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Operating a full house using PV and batteries off grid using the PVSyst program

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تشغيل منزل كامل باستخدام الطاقة الشمسية والبطاريات خارج الشبكة باستخدام برنامج PVSyst

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Abstract:
This study designs an off-grid solar and battery-powered solar energy system for a hypothetical home in Libya. A stand-alone solar energy system was proposed as a means of supplying this home with electricity throughout the day. Meteorological data for a hypothetical location was examined to gather additional facts. This study includes a detailed discussion of the main components of this system: batteries, charge controllers, inverters, and solar panels. Calculations were performed to determine the home's electrical load and the amount of solar radiation present. Data from this system was measured and analyzed using PVSyst software. In terms of scale and design, this study supports the operation of an integrated off-grid home in the Libyan desert, so the same procedures used in this research can be used in other locations to benefit from these findings.

Keywords: solar energy, sizing, design, photovoltaic cells, off-grid, PVSyst.

الملخص:

هذه الدراسة هي لتصمم نظام طاقة شمسية لمنزل افتراضي في ليبيا يعمل بالطاقة الشمسية و البطاريات خارج الشبكة، تم اقتراح نظام طاقة شمسية مستقل كوسيلة لتزويد هذا المنزل بالكهرباء طوال اليوم. وقد تم فحص بيانات الأرصاد الجوية لموقع افتراضي لجمع الحقائق الأخرى. هذه الدراسة تشمل الحديث المفصل عن الأجزاء الرئيسية لهذا النظام من البطاريات ووحدات التحكم في الشحن والعاكسات والألواح الشمسية. أُجريت حسابات لتحديد الحمل الكهربائي للمنزل ونسبة الإشعاع الشمسي الموجود. وتم قياس بيانات هذا النظام وتحليلها باستخدام برنامج PVSyst. من حيث الحجم والتصميم، تساعد هذه الدراسة تشغيل منزل متكامل خارج الشبكة في الصحراء الليبية بحيث يمكن استخدام نفس الإجراءات المستخدمة في هذا البحث في مواقع أخرى للاستفادة من هذه النتائج.

الكلمات المفتاحية: الطاقة الشمسية، الحجم، التصميم، الخلايا الكهروضوئية، خارج الشبكة، أنظمة الطاقة الشمسية الكهروضوئية.

I. INTRODUCTION

Electricity generation and water heating are among the most important uses of solar energy, which is the world's primary source of renewable energy [1]. Through an electronic process, solar panels convert sunlight directly into electrical energy [2], an efficient tool for converting sunlight into electrical current [3]. With the development of solar cell and battery manufacturing, as well as various charge controllers and inverters, which are believed to have experienced rapid and significant growth in the past decade, the renewable energy market, particularly solar energy, has seen extremely rapid growth over the past ten years [4].

Solar energy is considered one of the best and most reliable off-grid energy options compared to wind power and other alternative energy sources. As a standalone off-grid system, solar photovoltaic (PV) technology has proven to be a highly stable and reliable means of providing electricity to rural areas [5]. Solar cells can be installed almost anywhere and are inexpensive, simple, quiet, and easy to maintain, despite producing electricity from sunlight [6]. Their only drawback is their relatively high initial cost [7]. The subject of this simulation was a hypothetical residential site in a semi-desert area in Libya. A standalone solar photovoltaic (PV) system was built and expanded for a small hotel there. The PVSYST system was used to collect site data and aerial photographs of the proposed site.

Based on the electrical appliances used and the electrical power required, the first phase of this study project was to build an off-grid PV system with batteries. This system would generate the energy needed to power this home for relaxation. The second phase involved using PVSYST to simulate the system to verify its overall performance.

II. OFF-GRID PHOTOVOLTAIC SYSTEM DESIGN

Off-grid solar cell systems are used to power loads and locations that are remote from the public grid. The primary components of the autonomous solar energy system are depicted in Figure 1, with solar cells, batteries, charge controllers, and inverters being the most crucial elements of this system [9]. Sunlight is converted into electricity by solar cells angled at a specific angle. The electricity is then sent to the charge controller, where it is organized in an electronic process and split into two parts. One part of the electricity is sent to the batteries to be charged and supplied during dark periods like fog, while the other part is raised to 220 volts as alternating current to supply these loads [10].

