papers that related to this issue.

Reference [5] use HOMER software for optimal sizing and cost evaluation of standalone PV system.

However, the variation of solar energy is the main disadvantages of their use because it make a sizing difficult to predict.

II. LOAD PROFILE

The house is located in Bou-Ismaïl, 2°41′24″E 36°38′33″N. Heating is primarily done with gas. The electrical equipments of the house are: TV, fridge, washing machine, Coffee machine, Microwave oven, Conventional electric oven, LED TV (on), LED TV (In sleep mode), Low-energy light bulbs, Computer with flat screen (on), Mobile phone charger, Hairdryer.

The choice of technology and the time of use are the two principals factors that determine the consumption of energy. Based on a daily time usage of the device and its consumption of electricity, the average of electricity used for each equipment is presented in the table below:

Table 1. Daily load estimate for a house.

Type of appliance	Capacity	Length of use	Consumption/day
Combi fridge-freezer	200 to 350 W	1 day - continuously	1370 Wh
Coffee machine	500 to 1000 W	10 mins./day	118 Wh
Microwave oven	1000 to 1500 W	0.3 h /day	268 Wh
Conventional electric oven	2000 to 2500 W	0.3 h /day	482 Wh
LED TV (on)	20 to 60 W	4 hours per day	161 Wh
LED TV (In sleep mode)	0.3 W	continuously	7 Wh

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Low-energy light bulbs	12 W	5 hours per day	59.7 Wh
Washing machine A+++	2500 to 3000 W	0.9 kWh/cycle	900 Wh
Computer with flat screen (on)	70 to 80 W	4 hours per day	300 Wh
Mobile phone charger	5 W	1 hour per day	5 Wh
Hairdryer	300 to 600 W	30 mins./day	300 Wh

Using the data in the table, the load profile is drawn using the MATLAB for one day (Fig.1,2,3).

Optimal energy management is linked to the planning of equipment in operation. So, switching on the maximum of appliances at the middle of the day during summer and spring is necessary, however they should choose another strategy for winter and autumn.

The figure 1, 2 and 3 present the profile of the charge of three cases according to the most powerful device in one side and in the other side the device which does not influence the comfort of the person:

Case 1: using the washing machine at the morning.

Case 2: using the washing machine at noon.

Case 3: using the washing machine at the evening.

This energy management is efficient during the period between may and October because the irradiation is high in the middle of the day. Thus, the energy production is high, there isn't shortage of energy. Also, the batteries can be protected by minimizing the number of cycle of charge.

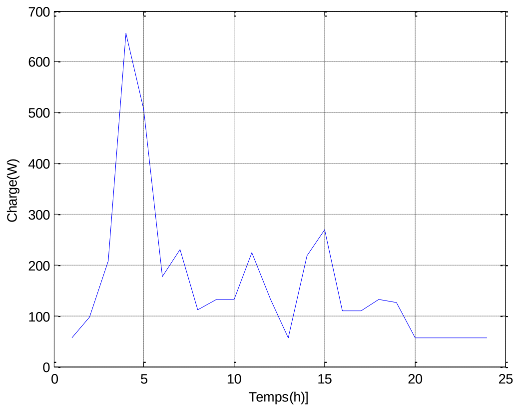

Fig. 1. Hourly averages demand of a house (washing machine switch on at noon).

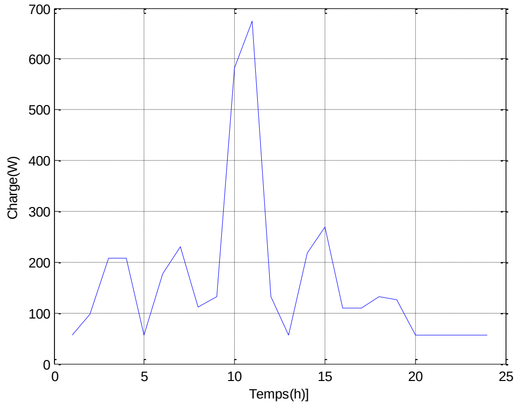

Fig. 2. Hourly averages demand of a house (washing machine switch on at noon).

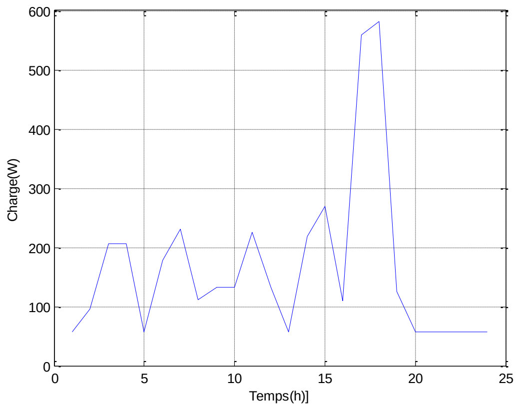

Fig. 3. Hourly averages demand of a house (washing machine switch on at afternoon).

