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Designing a stand-alone PV system to operate an Abu Njeim Hotel in Libya

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A B S T R A C T

This research is a study and design of a stand-alone solar energy system for a tourist hotel in the Libyan desert in an area called Abu Njeim Hotel, the problem facing tourists in that rugged desert that is no public electricity network nearby. Many tourists have their cars were broken down and they get lost in the desert. So far, there is no hotel or a small rest house in this area, due to the inability to provide an electric energy source. This case was studied to provide a safe place for people and tourists to rest, to solve this problem: It was proposed to design a stand-alone solar energy system to provide this hotel with electricity throughout the day. This research has studied all information about the site and its meteorological data. The main components of this system are solar panels, inverters, charge controllers, and batteries. The electrical load of this hotel, as well as the percentage of solar radiation on-site, was calculated. PVSyst software was used to scale and analysis the data for this system. This study contributes to finding a solution for operating a tourist hotel in the Libyan desert in terms of design and sizing. These results can be benefited from in other sites by following the same steps that were used in this paper.

تصميم نظام طاقة شمسية مستقل لتشغيل فندق أبو نجيم في ليبيا

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الطاقة الشمسية
تحديد الحجم

الملخص

هذا البحث هو دراسة وتصميم نظام طاقة شمسية مستقل لفندق سياحي في الصحراء الليبية في منطقة تسمى فندق أبو نجيم، المشكلة التي تواجه السياح في تلك الصحراء الوعرة التي لا توجد بالقرب منها شبكة كهرباء عامة. العديد من السياح تعطلت سياراتهم وضاعوا في الصحراء. حتى الآن، لا يوجد فندق أو استراحة صغيرة في هذه المنطقة، بسبب عدم القدرة على توفير مصدر للطاقة الكهربائية. تمت دراسة هذه الحالة لتوفير مكان آمن للناس والسياح للراحة، لحل هذه المشكلة: تم اقتراح تصميم نظام طاقة شمسية مستقل لتزويد هذا الفندق بالكهرباء طوال اليوم. درس هذا البحث جميع المعلومات حول الموقع وبياناته الجوية. المكونات الرئيسية لهذا النظام هي الألواح الشمسية والعاكسات ووحدات التحكم في الشحن والبطاريات. تم حساب الحمل الكهربائي لهذا الفندق، وكذلك نسبة الإشعاع الشمسي في الموقع. تم استخدام برنامج PVSyst لقياس وتحليل البيانات لهذا النظام. تساهم هذه الدراسة في إيجاد حل لتشغيل فندق سياحي في الصحراء الليبية من حيث التصميم والحجم، ويمكن الاستفادة من هذه النتائج في مواقع أخرى باتباع نفس الخطوات التي تم استخدامها في هذه الورقة.

1. Introduction

Solar energy is the main renewable energy in this world, it is the most important alternative energy on earth, its most important use it is electricity production and water heaters [1]. Solar panels convert sunlight into electrical energy directly via an electronic process [2]. And they are electronic processes in an excellent system for converting sunlight into an electric current [3]. The market for renewable energy, and solar energy, in particular, has been growing very rapidly during the last ten years in terms of the development of the manufacture of

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solar cells and batteries, as well as charge controllers and inverters of all kinds, which are considered to have rapid and significant growth in the past decade [4]. Compared to the energy of Wind and other alternative energies, as it is considered one of the best ideal and reliable off-grid solutions. The technology of solar energy systems has been used with great reliability and stability successfully to supply electricity to rural areas as an independent network outside the public grid [5], while it produces electric energy by itself from sunlight, solar cells do not emit noise, their maintenance is simple, easy and inexpensive [6], can be installed almost anywhere, its only drawback is that the initial cost is rather high [7]. In this research, a simulation was made of a real site located in the State of Libya in the for a tourist hotel in the Libyan desert in an area called Abu Njeim region, which is a semi-desert and tourist area par excellence, where an independent solar energy system was scaled and designed for a small hotel rest for that region. Also, the site data and meteorological data for the proposed site were collected by the PVSYST program. This research paper was accomplished through two steps, the first is the construction of a solar energy system equipped with off-grid batteries based on the energy needed to operate this small rest hotel depending on the electrical appliances used and the lamps needed for that in terms of wattage, and the second is to simulate it through a program PVSYST to determine the overall performance of this system.