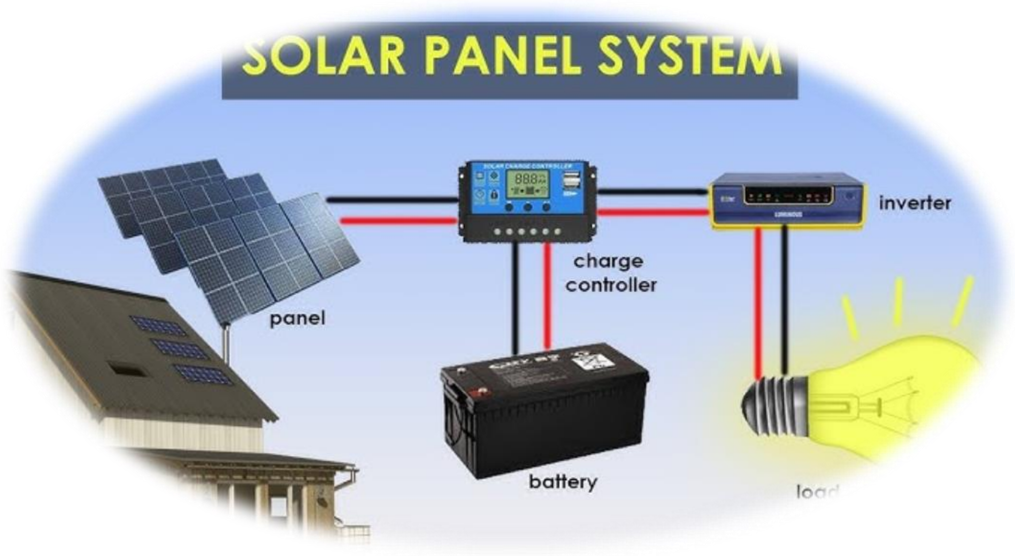

Fig. 1. Shows the components of the solar energy system

III. METEOROLOGICAL DATA SITE FOR THE HAMADA RES.

The location of the installation is crucial for the design of the solar energy system from a number of perspectives, including the percentage of days when the sun's rays are small, monthly, and annually, as different geographic areas have different weather patterns. According to Figure (2), the recommended location is the Hamada Al-Hamra desert tourist rest house, which is roughly 400 kilometers from Tripoli. It is situated at 29.2049 degrees latitude and 12.3761 degrees longitude, with a horizontal spread and worldwide horizontal radiation of 2028.9 kWh/m²/year. At 631 meters above sea level, the radiation rate is 538.9 kWh/m2/year.

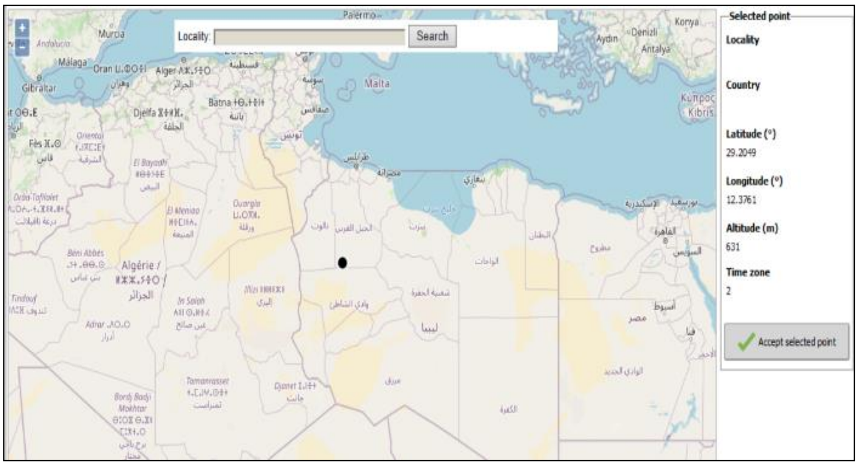

Fig. 2. Shows the location of Al Hamada Al-Hamra – Libya.

IV. DESIGNING AND SIZING THE STAND-ALONE SOLAR SYSTEM.

in Table 1. This rest house's daily electricity consumption percentage is displayed. The daily power consumption was 14650 W/day, and if all the devices were operating simultaneously, the total power requirement for the loads would be 4.730 kWh. However, this is unlikely because, for instance, we don't use lightbulbs during the day and don't use kitchen appliances or washing machines after midnight.

Table 1 shows THE DAILY CONSUMPTION OF ELECTRICAL APPLIANCES INSIDE THE RESTHOUSE.

