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Modelling the use of PVSYST software for a stand-alone PV solar system "off grid" with batteries by utilizing silicon hetero-junction technology (HJT) panels in Iraq/Basra.

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ABSTRACT

Fossil fuels have been widely used in electricity generation in recent years, resulting in excessive CO_2 emissions. Continuing this would increase the temperature of the atmosphere, causing storms, hurricanes, droughts, dust storms, and flooding. Due to the fact that renewable energy produces few or no emissions, it has become increasingly important for it to be adapted in recent years. During the past few years, the PV sector has experienced rapid growth. New technology has enabled PV cells to become more efficient, and the sector is rapidly embracing new technologies. In this regard Silicon Hetero-junction technology HJT has been able to offer additional benefits: It is able to achieve efficiency levels above 24% at temperature 20C°. HJT solar panels have over 90% module bifaciallity and a low temperature coefficient (-0.24%/°C), which benefits to the levelized cost of energy (LCOE) and output power for PV systems. The objective of this study is to assess and compare the efficiency of high-quality (HJT) solar panels and SI-MONO solar panels for a residential off-grid system with at a peak power of 3 kWh and a daily power close to 20 kWh with a 48V system in Iraq/Basra. In order to calculate energy output, and enhance the system design, PVSYST (7.2.11 version) software was used. PVSYST's database contains meteorological data, including characteristics, solar radiation, and ambient temperature.

Abbreviations:
GlobHor Global horizontal irradiation
GlobEff Effective Global, corr. for IAM and shadings
E_Avail Available Solar Energy
EUnused Unused energy (battery full)
E_Miss Missing energy
E_User Energy supplied to the user
E_Load Energy need of the user (Load)
SolFrac Solar fraction (EUsed / ELoad)

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1. Introduction

It is becoming increasingly common to develop PV (photovoltaic) systems. The importance of renewable energy in creating a safe environment makes it a vital part of the world's economy. To maintain maximum power from solar panels, the PV system must operate at maximum efficiency during good weather conditions [1].

Climate conditions have a significant impact on the efficiency of PV systems. In addition, A PV system's overall efficiency is also affected by factors such as the material and method of installation of the photovoltaic cells, the system's inclination or orientation, the placement of the PV cells in the system, the local climate, and others. In order to understand how a PV system generates power, it is vital to study and examine these elements. Even though analysis can be done manually, technology now allows us to create simulation software, such as **PVSYST**, PV Planner, Homer Pro, etc. Due to its advanced functionality and speed, **PVSYST** was chosen for this study [2].

Due to its bi-facial capability, low operating temperature coefficient, and relatively simple manufacturing process, silicon hetero-junction technology (HJT) has shown great promise in the exploration of both high conversion efficiency and mass production in recent years. [3].

As the next generation PV production technology, HJT is only one of the contenders, and committing to fully overhauling production facilities. By using HJT, we can resolve a problem associated with both standard production cellular architectures. Solar cells with silicon hetero-junctions are formed by depositing thin layers of amorphous silicon on crystalline silicon wafers. Over 20% of energy can be converted into manufacturing energy using this model [4]. Recombination is highly active in metal contacts, which causes losses. By removing the band-gap layer between the contact and absorber, we can avoid this problem. HJT strives to achieve this change. A cell architecture without patterning produces extremely high open-circuit voltages [5].

Low temperature processes are used in HJT. This simplifies the process—from about 13 steps for PERC (Passivated Emitter and Rear Cell) to 8. Degradation and thermal coefficient are low. However, HJT requires a completely different processing sequence than today's mainstream cell production [6]. Corporations (including Panasonic Corp. and Meyer Burger) have already demonstrated that the excellent performance of HJT solar cells can translate into highly effective solar modules. Cell-to-module power ratios, or CTMs, are crucial parameters for module producers to measure. This ratio divides the module's power by the power of its cells. Module type and features can significantly affect the power ratio of a CTM [7]. The HJT process development aims to reduce manufacturing costs and optimize efficiency for high yield cell manufacturing [8].

