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Designing and Optimal Sizing for Off-Grid PV System in Al- Muwailiha village/Iraq by using PVsyst and Homer Software: A Case Study

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ABSTRACT

The future energy demand's dependence on solar power plants is determined by the payback period and specific electrical grid parity pricing. This emphasizes the significance of using the most effective and suitable techniques for determining the appropriate size of these systems. Furthermore, designers are increasingly prioritizing the development of straightforward and dependable sizing models for freestanding photovoltaic (PV) systems. Various methods, from basic guidelines to advanced software programs, are available for analyzing and sizing stand-alone solar systems. This study for sizing solar system which contains 5 houses for modest residences in the village of Al-Muwailiha located rural area of Babil Governorate in Iraq situated at the coordinates 32°51'37.7" North and 44°24'40.6" East. To accomplish this goal, the system is designed by utilizing two well-known software programs (HOMER Pro, PVSYST 7.2). The yearly results showed that Pvsyst whose annual energy production is 38,903 kWhr and its energy consumption is 32,425 kWh, while HOMER's production is 41,187 kWh and its energy consumption is 28,910 kWh. It clearly obvious that PVsyst has a higher utilization factor than HOMER due to the missing energy in the PVsyst program is 324.3 kWh/yr and the unmet loads in the HOMER program are 3,840 kWh/yr. The primary emphasis of this work was on the PVsyst program for designing the necessary off grid PV energy system. This study provides a useful guide for sizing and developing standalone PV systems in different locations, using the same technique outlined in the paper.

1. Introduction

The increasing prevalence of Photovoltaic (PV) systems for power generation is due to the decreasing accessibility of traditional energy sources, namely fossil fuels. The transition has required a fundamental change in thinking toward dependable and environmentally friendly alternatives, like PV systems that utilize the limitless energy of sunshine to produce electricity [1]. On a global scale, there is a significant and fast rise in the need for energy, particularly in the realm of clean energy [2]. It has been reported by International (RE) Agency, achieving a full decarbonization of energy usage during the next 50 years requires the present pace of growth in (RE) systems to be at least seven

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times quicker [3]. In the Paris agreement, a significant diplomatic undertaking, has mandated the reduction of global carbon emissions (UNFCC, 2015) [4]. Solar energy is a method of producing power that does not require the use of fuel, has minimal expenses associated with its maintenance, does not cause any pollution, and does not make any noise [5]. PV power systems may be categorized into three primary types: Grid-connected systems, also known as on-grid or grid-tied systems, Stand-alone systems (or off-grid systems), and hybrid systems [6]. In the field of solar energy application, one of the most important areas of study is the measurement and optimization of the size of a photovoltaic system. A stand-alone photovoltaic (PV) system's performance is contingent upon the amount of solar radiation, the size of the PV array, and the amount of storage capacity [7]. Determining the ideal number of solar cells and the appropriate size of a storage battery for an application at a specific site is a significant economic challenge [8].

PV power is a promising (RE) source for the future Technology that transforms solar radiation into usable power is the backbone of this energy source. Surprisingly, the PV market has experienced rapid expansion. The cost of this energy is high compared to other sustainable options [9]. Despite the numerous benefits of the solar supply chain, it faces two significant difficulties. Efficiency management in the solar supply chain, particularly in PV systems, is a notable problem that requires focused attention. Moreover, the exorbitant expenses associated with utilizing PV systems pose a significant barrier to their extensive advancement [10]. The performance of a PV system mostly depends on the environmental conditions of a specific location. Not every country worldwide experiences hot weather. Installing solar panels in these areas may not be feasible. The cyclical changes in seasons are a crucial feature that must be taken into account. Several factors affect the total efficiency of a PV system, including the material of the PV cell, installation technique, orientation of the system, arrangement of the PV cells, and local meteorological conditions [11,12]. Researching cost-effective PV systems that meet national and international power quality criteria is a crucial field of study. Most prior research on cost-effective PV system design did not initially incorporate power quality needs as part of the design criteria. Most research has concentrated on determining the ideal size of PV system components using artificial intelligence methods[13-16] as well as on the management of energy [17-19] and [20].

The power quality problems that are associated with PV systems are explored independently and resolved using a variety of design approaches, including inverter topologies [21]. Various software tools have been created and used as well. HOMER and HOGA are occasionally used in the design of HRESs [22]. Technology has enabled the development of several simulation tools like PV Planner, HOMER Pro, PVsyst, and others. This software has shown exceptional talents and fast performance [23].

The ambition to reduce conventional power system disruptions and dependency on fossil fuels by utilizing locally available (RE) sources is the impetus behind the construction of micro-grids. Therefore, it is very necessary to conduct out unit sizing when designing designs for micro-grids based on this principle. The appropriate mix of dispersed units would be beneficial to the optimum configuration of the system in terms of the overall size of the system and the cost of the system. Taking into consideration the kind of micro-grid units as well as the quantity of units would have a significant influence on the overall device size. This study presents the design of a off grid PV system for the community which contains 5 houses for modest residences in the village of Al-Muwailiha village located in rural parts of Iraq. The systems have a power output of 10 KW and were produced using PVsyst, HOMER, an original tool created by the authors. Computer simulation and evaluation of solar systems have been increasingly prevalent in recent times due to their high level of accuracy and reliability. Consequently, there is a plethora of software that now exists and is continuously being developed. The following parts provide an explanation of the modeling and size of the proposed

system, the tools used for designing, the results obtained, and a comparison and analysis of the output from both softwares. The study ultimately finds that PVsyst is the most suitable software for designing the suggested system.