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 primary factors influencing the amount of electrical energy that solar panels can produce are location and climate [11]. As a result, the orientation and angle at which solar cells are installed on electrical energy are crucial. The panels gather more energy if you track the sun's path, but this comes at a high cost. As a result, solar panels are frequently positioned at the ideal angle, known as the angle of inclination, which fluctuates according to the weather and the seasons, as figure 3 illustrates.

In the northern hemisphere, fixed arrays of solar panels are frequently facing south. A tilt angle about equivalent to the site's latitude will yield the best PV production. Therefore, facing south and tilting 29 degrees with respect to our selected position is the optimal arrangement for this solar array.

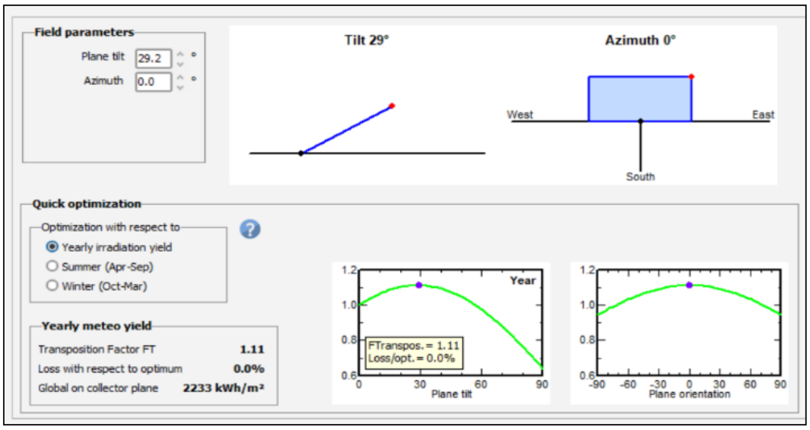

Fig. 3. Shows the best angle for installing panels on the site.

A. solar system sizing

The size of the components of the suggested solar system for this location is shown in Figure 4. We used the PVSyst program, and the solar panels that were selected were 450-watt wLG panels, 200-amp Narada batteries, and an MPPT generator-type inverter.

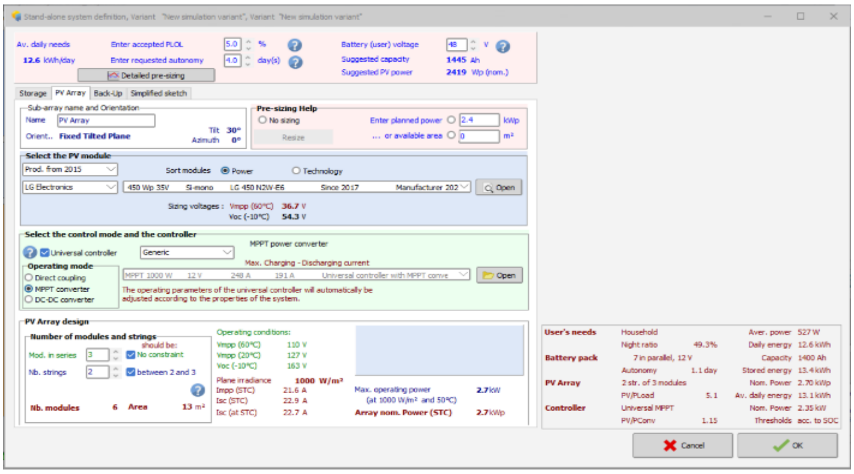

Fig. 4. Components of the proposed solar system

Following system design and load calculations in this rest hotel, the following needs to be taken into consideration:

• The system's constant current-voltage (VDC) is 48 volts, which is ideal in this situation due to the high demand for loads.

• Based on NASA statistics from a PVSyst program, the site's average solar radiation ® is roughly 5.51 kWh/m2/day, as indicated in the site coordinates, as illustrated in Figure (5).

• The average appliance uses 14650 Wh of power each day.