An HJT solar panel-based stand-alone photovoltaic system is presented in this paper. Meteorological data and site details are collected. In order to design a PV system, two processes must be followed. PV systems are designed using watt-hour calculations first. Lastly, **PVSYST** is used to determine the overall performance of the stand-alone PV system [9].

Compared to traditional solar panels, silicon heterojunction panels have several advantages instead of their high efficiency. Silicon heterojunction solar panels are considered lighter and more flexible than traditional solar panels. It makes them more versatile and easier to install in various locations. Compared to other traditional solar panels, silicon heterojunction panels are also cheaper to produce. For those in Basra, Iraq who are seeking to install solar panels, they are a more affordable option [10].

A silicon heterojunction solar panel has a longer lifespan and requires less maintenance than a traditional one. This means they can provide a reliable and sustainable source of electricity for a longer time, reducing the need for frequent repairs and replacements. Furthermore, silicon heterojunction solar panels are cleaner to manufacture than traditional solar panels because they do not require rare earth elements as doping materials and can be fabricated using a low-temperature process that is environmentally friendly and more sustainable [11].

The primary purpose of using HJT solar panels in Barsa is to maximize energy efficiency and promote sustainability in the region. A major objective is to reduce reliance on traditional energy sources, such as fossil fuels, and transition to cleaner and renewable sources. Achieving this objective aligns with the global shift towards sustainable development and addresses concerns about climate change andgreenhouse gas emissions. HJT solar panels will reduce carbon footprint, reduce energy costs, promote energy independence, and contribute to a greener community in Barsa.

2. PVSYST Description

In terms of designing and estimating the performance of solar PV power plants, **PVSYST** is considered one of the most powerful applications. This software produces results that are almost identical to theoretical results when used with many of its features and options. In addition to importing data from multiple Mateos, this software is able to import personal information as well. Furthermore, this software allows us to evaluate the PV Planet's primary performance in three scenarios: stand-alone, grid-connected, and pumping [12]. It is also easy to calculate how much energy is produced. A PV system's sizing and location affect the result of the simulation. It may include multiple simulation factors, and the values may be displayed daily, monthly, or hourly. The System design weaknesses can be predicted by the Loss Diagram [13].

3. Design and Methodology

As shown in Figure 1, the stand-alone PV system consists of PV panels, batteries, a charge controller, and an inverter.

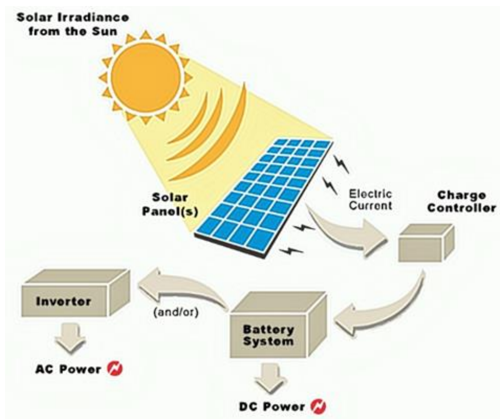


Figure 1: The parts sketch of a stand-alone system

Sunlight is collected by tilted PV panels and converted into electricity. Charge controllers regulate the flow of electricity. Electricity excesses can be stored. Battery backups can be used anytime during the day or night when the sun is hidden by clouds. An inverter converts DC electricity generated by solar panels into AC electricity for use by AC loads, the layout design is shown in PVSYST software [14]. See Figure 2.

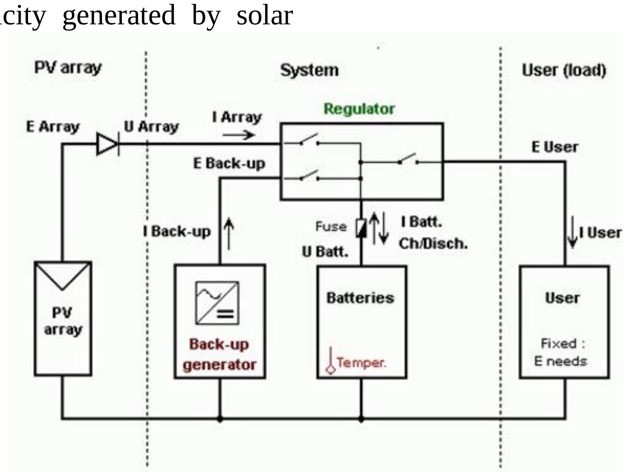


Figure 2: The System layout by a PVSYST

There are several factors to consider when choosing solar panel systems, such as the type of PV modules, the geographical coordinates, the quality of the inverter, the inclination of the PV panels, and the battery type [1].