2. Off-Grid Photovoltaic System Design

The off-grid solar cell system is a system used to feed areas and loads far from the public grid [8]. Figure 1 shows the main components of the independent solar energy system, as the most important components of this system, are, solar cells, batteries, charge controllers, and inverters [9]. Solar cells directed at a certain angle receive sunlight and convert it into electricity, from which it is transmitted to the charge controller and organized in an electronic process, and divides into two parts, It raises it to 220 volts as alternating current to supply these loads, while the other part is transferred through the MPPT charge controller to the batteries to be charged and supplied during night hours and dark times such as fog and others [10].

Fig. 1. Shows the components of the solar energy system.

3. Meteorological data site for the Abu njeim res.

Geographical areas differ in terms of changes in weather patterns, so the installation location is an important factor for the design of the solar energy system from several aspects, such as the angle and direction of panel installation, the percentage of days when the rays from the sun are small, monthly and yearly. The proposed site is the Abu Njeim desert tourist rest house about 400 km from Tripoli as shown in Figure (2), located at 29.2049 degrees latitude and 12.3761 degrees longitude, with global horizontal radiation 2028.9 kWh/m²/year, and horizontal spread. The radiation rate is 538.9 kWh/m2/year, and this area is 631 meters above sea level.

Fig. 2. Shows the location of Abu Njeim– Libya.

4. Designing and sizing the stand-alone solar system.

In Table 1. The percentage of daily electricity consumption of this rest house is shown where the daily power consumption was 14650 W/day, and the total power requirement for the loads is 4.730 kWh if all the devices are working together at the same time, but this is not likely, for example, we do not use light bulbs during the day and do not use kitchen appliances and washing machines after midnight.

Table. 1. Shows the daily consumption of electrical appliances inside the rest house.

appliances	No.	Power (watt)	Total Power (w/h)	Working time (h)	Daily consumption (watt)
lamps	**10**	**10**	**100**	**12**	**1200**
TV	**1**	**180**	**180**	**5**	**900**
Water pump	**1**	**750**	**750**	**1**	**750**
Refrigerator	**1**	**200**	**200**	**24**	**4800**
Washing Machine	**1**	**1000**	**1000**	**2**	**2000**
Cooking machine	**4**	**500**	**2000**	**2**	**4000**
Fans	**5**	**100**	**500**	**2**	**1000**
Total			**4730**		**14650**

The climatic conditions and geographical location are the main controllers in producing the greatest value of electrical energy through solar panels [11]. Thus, the direction and angle of the installation of solar cells on electrical energy are very important. If you follow the sun's movement, the panels collect more energy, but the costs of this process are very large. Therefore, solar panels are often installed at the best angle, which is called the angle of inclination, and it varies based on weather and seasonal changes as shown in figure 3. Fixed arrays of solar panels are often oriented to the south in the northern hemisphere. The best PV output can be obtained using a tilt angle approximately equal to the site's latitude. Thus, the best configuration for this solar array is southward and at a 29° tilt relative to our chosen location.

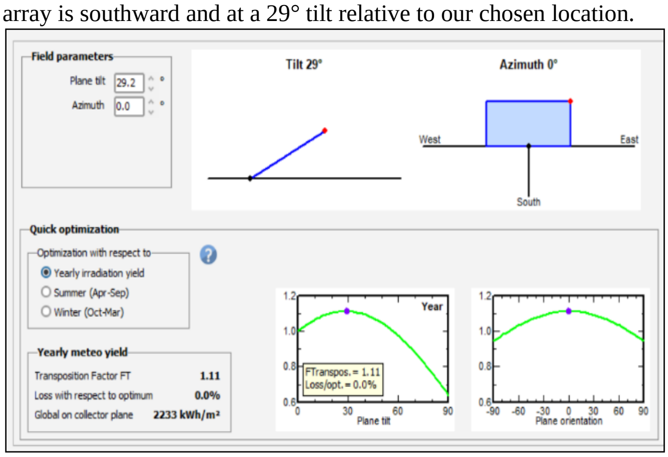

Fig. 3. Shows the best angle for installing panels on the site.