1.1 Off-Grid Systems PV System

In order to provide consumers regardless of their location, off-grid technologies generate power independently of the electric grid. A variety of uses can be satisfied by this type of arrangement. From telemetry devices to feeding repeaters for telecom installations, it has a wide range of technological applications and it also allows us to feed systems in human space, like the International Space Station or telecommunications satellites. Traffic lights, which have their own battery and solar panel, are another example of an application. Providing power to remote and rural locations is a crucial use case. Typically, they employ a battery-based storage mechanism. In places without access to the commercial electrical grid, particularly in poor nations, this can serve as a source of electricity. Public illumination in places where connecting to the traditional electrical grid is difficult sometimes makes use of off-grid installations. Pumping stations on farms and ranches are another application for these types of systems [24]. The component of Stand-Alone solar PV system is well illustrated in Figure 1 below:

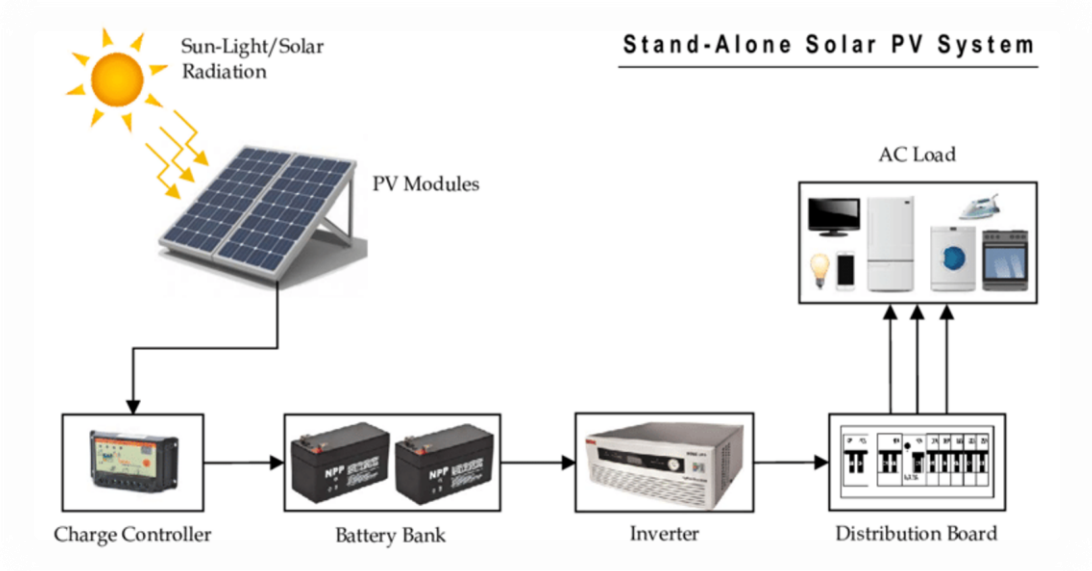


Fig. 1. The different parts of a stand-alone photovoltaic (PV) system

2. Methodology and Material

A stand-alone system was analyzed in this study. The storage system is intended to provide electrical power for the for the community which contains 5 houses for residences in the village of Al-Muwailiha village located in the Babylon Governorate / Iraq. A 10kW load is modeled using PVsyst 7.2 and HOMER

a. Freehand Sizing

A. Daily energy consumption
By utilizing the below equation

Energy consumed by the device per day=1.3×(Number×power of device×Operating hour) (1)

B. The number of PV panels

To calculate the power of the PV panels, divide the desired power output by the average daily solar radiation rate for the specific location, which usually falls between 4 and 6.3. This ratio is among the highest globally [25].
Following is the formula for determining the total number of PV panels:

$$Number\ of\ panels = \frac{Energy\ \ to\ \ produce}{power\ of\ the\ panel\ we\ want\ to\ purchase} \quad (2)$$

C. Number of batteries

The battery capacity is determined by the following formula [26] :
Battery Capacity (Ah)=

$$\frac{Energy\ to\ generate \times Number\ of cloudy\ days}{voltage} \times \mathbf{1.3} \quad (3)$$

$Number\ of cloudy\ days(when\ panel\ charging\ is\ interrupted)$
1.3 = required to retain 30% of battery capacity of maintenance
After using the following relationship, we are able to get the total number of batteries:

$$Number\ of\ batteries = \frac{\boldsymbol{Battery\ \ capacity}}{\boldsymbol{capacity\ of\ the\ battery\ we\ want\ to\ purchase}} \quad (4)$$

D. Solar regulator size

The formula is as follows:
Solar regulator size = $\boldsymbol{Number\ of\ panels\ planned\ in\ the\ system} \times \boldsymbol{I_{SC}}$ ($\boldsymbol{the\ highest\ short-circuit\ current\ of\ the\ panel}$) (5)

E. Inverter size

The overall power consumption of the devices during peak hours would determine the size of the required inverter.

$$\boldsymbol{Inverter\ size} = \mathbf{1.3} \times \boldsymbol{Total\ power} \quad (6)$$

b. Description of the PVSYST

PVSYST is believed to be among the most effective uses when it comes to the design and estimation of the efficiency of photovoltaic power plants. When utilized with a significant number of its features and settings, this software generates results that are nearly comparable to the theoretical results one would expect. Not only is this software able to import data from numerous Mateos, but it also has the capability to import personal information. In addition, this software gives us the ability to examine the primary performance of the PV Planet in three different scenarios: stand-alone, connected to the grid, and pumping [27]. Additionally, it is not difficult to determine the amount of energy that is generated.

The size of a (PV) system and its location contribute to the outcome of the simulation. The simulation may incorporate a number of different elements and the numbers may be displayed on a daily, every month, or hourly basis simultaneously. By using the Loss Diagram [28], it is possible to anticipate the vulnerabilities in the system architecture.

c. Specify the geographical location

Select the specific geographical location for analyzing the installation of the PV system. The software offers the choice between selecting existing sites or creating new ones. PVsyst has the capability to recognize and assess any geographical location on the planet. As shown in figure 2 the main and important settings that need to be considered while using the PVsyst (PVsyst. page layout).