4. PVSYST's platform

Consists of the following:

4.1 *Site coordination*

This study was carried out in the city of Basra at a coordinate of 30.52° N, 47.18° E, and 8 meters above sea level as shown in Figure (3).

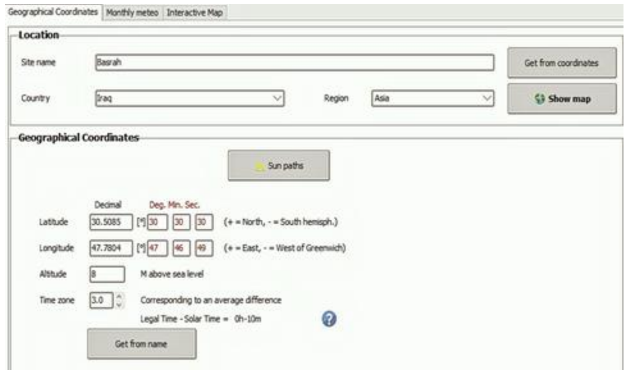


Figure 3: The site coordination with PVSYST

According to PVSYST stored data, Basra City experiences an average annual **Global Horizontal Irradiation (GHI)** and **Diffuse Horizontal Irradiation(DHI)** of around 1841kWh/m^2/month and 916.4 kWh/m^2/month respectively see **Table(1)** [2],[12].

Table (1) PVSYSTS global horizontal irradiation data average.

Interval beginning	**GHI kWH/m^2/mth**	**DHI kWH/m^2/mth**
January	100.7	45.5
February	113.1	56.2
march	144.2	77.4
April	176.1	93.1
May	195.6	108.0
June	215.4	100
July	210.7	100.2
August	190.6	98.7
September	170.5	72
October	133.2	68.8
November	100.7	50.2
December	90.1	44.5
Year	1840.9	916.4

4.2 *Tilt and azimuth angle installation*

In this model, the tilt angle and azimuth angle are set to 27° and 0°, respectively. Figure 4 illustrates the optimization with regard to yield irradiation based on yearly yield irradiation. The tilt angle is the angle at which the system is inclined. Further, azimuth angle refers to the angle between the collector plane and south/north.

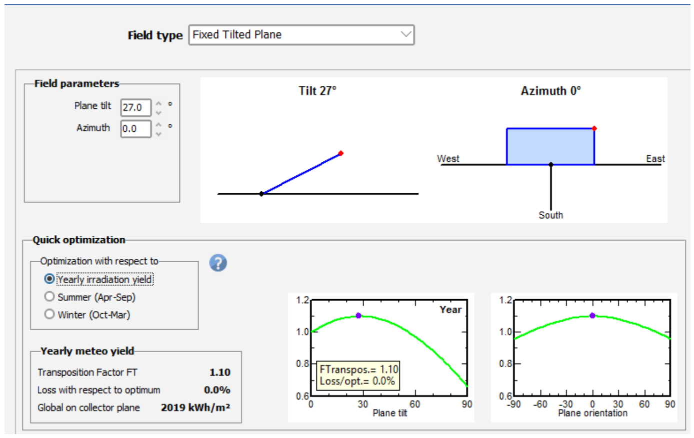


Figure 4: the installation of tilt and azimuth angles

The sun path is shown in Figure 5 and the system simulates without shading due to the real location at which the system is installed.