A. solar system sizing

Figure (4) explains the size of the components of the proposed solar system for this site, we used the PVSyst program, and the type of solar panels chosen, it was LG type with 450 watts, Narada batteries with 200 amps, and the MPPT generator type inverter.

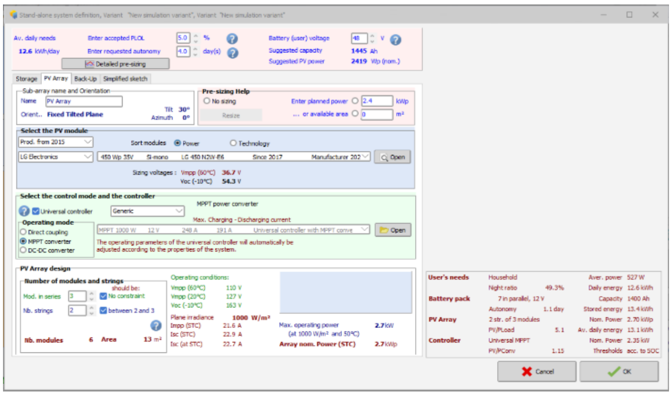

Fig. 4. Components of the proposed solar system

After calculating the loads in this rest hotel and designing the system, must be attention to the following:

• The constant current-voltage (VDC) of the system is 48 volts, which is better in this case because the demand for loads is large,

• The site's average solar radiation is approximately 5.51 kWh / m2 / day as stated in the site coordinates, according to what was stated in the NASA statistics through a PVSyst program, as shown in Figure (5).

• Average appliance's power daily demand is 14650 Wh/day.

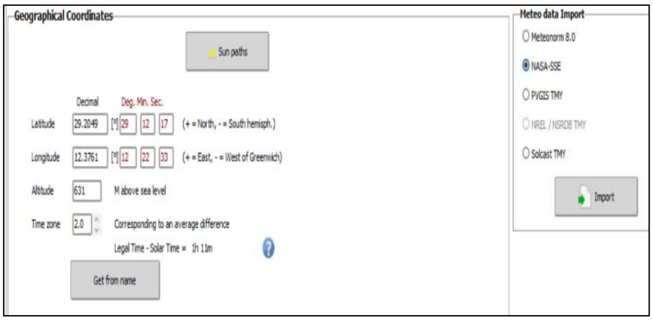

Fig. 5. Shows the Location data by NASA.

B. Efficiency data of the solar system components

Charge Controller Efficiency 0.85, Inverter Efficiency 0.97, Battery Efficiency 0.85, For Solar System Scaling, Appliance's power daily (Ad), System Efficiency (Total), System Constant Voltage (VDC), Solar Irradiance (R) for Site, Required Voltage Pmax (Vmax). To avoid under-sizing, we divide the energy we need per day by the total efficiencies of the system components to get the daily energy requirement from the solar array:

Overall Efficiencies = Charger Controller Efficiency * Inverter Efficiency * Battery Efficiency………… (1)

Ef total = CCe * Ie * Be

Ef total = 0.85 * 0.97 * 0.85 = 0.7008

From here, know that the actual power needed to operate the appliances of this site will be as it is in Equation No. 2 where Pd is the power required per day.

Pd = Apd / Ef total……………………………………… (2)

Pd = 14650 / 0.7008 = 20903. 7804 w/d

And then, the required power must be 20903.78 W/day to operate the appliances of this system.

With this, the required electrical capacity from the array of solar panels that will be installed through Equation 3, which is by dividing the required daily power of the devices (Pd) and its value (20903. 7804 kW / d) by the average solar radiation of the site today (Ri), an opportunity of 5.51kwh/m2/day:

Scpower = Pd / Ri. …………………………………..… (3)

Scpower = 20903.68 / 5.51 = 3793.95 w

Table. 2. Shows the Symbols used in the Previous Equations.