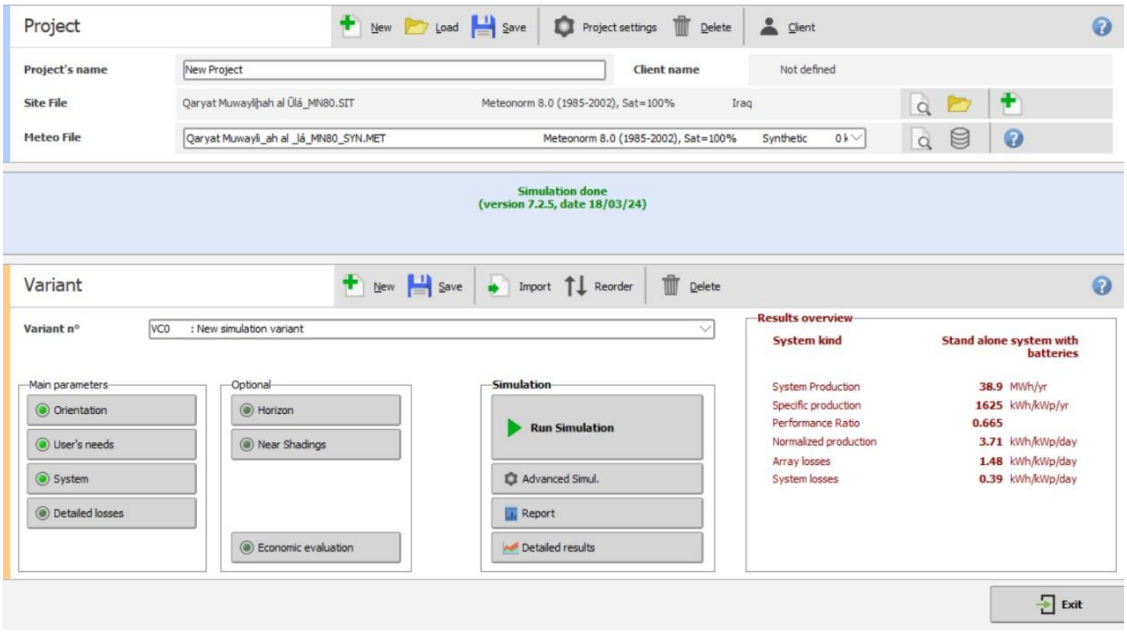


Fig. 2. Project page layout and important settings

d. Setting the tilt and azimuth angles

The angle of tilt is the system's inclination angle. This is contingent on the geographical location. The tilt angle should be adjusted to maximize the system's output. The azimuth angle is the angle that lies between the south/north direction and the collector plane.

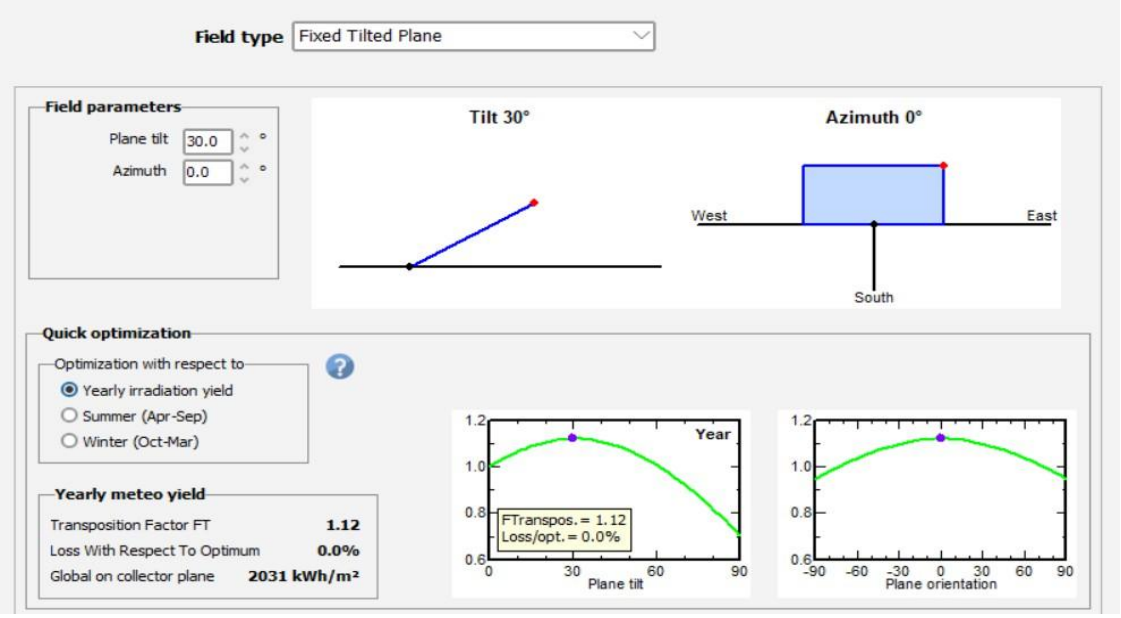


Fig. 3. Tilt and azimuth angle selection in Pvsyst7.2

e. Electrical Load Profile

The figure 4 displays the minimal daily load consumption needs for the electrical supply of data for five houses in the rural Al-Muwaileha area, south of Baghdad 89.724 Kwh/day.