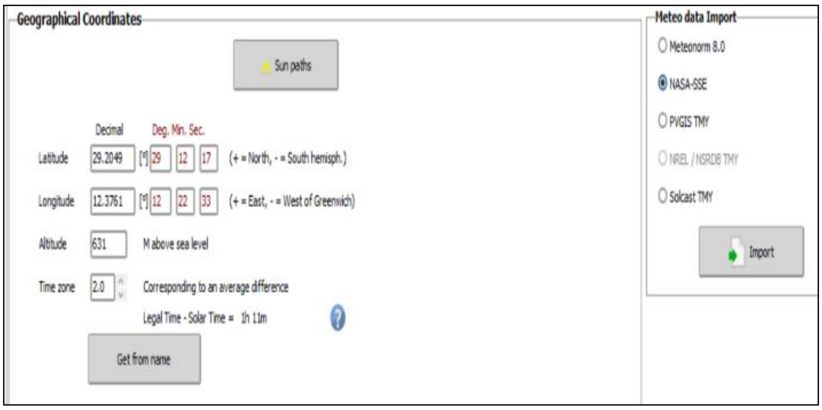

Fig. 5. Shows the Location data by NASA.

B.Efficiency data of the solar system components

Battery Efficiency 0.85, Inverter Efficiency 0.97, and Charge Controller Efficiency 0.85 Appliance power per day (Ad), system efficiency (Total), system constant voltage (VDC), site-specific solar irradiance (R), and required voltage Pmax (Vmax) are all important factors for solar system scaling. To determine the daily energy requirement from the solar array, we divide the amount of energy we require by the overall system component efficiencies in order to prevent under sizing:

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

CCe * Ie * Be = Ef total
0.85 * 0.97 * 0.85 = 0.7008 is the Ef total.
From this, you can infer that the real power required to run the site's appliances will be as shown in Equation No. 2, where Pd is the daily power need.

Pd is equal to Apd / Ef total (2).
7804 w/d = 14650 / 0.7008 = 20903.

In order to run the appliances in this system, 20903.78 W of power must be needed per day.
Equation 3, which divides 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), yields the

necessary electrical capacity from the array of solar panels that will be installed. This represents an opportunity of 5.51 kwh/m2/day:

Scpower is equal to Pd / Ri (3).
20903.68 / 5.51 = 3793.95 w is the Scpower.

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

V. RESULTS OF PVSYST SIMULATION AND ANALYSIS.

We can size solar energy projects both on and off the grid using a variety of techniques and methods. A tool called PVSyst can be used to scale and analyze data from standalone solar energy systems that are linked to the public grid. In terms of geographic locations and meteorological data, it is a consistent and trustworthy program. PVSyst 7.2 is used to implement simulation in this work.

1. System designing in PVSYST

The electrical map of the system that will be put into use after being built in the PVSyst program is explained in Figure (6).

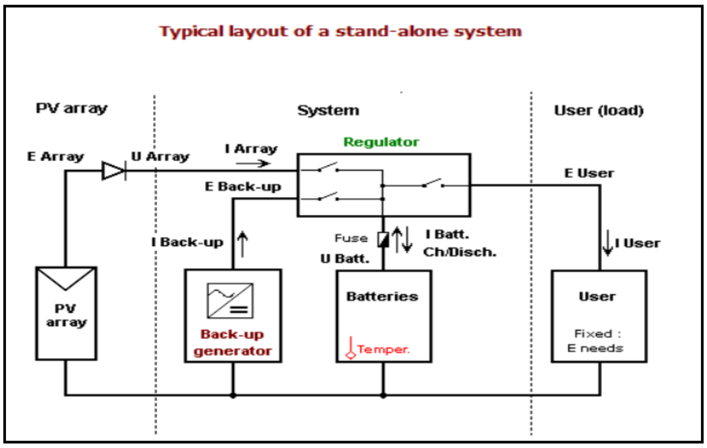

Figure 6. shows the electric circuit from PVSYST

2. Entering data into the PVSyst.

First, decide where you want to get weather information (Hamad Al-Hamra Rest House, Libya). selecting the solar panels' orientation and angle. selecting between tracking and a fixed mounting option. In contrast, the fixed plane in this project was selected at a 290-degree angle. As indicated in Table 1, enter the number of lamps and appliances, their wattage, and the hours they are in use each day. Enter the type of controller, inverter, batteries, and solar panels, along with their wattage. The simulation procedure will be executed once all of these data and values have been defined and entered. From there, we will have the necessary tables and results, which will be further discussed and clarified. The PVSyst interface's work steps are displayed in Figure (7).