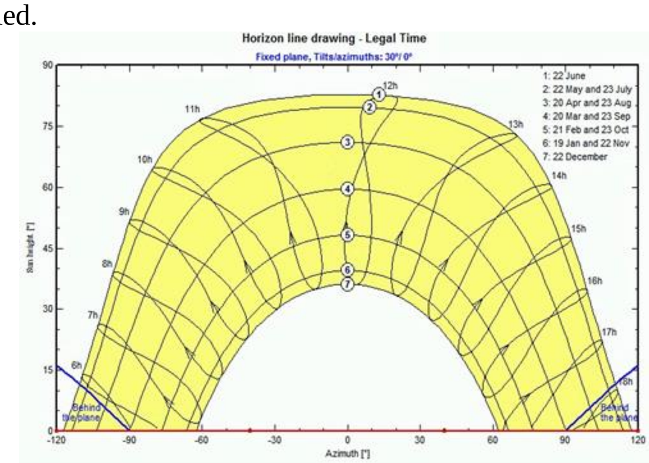


Figure 5: the sun horizon path

4.3 *Load Data*

As can be seen in Table 2, the daily energy consumption can reach 18 kWh, whereas the peak power is close to 3 kWh with the load data of this study.

Table 2: illustrates the load data consumption

APPLIANCE	NUMBER	POWER	DAILY USE
Lamps	3	18 w/lamp	5 h/day
tv/pc/mobile	1	100 w/app	9 h/day
Fridge	1	0.3 kwh/day	10 h/day
cloth washer	1	500 w	1 h/day
air-condition	2	1000 w/app	8 h/day
stand by consumers	1	1 w	24 h/day

4.4 *Battery selection*

The specifications of the selected battery are listed in Table 3.

Table 3: Specifications of the Battery

Model	BAE SECURA BLOCK SOLAR 12 V 1 PVV 70
Manufacture	BAE Secura
total no of battery	20
Voltage	12 V
battery in series	4
battery in parallel	5
total weight	860 kg
Capacity	300 ah
battery pack voltage	12 V
temperature mode	fixed 20 c°
stored energy (80% dod)	13kwh
total stored energy during the battery life	16396 kwh
number of cycles at 80% dod	1300
Lifetime	10 years

4.5 *Choosing an appropriate PV module*

A new generation of high-efficiency photovoltaic cells will be based on heterojunction solar cells. The design of the structure as well as the development of theory have enabled HJT solar cells to achieve a conversion efficiency of 24%. As a result, Si hetero-junction technology shows high potential and can reduce fabrication time and costs [15]. In order to achieve excellent passivation of c-Si surfaces, an HJT solar cell must be bi-facial, have a low operating temperature coefficient, and be relatively simple to produce. Amorphous silicon layers (i-a-Si:H) reduce interfacial defect density by hydrogenating silicon dangling bonds and reducing interfacial defects[3].

There are a number of different PV modules listed in the software, based on the PV modules "panel material, panel quality, power output, and robustness". The details of the PV modules used in this study are shown in Table.4.

Table 4: PV details and specifications

pv model	SKA611HDGDC-700
manufacturer/year	AKCOME/2022
module power	700 wp
number of strings	6
number of modules in series	1
sizing voltage	vmpp 38.7 v
Voc	54.3v
temperature coefficient	-0.24 % C°
Lifetime	20 years

Figures 6, 7, and 8 show several relationships between incidence irradiation and cell temperature. As can be seen, increasing incidence irradiation and cell temperature are related by increasing voltage [2].

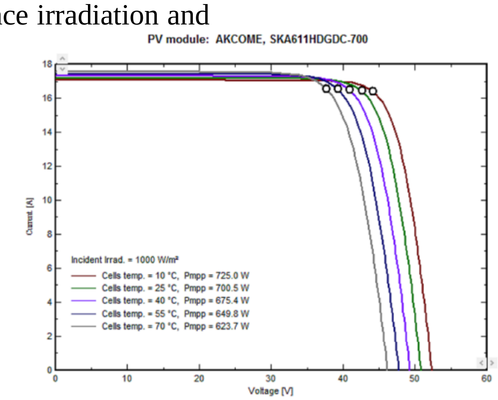


Figure 6: Current and voltage with increasing temperature

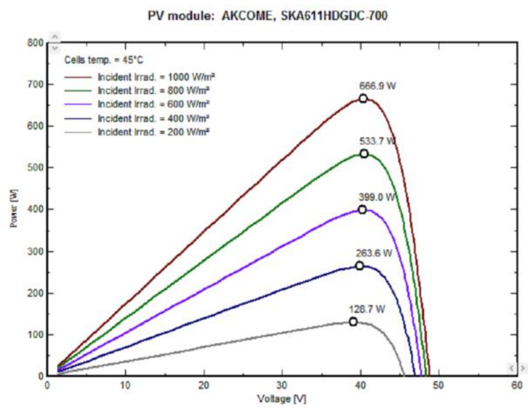


Figure 7: power with incident irradiation of the module.