Detailed User's needs

Daily household consumers, Constant over the year, average = 90 kWh/day

Annual values

	Number	Power	Use	Energy
		W	Hour/day	Wh/day
Lamps (LED or fluo)	10	15W/lamp	10.0	1500
TV / PC / Mobile	10	100W/app	12.5	12500
measuring devices	5	1000W/app	5.0	25000
Fridge / Deep-freeze	5		24	6000
Dish- and Cloth-washer	5		5	22500
Other uses	3	1800W tot	3.0	16200
Other uses	5	60W tot	20.0	6000
Stand-by consumers			24.0	24
Total daily energy				89724Wh/day

Hourly distribution

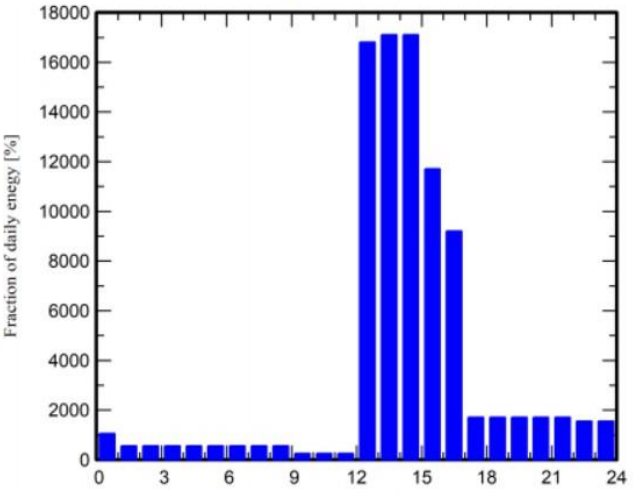


Fig. 4. User daily consumer

f. Choosing the right (PV) module and storage batteries

Different (PV) modules and storage batteries can be chosen from the list that is provided by the program as shown in figure 5. These choices can be made according to the panel's material, panel quality, output of power, and robustness. Table 1 below indicates the parameters that used in PVSYST model where the Power of PV model selected to be 285 W, capacity of used battery was 1100Ah and capacity of controller was 123.6/100.3 V.

Table 1
Specification of PVSYST. Components

Rated power of PV Module	285 W
Open circuit voltage of PV	44.90 V
Short circuit current	8.370 A
Rated capacity of Battery	1100 Ah
Rated voltage of Battery	96 V
Minimum state of charge of Battery	123.6/100.3 V
Rated capacity of Controller	96 V
Efficiency of Controller	80%

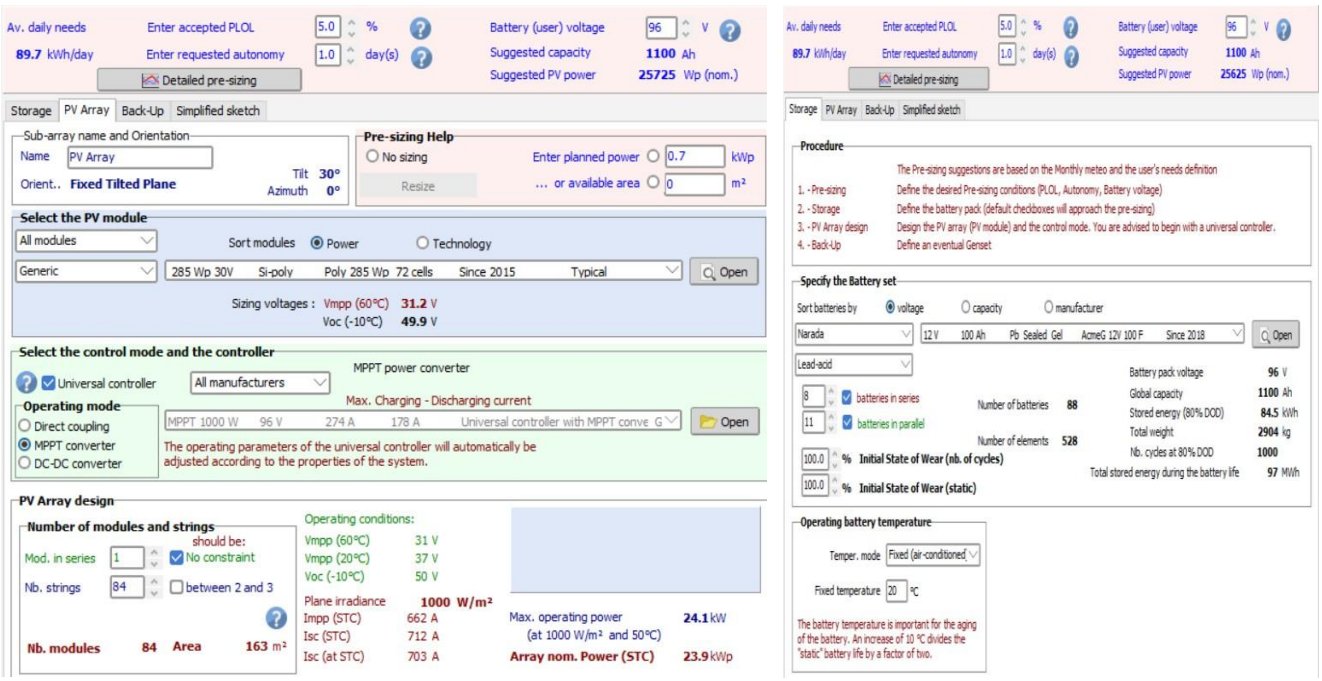


Fig. 5. Select PV modules and storage batteries

g. HOMER pro

Hybrid system designs make use of a variety of optimization and sizing software tools. This software are beneficial for designers as they offer several chances regarding geographical and economic data, as well as economic and technological analysis [29-31]. The HOMER Pro operates through many steps in its functioning concept. To simulate the design, start by choosing the installation region in the application and enter data regarding energy resources into the system. HOMER Pro retrieves data on (RE) sources from NASA's POWER database in the specific location where the system will be constructed [32]. Next, choose the components to be utilized in the system. HOMER Pro features a variety of models for wind turbines, PV panels, converters, and batteries. The application does not include predefined hydraulic and biogas models and data, but users may manually input and develop these models. The discount rate, inflation rate, and simulation periods are established. This section is crucial for achieving economic outcomes. The parameters have a direct bearing on the computation of payback time. Finally, the preferred dispatch technique should be used.