The average daily load can be calculated from table 1 to be 3970.7 Wh / day and can be estimated to 4000 Wh/ day.

Nominal power, current and voltage of Condor photovoltaic panels are given in the table 2

Table 2. PV panel parameters.

Type	Nominal power	Nominal current	Nominal voltage
Condor	200W	5.75A	34.8 V

III. RESULTS & DISCUSSIONS

In this study, the intuitive method is used for sizing the house.

To obtain the optimal sizing, first we should make :

- Average daily power demanded by load.
- Average powers generated by PV and determine the number of solar panel.
- The required battery capacity.

A. Irradiations

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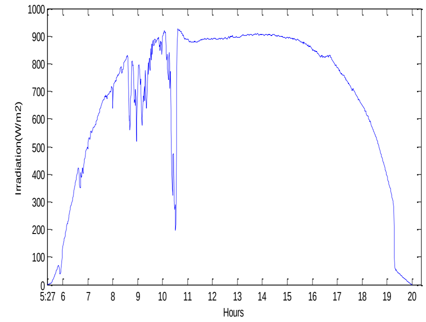

Fig. 4. Irradiation for 23 June 2018 with tracking

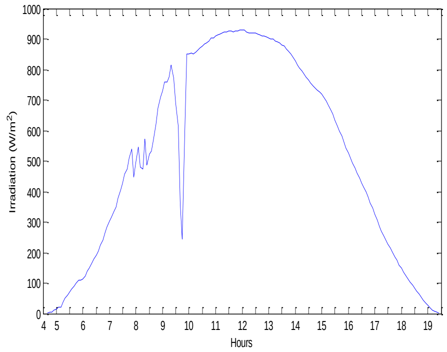

Fig.5. Irradiation for 23 June 2018 without tracking

Figure 4 and figure 5 represent the daily irradiation for same day by using a tracker and without a tracker. It is clear that by using a tracker we can get more solar radiation.

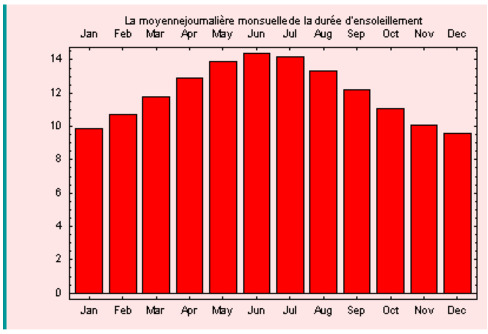

Fig. 6 : Monthly peak sunshine hours.

Figure 7 shows the monthly peak sunshine hour in Bou-Ismail and it proves the potential of solar energy in this location.

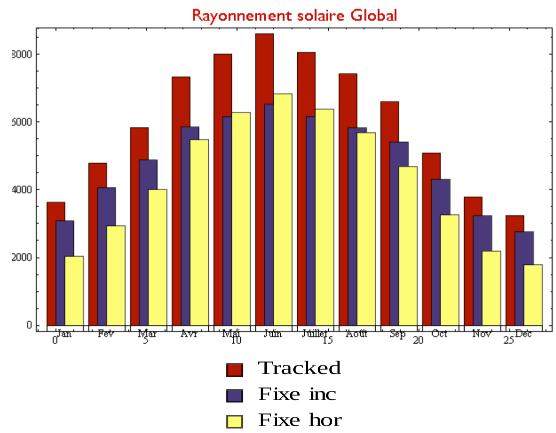

Fig.7. monthly representation of average daily global solar radiation measured on a horizontal plane, on a tilted plane at 36° and on plane with sun-tracker.

This figure shows the global solar ra measured on a horizontal plane, on a tilted plane and on plane with sun-tracker diation As it presented in the figure the level of solar radiation exceeds 1000W/m^2 and this result lets the use of solar energy in this area feasible.

The use of optimal sizing allow us to avoid the deficit in the energy.

B. Sizing of the PV array

1) Method1 :

The sizing of the PV array depends on the daily required load. As it presented in [10] the estimated PV array can be given as:

$$P_{pv} = \frac{E_{Load}}{\eta_{pv}\eta_o P_{sh}} f_e \qquad (1)$$

Where

P_{pv} is the optimum size of the PV array.

E_{Load} is the daily load energy consumption.

