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Calculation for the Required Power and Material Cost of the Off-grid Solar Powered House in Remote/Desert Area in South Libya

[1]Omar.M.M. Mayouf, [2]Inayati, [1]M, Nizam

[1]*Mechanical Engineering Department, Sebelas Maret University, Indonesia*
[2]*Chemical Engineering Department, Sebelas Maret University, Indonesia Ir. Sutami Street 36A Kentingan, Surakarta – Indonesia.*

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ABSTRACT

The objective of this paper was to calculate the electric energy and material cost which was required to run a solar-powered house with full necessary electrical appliances for daily life. Solar powered house has been successful applied in northwest and southwest Libyan remote areas such as Bi'r al Marahan village in Al Jabal al Gharbi area and Guber Aoun Lake. Both areas are not connected to the electric network. The results showed a house required 21.095 KWh per day to run all devices and monthly cost for the electricity was 12.657 Libyan dinars (USD15.94) where the electricity price in Libya was 2 pennies/kW. The solar system for the house consisted of 50 m^2 solar panels, 100 Ah batteries, inverters, charger controllers, and accessories. The solar system price to run a house was 16,400 Libyan dinars (USD20.664).

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INTRODUCTION

Libyan state is located in the Mediterranean region in the north of Africa, with population of almost 6 million people spread over in area of 1,760,000 m2 and is ranked sixteenth in the world, in terms of area. In Libya there are enormous deserts but most of the population is concentrated on the coast. There are very few people in remote areas which cannot be assessed by electrical net work. The area such as Bi'r al Marahan, Al Jabal al Gharbi located in the southwest Libya has approximately 30 to 50 houses, and is located between $12^0 21^" 49.00^"$ E and $31^0 03^" 45.84^"$ N

Guber Aounin is located in Libyan Desert. It is a resort lake which is considered as a tourist resort in the desert and is located between $13^0 32^" 07.00$ E$^"$ and $26^0 48^" 11.00^"$ N. People there use diesel generators instead of utilizing solar radiation. Generators need constant maintenance and require fuel. The solar radiation in this area ranges from 9.30 to 10.69 kW/h.m^2- day at the north and south, respectively, which is considered a very large portion.

Fig. 1: Village of Bi'r alMarahan - AlJabal al Gharbi, Libya

Corresponding Author: Omar.M.M. Mayouf, Mechanical Engineering Department, Sebelas Maret University, Indonesia.

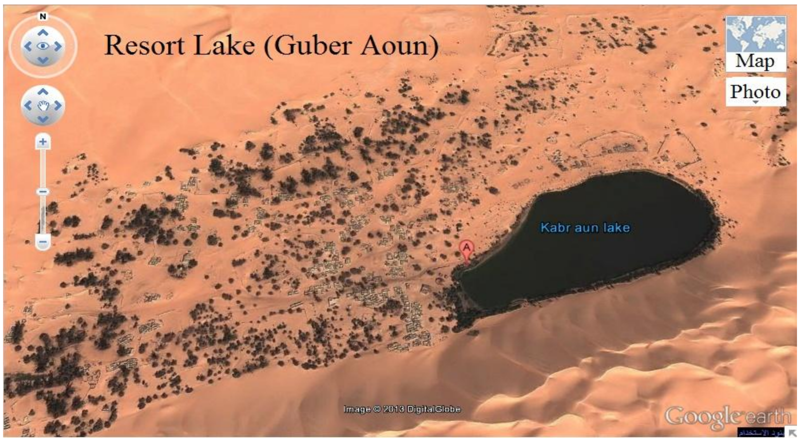

Fig. 2: Resort Lake (Guber Aoun)

In this study, the authors calculate the energy required to run all the electric devices in house and calculate the total material cost for the solar system.

2. Solar System Components:

Components used in the solar system are solar panels, charge controller, batteries, and inverters. The schematic of the house with fixed solar panels is presented in Fig. 3.

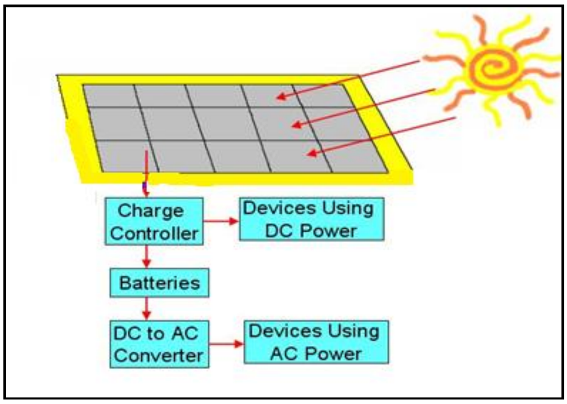

Fig. 3: Schematic diagram of a house with solar panels.

Solar Panels:

Solar panels are cells that convert photon into electricity through several steps. The movement of electrons inside the cell is transformed into electricity. There are two types of panel installation above the houses. Firstly fixed panel above the house with certain angle (Fig.. 4). The value of the angle is determined to assure large amount of solar radiation is captured by the panels. The second method is installation of electric motor which controlled by fuzzy logic to adjust the panel in capturing sun radiation during day time.