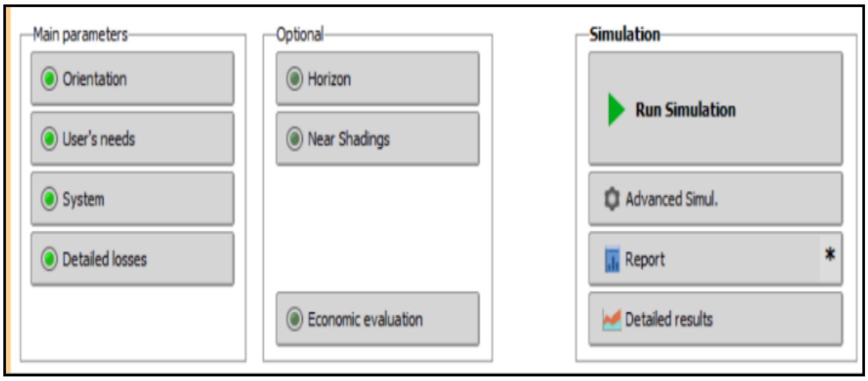

Figure 7. shows the running PVSyst interface.

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

As illustrated in figure (8), utilizing the PVSyst toolbar at the beginning of the simulation will obtain a year's worth of meteorological data straight from the NASA website. The following table displays the statistics for the Hamad Al-Hamra Rest House in Libya, which includes the following variables: ambient temperature, clarity index, wind speed level, diffused horizontal radiation (DiffHor), and global horizontal radiation (GlobHor).

Red hamada

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Meteo and incident energy

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	WindVel m/s	GlobInc kWh/m²	DifSInc kWh/m²	Alb_Inc kWh/m²	DifS_GI 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

Figure. 8. Meteorological data for the site in the PVSyst program.

4. The proportion of natural production.

Following the identification of the solar panel type utilized in this proposed system, which had a power of 450 watts, a value of 35 volts, and was manufactured by LG Electronics in 2017, all of these details were input to create the simulation in the PVSyst application, as shown in figure (8). The modeling of natural production reveals the following daily production values for the months of the year: 3.73 kWh/kWp/day of energy given to the customer; 0.43 kWh/kWp/day of system losses and battery charging.

PV-array losses, or collection loss, are 0.85 kWh/kWp/day.

Battery full, or unused energy, is 1.1 kWh/kWp/day.

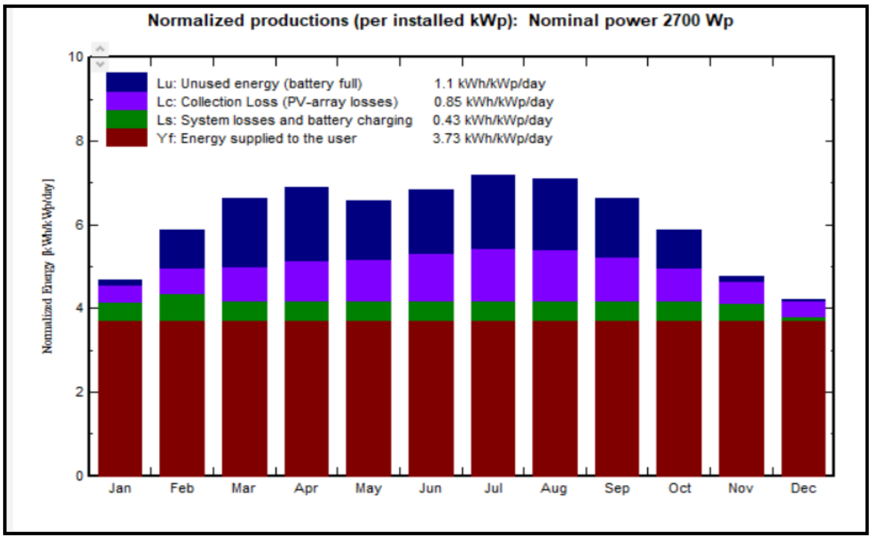

Figure. 9. shows the natural production values of daily production over the months of the year.

5. Battery charging, operation, and performance.

Twenty batteries of the Narada lead-acid type, each with 12 volts and 200 amps, were identified for this system. Four batteries were connected in series in five groups in parallel, with each line having a 48-volt strength and an equal current of 200 amps, as illustrated in figure (10).