The cycle charging technique is intended for systems with modest penetration. This technique involves generators operating at full capacity whenever needed, with excess electricity being stored in batteries. High penetration systems utilize a load-following method. Generators provide electricity specifically to match the demand of the load. Next, choose the economic inputs, limitations, and sensitivity parameters before running the experiment. The program identifies the most economically feasible system as the winning solution based on the simulations. The findings section is replete with several graphs and tables. Each system element has distinct graphs representing economic and power values [33].

3. Simulation using HOMER

The case study focuses on a secluded location energy system for the community which contains 5 houses for residences in the village of Al-Muwailiha village located in the Babylon Governorate / Iraq with coordinates 32°51'37.7"N 44°24'40.6" E as shown in figure 6 below:



Fig. 6. Location village of Al-Muwailiha

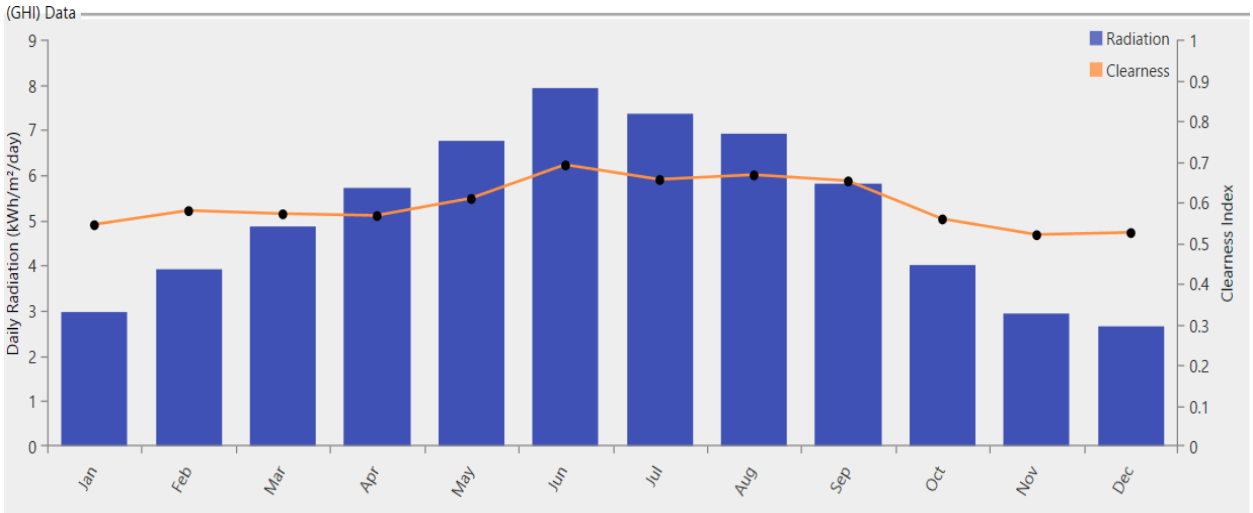


Fig. 7. Al-Muwailiha village solar radiation, clearness index per month

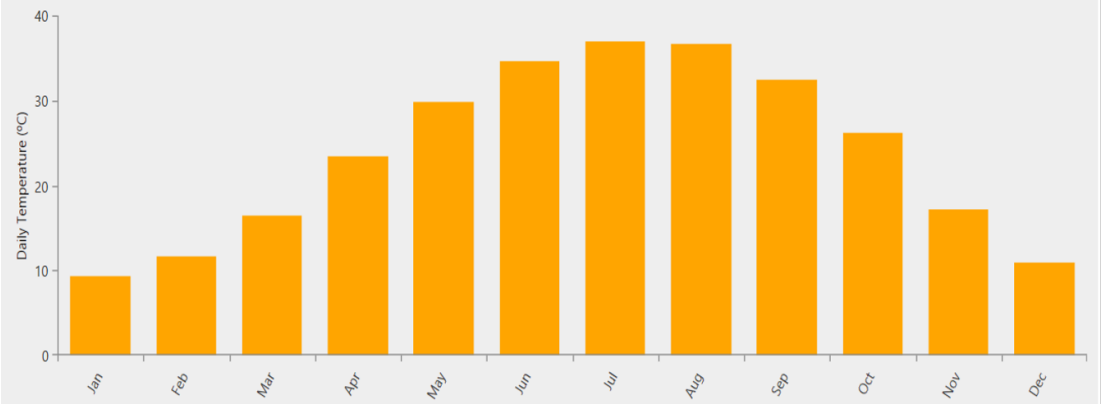


Fig. 8. Monthly average air temperature at Al-Muwailiha

Figure 7 shows the average solar irradiation , clearness index while Figure 8 shows the average air temperature per month in the Al-Muwailiha village acquired via HOMER from NASA's Surface Meteorology and Solar Energy Database.

h. Estimation of Electric Load

Standard component ratings and average human power consumption form the basis of the hourly load profile with consumption power of 89.724 Kwh/day, as seen in Figure 4. Lights, fans, refrigerators, televisions, and other common home equipment make up the bulk of an average day's electrical consumption. Throughout the year, the load requirement remains constant. HOMER load profile is shown in figure 9 below:

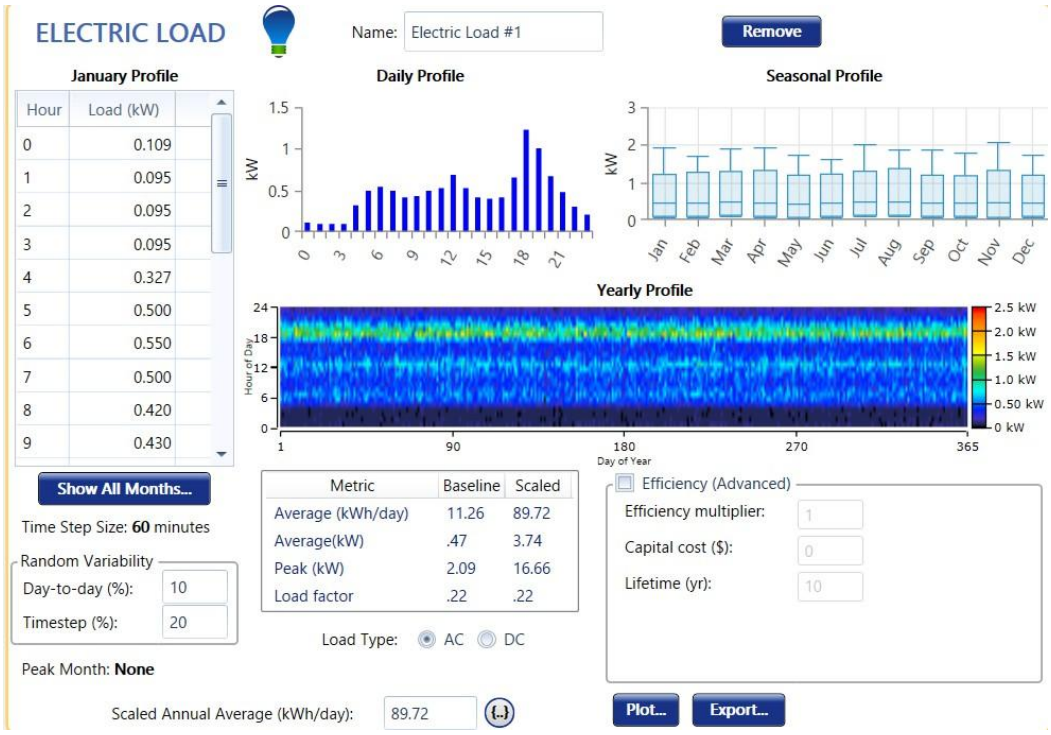


Fig. 9. Load profile of the location under consideration

There was a random fluctuation in the load of 10% from day to day and a 20%-time step, resulting in average energy consumption 89.72 kWh and a peak load of 16.66 kW.

i. System configuration

The PV system was created independently using HOMER software. The system comprises a PV system, a Battery storage system connected to the 24V DC bus, and a converter DC/AC to power the load from the DC bus. As shown in Figure 10 the solar PV capacity is 2.5kw and the battery storage capacity12v-83.4Ah for system configuration utilized in this study. Table 2 shows the main parameters used in this study model which described below:

Table 2
Sizing analysis of solar PV energy system in HOMER

Description of Parameters	Rating	Total Units	Total
Solar PV capacity	2.5kw	10	25kw
Battery storage capacity	12V- 83.4 Ah	120	120kwh

The project's entire duration was established at 25 years. This study used a (PV) module with a 25-year operating lifetime in this simulation, a standard 1 kilowatt-hour lead acid battery was utilized. The battery had an average voltage of 12 volts, a maximum capacity of 83.4 ampere-hours, an efficiency of about 80%, a maximum charging current of 16.7 amperes, and a lifespan of 10 years. Battery throughput is the difference in the energy level of the battery bank after considering charging losses and before discharging losses. To calculate the anticipated battery lifespan in years, divide the battery lifetime throughput (kWh) by the battery throughput per year (kWh/yr). Both the AC/DC converter and the PV-dedicated converter have a lifespan of 15 years.

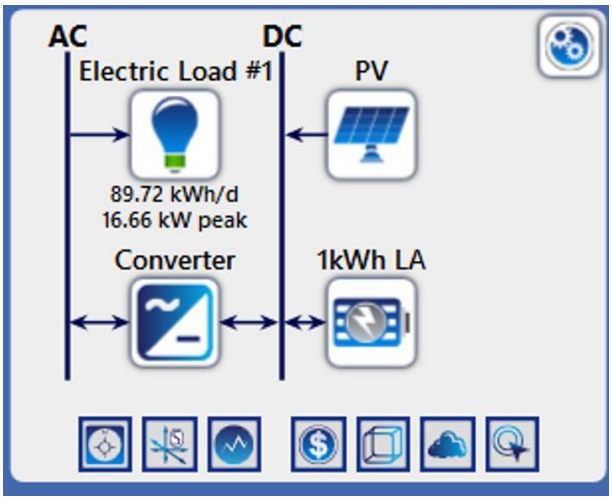


Fig. 10. The stand-alone PV system configuration

3. Result

a. Result Using Pvsyst

After choosing the site, setting the tilt and azimuth angles and sizing the PV system by Pvsyst software for system power of 23.94 kWp, with consumption power of 89.724 Kwh/day. the

simulation results as shown in Table 1. The loss diagram shown in figure 11, the monthly daily normalizing energy shown in figure 12.

Table 1
Pvsyst output result

Parameter	Value
Wiring loss	1.5% at STC
Module quality loss	0.8%
Module mismatch loss	2%
PV module size	23.9 kwp
Available energy	38,903 kwh/year
Used energy	32,425 kwh/year
Excess energy	4,558 kwh/year
Missing energy	324.3 kwh/year