CODE	MEANING
Ef	Overall Efficiencies
CCe	Charger Controller Efficiency
Ie	Inverter Efficiency
Be	Battery Efficiency
Pd	Total power required per day
Apd	Appliances power per day
Scpower	Maximum power needed from the solar cell
Ri	Solar radiation of the site

5. Results of PVSyst simulation and analysis.

There are many programs and tools through which we can size solar energy projects with the grid as well as off-grid. PVSyst is a program that can be used to scale and analyze the data of the independent solar energy systems connected to the public grid. It is a stable and reliable program in terms of meteorological data and geographical locations. In this paper, simulation is implemented using PVSyst 7.2.

1. System designing in PVSyst

Figure (6) explains the electrical map of the system that will be installed in practice after it was designed in the PVSyst program.

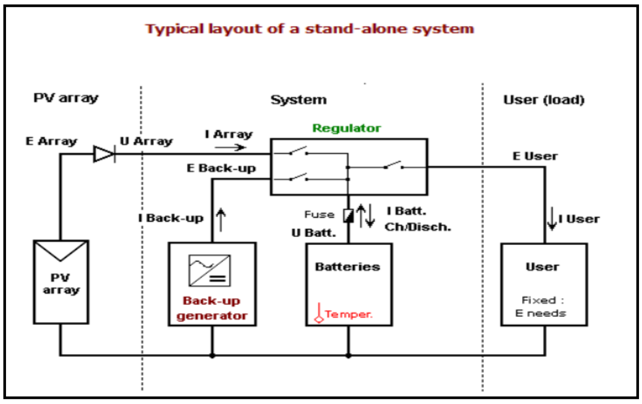

Fig. 6. Shows the electric circuit from PVSYST

2. Entering data into the PVSyst.

First, choose the location Abu Njeim rest House - Libya - location) to obtain meteorological data. Choosing the angle and orientation of the solar panels. Choosing a fixed mounting type or a tracking option. Whereas, in this project, the fixed plane was chosen at an angle of 290 degrees. Enter the number of appliances and lamps with their value in watts and daily operating hours as shown in Table 1. Enter the type of solar panels, batteries, inverter, and controller, and enter their value in watts. After defining and entering all these data and values, will run the simulation process, from which we obtain the required results and tables, which will be explained and clarified later. Figure (7) shows the work steps in the PVSyst interface.

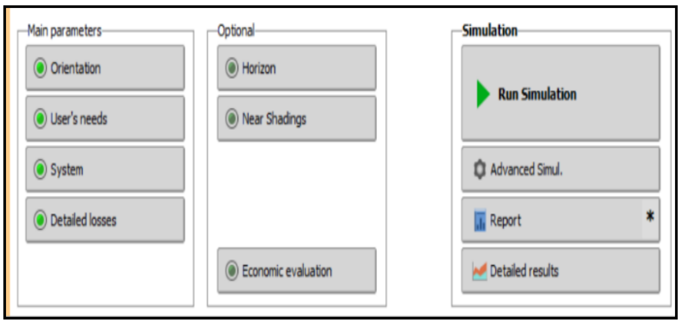

Fig. 7. Shows the running PVSyst interface.

3. Meteorological data for the site in the PVSyst program and its importance.

When using the PVSyst toolbar at the simulation start, will get one year's worth of meteorological data directly from the NASA website as shown in figure (8). These data include Diffused Horizontal Radiation (DiffHor), Global Horizontal Radiation (GlobHor), Ambient Temperature, Clarity Index, and Wind Speed Level for the Abu Njeim rest House - Libya - location, the data is shown in the following table.

Table. 3. Shows the symbols used in the previous equations.