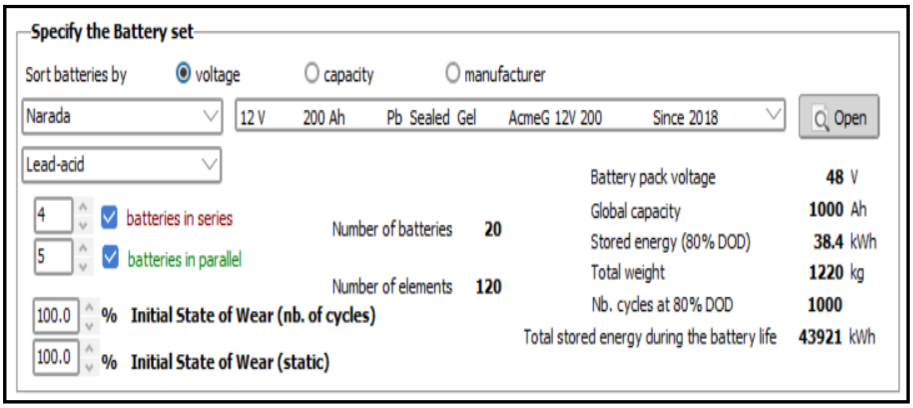

Figure (10). Shows the specification of the Battery.

Throughout the year, the percentage of battery performance and operation varies from month to month due to a variety of natural factors, including temperature, solar brightness, and the number of hours of sunlight. The most significant of these factors were the average battery voltage (U-Batt), the average charging state during the period (SOCmean), the state of charge at the end of the time interval (SOC-End), the dissociated electrolyte mass per cell (MGass), the battery current charge/discharge efficiency (EffBati), and the battery energy charge/discharge efficiency (EffBatE).

Red hamada

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

Figure. 11. shows battery operation and performance.

6. **Operating losses**.

Figure (12) illustrates that the global horizontal radiation is 2232 kWh/m2, while the effective radiation on the collectors is 2338 kWh/m2 under standard test conditions. This is one of the most significant results that can be obtained through simulation, which will be found on the ground in a ratio that is similar to the software results in this system. The optimum standard circumstances were solar panels producing 13.75 kWh since the light spectrum is identical to the solar spectrum in terms of radiation, intensity, and temperature. However, as Figure 8 illustrates, the efficiency of STC was 17.7%. After accounting for early losses, the array's energy output efficiency was 9.87 kwh, whereas the user's (the load's) energy consumption was 9.02 kWh.

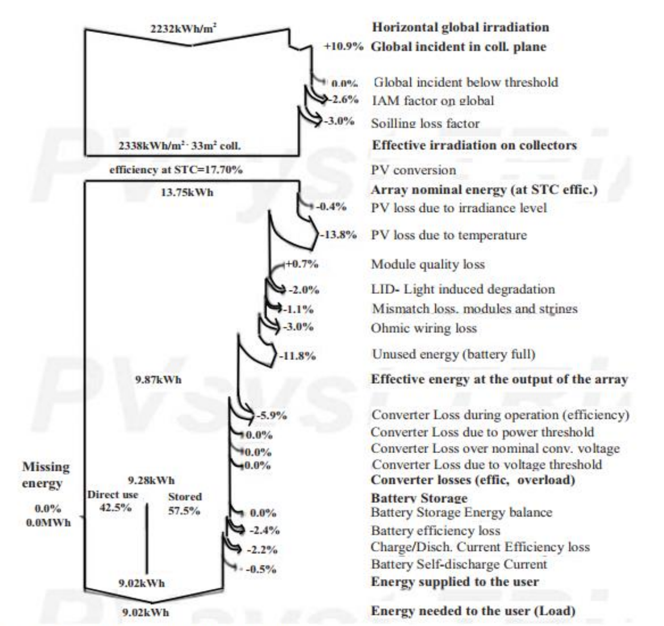

Fig. 6. Loss diagram of 450W PV panel

VI. CONCLUSION

This paper describes the design and implementation of a standalone off-grid solar energy system for a small tourist hotel in the Al-Hamada Al-Hamra region of Libya, which is situated in a desert. Energy use per day Based on the watt-hour demand estimations, the PVSyst was used to simulate and compute every component of this system, including the solar panels, batteries, and other parts. The method generates 220 volts of alternating power using 12 volts DC from batteries. The 450-watt panels were manufactured by LG Electronics. In the case of STC, PVSyst reported a PV conversion efficiency of 17.7%. Five 48V D parallel batteries and a 2.35 KW MPPT universal inverter are required for the setup.

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