η_{pv} is the PV efficiency and η_o is the battery efficiency multiply by the inverter efficiency.

P_{sh} is the peak sunshine hours.

f_e is the safety design factor. In our work we didn't consider it because it chosen in most cases based on designer own experience which may be inaccurate [10].

Numerical application:

We choose the meteorigical data of the least-worst day, in Bou-Ismail. The solar radiation is taken with tracking and without tracking to show the difference between the two technics.

For the first method the results is the same for both technics because it based on the peak sunshine hours.

The daily load energy consumption is estimated by 4000Wh. The efficiency of the PV is 0.12 and η_o is 0.8.

According to figure 6, the minimum peak sunshine hour is 9h. The safety design factor is 0.8, then the PV peak power is:

$$P_{pv} = \frac{4000}{0.12 \times 0.8 \times 9} \qquad (2)$$

$$P_{pv} = 4629.6 \text{ Wh} \qquad (3)$$

The number of the panels that will be used is:

$$N_p = 4629.6 \div 200 = 23.15 \approx 24 \qquad (4)$$

2) Method 2

This method is based on the estimation of the PV area using the daily required load. The PV area PV_a is expressed as [12]:

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$$PV_a = \frac{E_{Load}}{S_d \eta_{pv} \eta_o TCF} \quad (5)$$

Where

TCF is temperature correction factor.

S_d is an average solar energy input/day (KWh/m^2/day).

The temperature correction factor is 0.999 for the temperature T=25°. For this method we calculate the number of panels required for conventional method and for tracking.

For tracking technics:

The daily energy consumption is estimated by 4kW and the average solar energy input per day is 5kW/m^2

$$PV_a = \frac{4}{0.680 \times 0.12 \times 0.8 \times 0.999} \simeq 61.33\ m^2 . \quad (6)$$

The PV peak power P_{peak} of solar modules measured in kW is calculated under standard conditions, temperature of modules is 25°C, and the solar irradiation is 1000/m^2 when the sun is at zenith. It is given by the equation below [13]:

$$P_{peak} = \eta \times PV_a \quad (7)$$

$$P_{peak} = 0.12 \times 61.33 = 7.359 \simeq 7.36 \text{ KW} \quad (8)$$

Number of solar panels N_p

By dividing the peak power on the nominal power of the solar panel $P_{nominal}$ we can get the number of panels that will be used.

$$\text{N}_p = \frac{P_{peak}}{P_{nominal}} = \frac{7.36}{0.2} = 36.8 \simeq 37 \quad (9)$$

Without tracking technics:

$$PV_a = \frac{4}{0.516 \times 0.12 \times 0.8 \times 0.999} \simeq 80.83\ m^2 \quad (10)$$

$$P_{peak} = 0.12 \times 80.83 = 9.699 \simeq 9.7 \text{ KW} \quad (11)$$

$$\text{N}_p = \frac{P_{peak}}{P_{nominal}} = \frac{9.7}{0.2} = 48.5 \simeq 49 \quad (12)$$

Without tracking, we must use 49 panels (200W) to power he house .

3) Comparison between the two methods

The second method is more accurate than the first one. By using the tracker the number of required panels is reduced. So, the cost of the photovoltaic installation will decrease.

C. Sizing of the battery:

The excess of energy generated by the PV panels must be stored in the batteries during the day to be used at night or in case of PV energy deficit. The storage battery capacity C_B must be well sized to ensure the good power management of the house. It can be expressed as [12]:

$$C_B = \frac{E_{load} D_{aut}}{V_B DOD \eta_B} \quad (13)$$

Where

D_{aut} is the number of autonomy day.

DOD is the battery depth of discharge rate.

V_B is the voltage of the battery.

η_B is the efficiency of the battery.

In our case, we use solar lead acid battery of 2v and 1000 Ah of each element. The maximum permissible depth of discharge is 50% and its efficiency is 0.5 then:

$$C_B = \frac{4000 \times 2}{2 \times 0.5 \times 0.85} = 9411.76 \text{ Wh} = 392.15 \text{ Ah} \simeq 400\text{Ah}. \quad (14)$$

The maximum successive cloudy days is often two days, thus we choose the maximum battery autonomy for two days.

IV. CONCLUSION

This paper presents a study of sizing a standalone PV system for a house located in Bou-Ismail . The study showed the potential of this area in term of solar energy. The feasibility of using only solar energy is demonstrated for a small simple house of load demand of 5KW. The monthly solar radiation showed the potential of solar energy in this area even in winter. In addition, by using tracking technics, the number of required solar panels is reduced by 25 per cent.

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