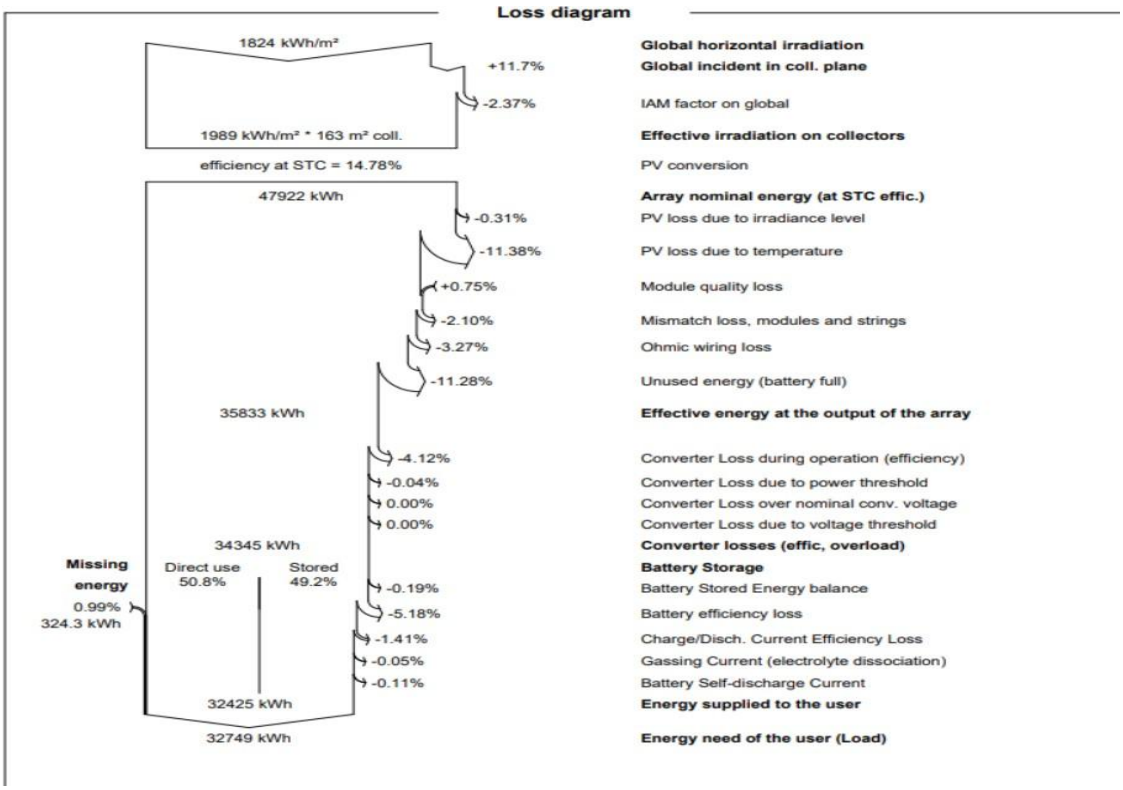


Fig. 11. Losses diagram

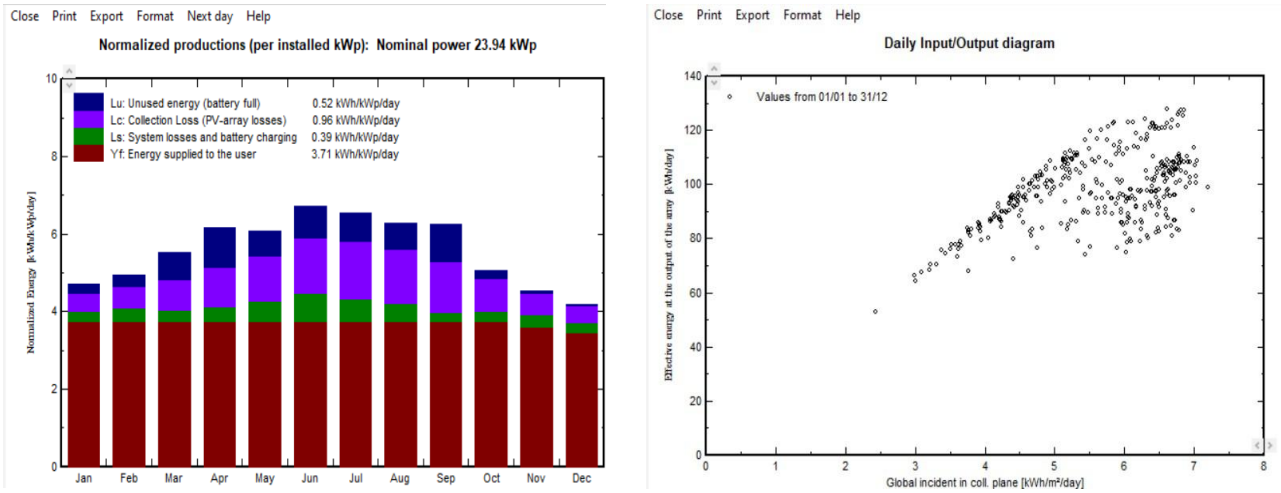


Fig. 12. Normalized energy per month and daily input/output diagram

Pvsyst, being a specialized program, demonstrates the capability to effectively simulate and develop this independent project. PVsyst determines the optimal configuration of a (PV) module and battery by considering factors such as the PV module's voltage-watt rating total load, and battery autonomy. To enhance the project's cost-effectiveness and efficiency, it automatically adjusts the battery voltage. Additionally, it offers a warning if the user selects an excessively large battery, PV module, or inverter.

b. Result using HOMER pro

National Renewable Power Laboratory has created HOMER software for optimizing, doing sensitivity analysis, and simulating hybrid renewable systems. It can also offer an economic analysis and assess the feasibility of the system. This software's standout feature is its ability to identify all the optimal combinations of a hybrid system comprising a wind turbine, PV panels, hydropower, and distributed generator. It may also display the performance of each component over the year and provide precise monthly data on the sun's global horizontal irradiation, azimuth angle, and other factors for a particular area. After entering the coordinates of data for five houses in the rural Al-Muwailiha. Figure 10 shows a diagram of a 10kW stand-alone system. HOMER provides suggested parameter with the following data about this stand-alone system, which may be found in Table 4 shown in addition to these charts.

Table 2
HOMER Pro suggested parameter

Parameter	Value
PV mean output	113 kwh/yr.
Capacity factor of PV	18.8%
Total production of PV	41,187kwh/yr.
Nominal capacity of battery	120 kwh
Usable capacity of battery	72.1kwh
Battery autonomy	19.3 hr.
Lifetime throughput of battery	96,000 kwh
Inverter mean output	3.30kw
Capacity factor of inverter	13.2%
Excess Electricity	7,037 kwh/yr.
Unmet Electric Load	3,840 kwh/yr.