Fig. 4: Fixed solar panels mounted on the roof

In this study, the researcher focused on the 50 m^2 fixed solar panels. Each panel was able to produce around 110 watts electricity. Solar panels operated 5 hours daily.

Charger Controller:

Charger controller converts the DC power from solar panels to charge battery and to inverter. This device had efficiency of 88%. There were 6 pins where two pins were connected to the solar panels, two pins were connected to the battery, and the rest were connected to the inverter.

The charger controller managed the charging and discharging process of the battery. When battery state of charge (SOC) was low, the chrger controller charge the battery using the electricity produced by solar panels. When battery was full, charger controller stopped the charging automatically..

Batteries:

Battery was used to store the electricity produced by solar panels. In normal operation, battery was charged up to 70-80% of the capacity. If full capacity was required, a special warning system was needed to assure safe operation. Battery used in this study were 28 batteries, each had voltage of 24 V and 100 Ah capacities. Batteries were designed for deep cycled (75% of the capacity) without being damaged during deep discharging. The efficiency of the batteries was 85%.

Inverter:

Inverter changed the DC voltage from charger controller to 220V AC. Inverter used in this study had efficiency of 87%. In case of inability of the solar panels to supply the required power, the inverter converted the electricity directly from the battery.

Algoritm:

In this calculation, the basis used is the devices which usually used in a normal house, such as air conditioner, lamps, television and receiver, computer, iron, refrigerator, washing machine, vacuum cleaner, etc. The algorithm for the calculation can be written as follows:

1. Calculate the energy consumed by devices in the house per day (kWh).
2. Calculate the energy loss in the inverter and charger controller.
3. Calculate the solar energy required to provide the houses.
4. Calculate the required number of solar panels and its cost.
5. Calculate the number of batteries needed to store energy and its cost.
6. Calculate the required space on the roof of the house to put the solar panels.
7. Calculate the cost of accessories such as a charger controller and an inverter
8. Calculate the total cost.

RESULT AND DISCUSSION

Energy consumption for air conditioning system (AC):

Daily consumption (8 hours per day) and monthly cost for an AC with 1200 W power can be calculated as follows:

Daily power consumption = Number $\times$ device power (KW) $\times$ working hours per day

$= 1 \times (1200/1000) \times 8 = 9.6$ (kWh)

Monthly cost (LP) = power expendable/day $\times$ Price in P/KW $\times$ 30 days

$= 9.6 \times 2 \times 30 = 576$ (LP)

Energy Consumption For Lamps:

Daily consumption (6 hours per day) and monthly cost for lamp with 40 W

Power expendable per day = Number $\times$ device power (KW)$\times$ working hours per day

$= 8 \times (40/1000) \times 6 = 1.92$ (KWh)

Monthly cost (LP) = power expendable/day $\times$ Price in P/KW $\times$30 days

$= 1.92 \times 2 \times 30 = 115.2$ (LP).

Energy Consumption For Television And Receiver:

Daily consumption (10 hours per day) and monthly cost for television and receiver with 150 W

Power expendable per day = Number $\times$ device power (KW)$\times$ working hours per day

$= 1 \times (150/1000) \times 10 = 1.5$ (KWh)

Monthly cost (LP) = power expendable/day $\times$ Price in P/KW $\times$30 days

$= 1.5 \times 2 \times 30 = 90$ (LP).

Energy Consumption For Computer:

Daily consumption (6 hours per day) and monthly cost for Computer with 150 W

Power expendable per day = Number × device power (KW) ×working hours per day
= 1 × (150/1000) × 6 = 0.9 (KWh)

Monthly cost (LP) = power expendable/day × Price in P/KW ×30 days
= 0.9 × 2 × 30 = 54 (LP)

Energy Consumption For Iron:

Daily consumption (0.25 hours per day) and monthly cost for Iron with 1500 W

Power expendable per day = Number × device power (KW)× working hours per day
= 1 × (1500/1000) × 0.25 = 0.375 (KWh)

Monthly cost (LP) = power expendable/day × Price in P/KW ×30 days
= 0.375 × 2 × 30 = 22.5 (LP)

Energy Consumption For Refrigerator:

Daily consumption (24 hours per day) and monthly cost for one refrigerator with 250 W

Power expendable per day = Number × device power (KW)× working hours per day
= 1 × (250/1000) ×24 = 6 (KWh)

Monthly cost (LP) = power expendable/day × Price in P/KW ×30 days
= 6 × 2 × 30 = 360 (LP)

Energy Consumption For Washing Machine:

Daily consumption (0.5 hours per day) and monthly cost for one washing machine with 300 W

Power expendable per day = Number × devic power (KW) ×working hours per day
= 1 × (300/1000) × 0.5 = 0.15 (KWh)

Monthly cost (LP) = power expendable/day × Price in P/KW ×30 days
= 0.15 × 2 × 30 = 9 (LP)