Meteo and incident energy

	GlobHor	DiffHor	T_Amb	WindVel	GlobInc	DifSInc	Alb_Inc	DifS_GI
	kWh/m²	kWh/m²	°C	m/s	kWh/m²	kWh/m²	kWh/m²	ratio
January	97.6	32.55	9.51	0.0	144.8	21.12	1.308	0.000
February	121.2	33.04	11.34	0.0	164.6	18.93	1.624	0.000
March	172.7	44.33	15.08	0.0	205.2	22.57	2.312	0.000
April	199.2	50.70	19.74	0.0	207.2	23.52	2.666	0.000
May	217.3	62.00	24.52	0.0	203.9	26.52	2.908	0.000
June	230.7	57.00	28.48	0.0	204.8	24.76	3.086	0.000
July	247.1	51.46	29.56	0.0	222.9	23.77	3.308	0.000
August	222.0	49.91	29.44	0.0	220.0	23.19	2.972	0.000
September	176.7	45.60	26.82	0.0	199.2	22.14	2.367	0.000
October	141.0	40.30	22.09	0.0	182.1	21.73	1.889	0.000
November	99.0	33.60	16.05	0.0	143.4	21.02	1.326	0.000
December	85.9	31.00	10.95	0.0	131.0	20.62	1.150	0.000
Year	2010.4	531.49	20.35	0.0	2229.1	269.89	26.916	0.000

4. The proportion of natural production.

After determining the type of solar panel used in this proposed system, whose power was equal to 450 watts, 35 volts value, and type of LG Electronics, made in the year 2017, and then all these data were entered to make the simulation in the PVSyst program as in figure (8) The natural production shows us through the simulation, the values of daily production over the months of the year are:

1. The energy supplied to the user is 3.73 kWh/kWp/day.
2. System losses and battery charging are 0.43 kWh/kWp/day.
3. Collection loss (PV-array losses) is 0.85 kWh/kWp/day.
4. Unused energy (battery full) is 1.1 kWh/kWp/day.

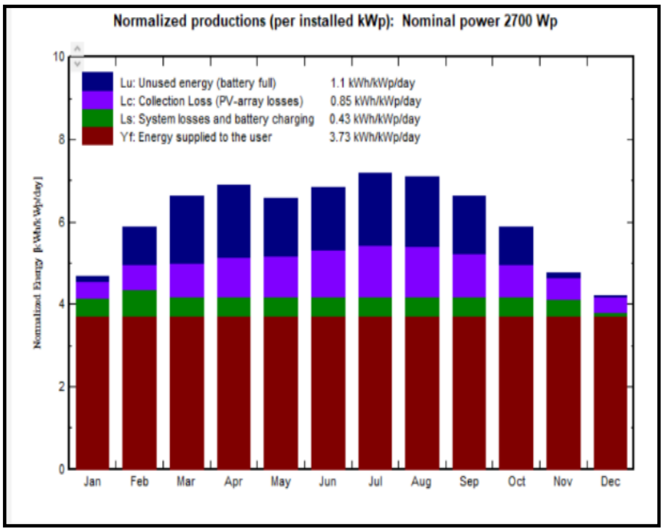

Fig. 9. Shows the natural production values of daily production over the months of the year.

5. Battery charging, operation, and performance.

The number of batteries that have been identified in this system was 20 batteries of 12 Voltas per battery and 200 Amps of the type Narada lead-acid, and 4 batteries in series were connected in 5 groups in parallel, as each line has a strength of 48 volts and an equal current of 200 amps as shown in figure (10).

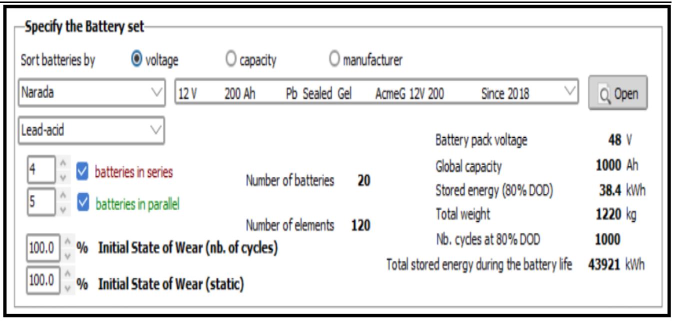

Figure. 10. Shows the specification of the Battery.

The percentage of performance and operation of batteries varies from one month to another month throughout the year, affected by natural factors such as the intensity of solar radiation, temperatures, and the number of hours of solar brightness, from several aspects, as shown in figure (11), where the most important of which was the average battery voltage (U-Batt), the average charging state during the period (SOCmean), state of charge end of time interval (SOC-End), dissociated electrolyte mass per cell (MGass), battery current charge/discharge efficiency (EffBati), battery energy charge/discharge efficiency (EffBatE).