The monthly solar power output from Homer's sources as shown in Figure 13 shows, and Monthly Inverter Output shown in Figure 14.

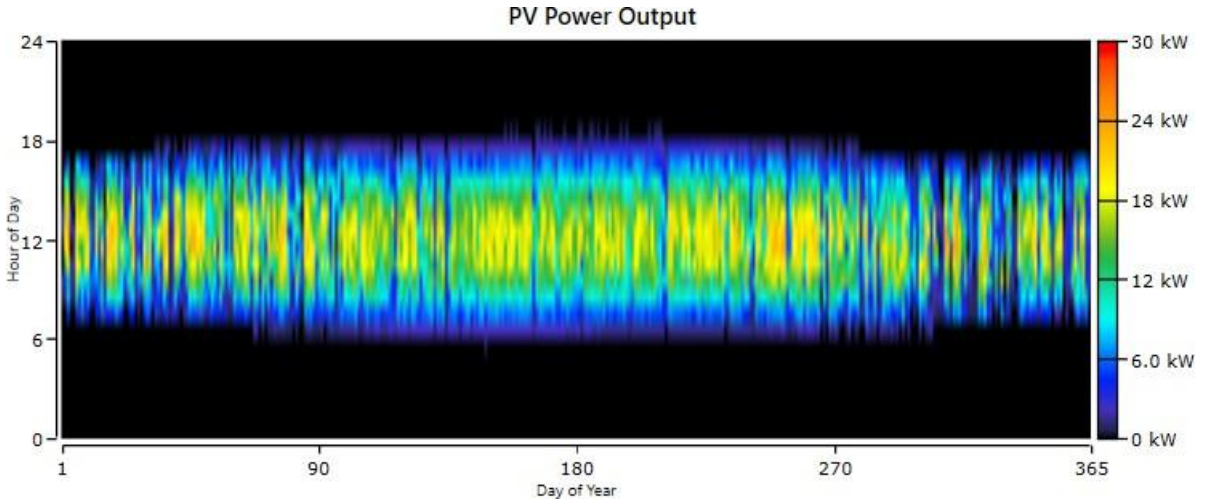


Fig. 13 PV output per month

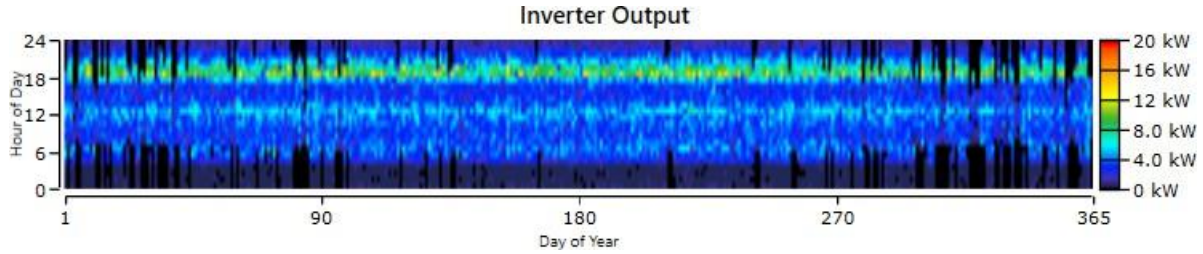


Fig. 14. Inverter output per month

Figure 13 and Figure 14 illustrate the PV output and inverters output, respectively. These numbers display the actual output of the inverters and PV module throughout the course of the year, based on hourly load.

c. Comparing analysis of results

As shown in table 5 the comparison results between the two software programs. HOMER has an annual energy output of 41,187 kWh and a corresponding energy consumption of 28,910 kWh. On the other hand, PVsyst has an annual energy production of 38,903 kWh and a corresponding energy consumption of 32,425 kWh. Therefore, the usage factor for PVsyst is higher than that in HOMER.

Table 3
Comparison of Results obtained by HOMER and PVsyst

Software	Number of PV panel	PV Unit Nom. Power	Number of Battery	Energy Production (kWh/year)	Used Energy (kWh/year)	Excess Energy (kWh/year)	Unmet load (HOMER) Missing energy(PVsyst) Kwh/yr.
By HOMER	10	2.5K.W	120	41,187	28,910	7,037	3,840
By Pvsyst	84	285 W	88	38,903	32,425	4,558	324.3

4. Conclusion

HOMER and PVSYST are commonly used tools for sizing a freestanding PV system and other green energy integration system designs in a standalone or grid-connected mode. The modeling of the PV/battery design model is performed using hourly energy demand and climatic data depending on the system life cycle cost. The study employs PVsyst and HOMER software to design and size an autonomous energy system to provide electricity to a community consisting of 5 models residences in the village of Al-Muwailiha, situated in the rural areas of Iraq at the coordinates 32°51'37.7" North and 44°24'40.6" East. An evaluation study is conducted to compare the production statistics derived from the two software applications PVSyst and HOMER. In order to accomplish this study goal, the results obtained from each simulation tool were compared. In PVsyst, the results showed that the yearly energy output was 38,903 kWh/yr, the annual energy consumption was 32,425 kWh/yr, and the missing energy in the PVsyst program was 324.3 kWh/yr. In addition, when using HOMER, the yearly energy production was obtained to be 41,187 kWh/yr. , the annual energy consumption obtained was 28,910 kWh/yr. , and the unmet load amount was 3,840 kWh/yr. It seems that the utilization factor of PVsyst is higher compared to the Homer program, as the unmet loads in the Homer program are significantly more than in the PVsyst program. This effort primarily focused on utilizing the PVsyst tool to design an off-grid PV energy system where this software not only decreases energy costs but also considers the geographical characteristics of the desired scale. This study offers a valuable reference for determining the appropriate size and designing independent photovoltaic (PV) systems in different places, employing the identical methodology described in the research report.

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