Energy Consumption For Vacuum Cleaner:

Daily consumption (0.25 hours per day) and monthly cost for Vacuum cleaner with 300 W

Power expendable per day = Number × device power (KW) ×working hours per day
= 1 × (1000/1000) × 0.25 = 0.25 (KWh)

Monthly cost (LP) = power expendable/day × Price in P/KW ×30 days
= 0.25 × 2 × 30 = 15 (LP)

Energy Consumption For Other Devices Such As Mobile Charging, Radio, Etc:

Daily consumption (2 hours per day) and monthly cost for others with 100 W

Power expendable per day = Number × device power (KW) ×working hours per day
= 2 × (100/1000) × 2 = 0.4 (KWh)

Monthly cost (LP) = power expendable/day × Price in P/KW ×30 days
= 0.4 × 2 × 30 = 24 (LP)

Total Energy and Cost:

Daily Energy Consumption For The Home Appliances:

Total cost for daily energy consumption for the house is presented is table 1.

Table 1: Daily Energy Consumption and Cost

Device name	Daily energy consumption (kWh)	Monthly cost (LP)
Air condition	9.6	576
Lamps	1.92	115.2
TV	1.5	90
Computer	0.9	54
Iron	0.375	22.5
Refrigerator	6	360
Washing machine	0.15	9
Vacuum cleaner	0.25	15
Mobile charging, etc	0.4	24
Total	21.095	1265.7

Calculation For Required Power For An Inverter And Charger Controller:

Number of Peak hours almost solar radiation is 5 hours per day for the fixed solar panels and not moving (This 5 hours is a peak time for fixed panels)

From table 2:

1. Power required operating all devices 21.135 KW/day.
2. Power needed to inverter = full house powered ÷ inverter efficiency

= 21.135 KW ÷ 87% = 24.29 (KWh/day)

3. Power needed to charger controller = inverter power ÷ charger controller effeciency
= 24.29 KW ÷ 88% = 27.60 (KW/day)

The full power needed from the solar cell to feed the charger controller and inverter is 27.60 KW in 5 hours.

Calculation For The Required Number Of Solar Panels, Roof Space Required And Cost:

Default solar panels we will use (110 watts) per $1m^2$

Power needed of solar cell every one hour = full power needed ÷ number of peak hours almost solar radiation
= 27.60 ÷ 5 = 5.52 (KWh)

Number of solar cell needed = power needed every hour ÷ power of one solar cell
= 5520 W ÷ 110 W = 50.18 ≅ 50 panels.

Which will be required space above the roof of the house 50 square meters.
Price of one panel equivalent to 200 LD
50 panels cost = 50 × 200 = 10000. Libyan dinars

Calculation On The Number Of Batteries Needed To Run The Home For 24 Hours:

The full house power needed = the output of charger controller = 24.29 KW/d that is the power which we need to get from batteries when the batteries efficiency used (Eff) = 85%

Number of battery needed = full house power ÷ battery efficiency
= 24.29 ÷ 0.85% = 28.23 ≅ 28

Battery voltage was 24 volt and its current was 100 Amps. Batteries were be connected parallels.

The required battery capacity followed this relationship:

$$\text{CAh} = \frac{\text{Ed}}{\text{DOD}\times\text{eff}\times\text{Vb}} = \frac{24290\ \text{w}}{0.75\times0.85\times24} = 1587.5817\ (\text{Ah})$$

Price for battery, in Libyan dinar, was about 200 LD. So, total cost for batteries was:
Batteries cost = 200 × 28 = 5600 (LD)

Note: Solar panels were equipped with voltage regulator to make sure that the produced electricity had stable voltage and high current.

To install the solar panels, silicon glue and screws were required. Price for this installation was up 300 LD.In this study, the researcher assumed that all devices worked at the same time. Meanwhile, the fact, it was only 75% of the devices worked at the same time.

Table 2: Total cost for solar cell system:

Type	Number	Libyan dinar	US Dollars
Solar cells	50	10,000	12,600
Charger controller	1	150	189
Inverter	1	150	189
Batteries	28	5,600	7056
Wires	200 m	200	252
Accessories	------------	300	378
Total		16,400	20,664

Currency conversion: 1USD = 1.26 Libyan dinars

Conclusion:

Power required and total cost for the solar system used in Libyan remote areas (Bir Al Marahan and Guber Aoun) has been evaluated in this paper. The solar system consisted of solar panels, batteries, inverters and some accessories. During the day, the solar system produced 27.1 kW to fulfill energy required for the home appliances, which consisted of lamps, air conditioning system, washing machine, iron clothes, television, personal computer, and vacuum cleaner. It was found that the total cost for the solar system investment was USD20, 664

Nomenclature:

Ah = ampere per hour. Cah = capacity of battery. d = day DOD = Depth of Discharge. Ed = energy per day	Ah = ampere per hour. Cah = capacity of battery. d = day DOD = Depth of Discharge. Ed = energy per day	P = Penny. P/KW = pennies per kilo watt. SOC = State of Charge Vb = Battery voltage

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