Table. 4. Shows battery operation and performance.

Battery operation and performances

	U_Batt	SOCmean	SOC_End	MGass	EffBatI	EffBatE
	V	ratio	ratio	liter	%	%
January	50.8	0.663	0.618	0.026	97.4	90.8
February	51.5	0.789	0.810	0.071	92.1	85.1
March	51.8	0.835	0.809	0.115	91.3	90.3
April	51.8	0.836	0.809	0.105	91.8	90.7
May	51.8	0.836	0.809	0.115	91.6	90.5
June	51.8	0.836	0.809	0.111	91.6	90.6
July	51.8	0.836	0.809	0.112	91.7	90.6
August	51.8	0.836	0.809	0.112	91.7	90.6
September	51.8	0.835	0.809	0.111	91.7	90.6
October	51.8	0.833	0.809	0.119	91.7	90.7
November	51.2	0.727	0.797	0.043	91.7	91.6
December	50.6	0.610	0.412	0.023	90.5	102.5
Year	51.6	0.789	0.412	1.063	92.1	91.2

6. Operating losses.

One of the most important results can get by simulation, which will find on the ground in a ratio close to the results of the software in this system, as shown in Figure (12), where it shows the global horizontal radiation is 2232 kWh/m2, while the effective radiation on the collectors is 2338 kWh/ m2 where the standard test condition STC. In the case of radiation, intensity, and temperature, the light spectrum is similar to the solar spectrum, meaning that the best standard conditions were solar panels producing 13.75 kWh. However, in the case of STC, the efficiency was 17.7% as shown in Figure 8, and after calculating the initial losses, the efficiency of the energy coming out of the array was 9.87 kwh, while the energy needed by the user (the load) was 9.02 kWh.

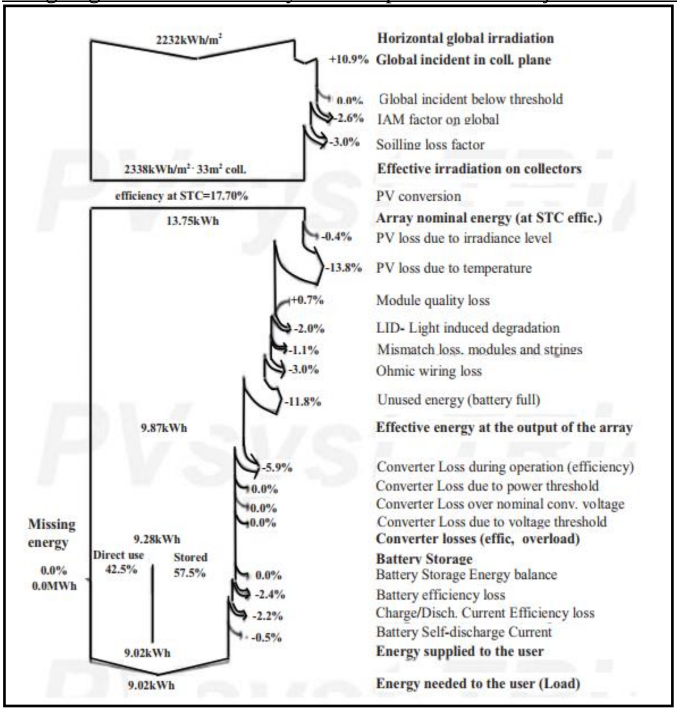

Fig. 11. Shows the losses of performance.

VI. CONCLUSION

In this paper, have established and designed a stand-alone off-grid solar energy system for a small tourist hotel located in a desert area in the Abu Njeim area in Libya. Daily energy consumption Was calculated also calculated and simulated all the components of this system from solar panels, batteries ... etc., based on the calculations of demand in watt-hours, in this simulation the PVSyst was used. The system works with 12 volts DC from batteries and produces 220 volts of alternating current. The panels used were LG Electronics, with a value of 450 watts. PVSyst gave a PV conversion efficiency of 17.7%, in the case of STC. The system needs 5 parallel batteries of 48V D and an MPPT universal inverter of 2.35 KW.

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