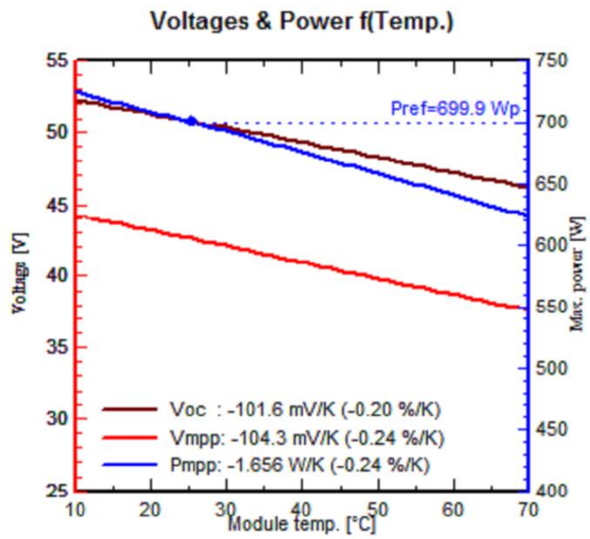


Figure 8 Voltage and power with increasing temperature

4.6 *Choose the inverter*

As part of the simulation, a stand-alone PV system with a maximum charging and discharging current of 83 A to 46 A was designed using an MPPT converter of 3.1W and 48V.

An inverter must be large enough to handle peak loads for a stand-alone PV system [16], [17]. In order to ensure safety, the motor size should be 20–30% greater than the sum of all running loads [18].

The inverter's size can be determined using the calculation below:

The inverter Size = Power demand × Correction factor for safety ……..(1)

For motor loads, the correction factor for safety is **3**, while for simple loads, it is **1.2** [4].

The recommended inverter size, when replaced in Eq. (1), is approximately 3 kW. The inverter's output voltage is 220 volts, while DC input voltage is 48 volts. Below the specification of the selected inverter is shown in Table 5.

Table (5) the specifications and electrical data for the inverter

Type	universal controller with mppt controller
input dc voltage	30-60 V
input dc current	83 A – 46 A
output ac voltage	48 v
nominal output power	2.9 kw
maximum output power	3.1 kw
no of inverters	1
Efficiency	97%

According to equation (2), the inverter's efficiency ($\eta_{inverter}$) is determined by the ratio of the AC power P_{AC} output to the P_{DC} input:

$$\eta_{inverter} = \frac{P_{AC}}{P_{DC}} \quad (2)$$

Figure 9, 10 have been illustrated curves of the Ac Input and DC Output efficiencies of an Inverter.

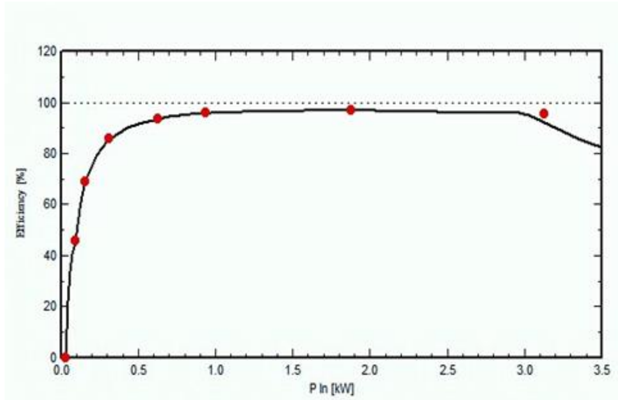


Figure 9: The Inverter AC input efficiency curve

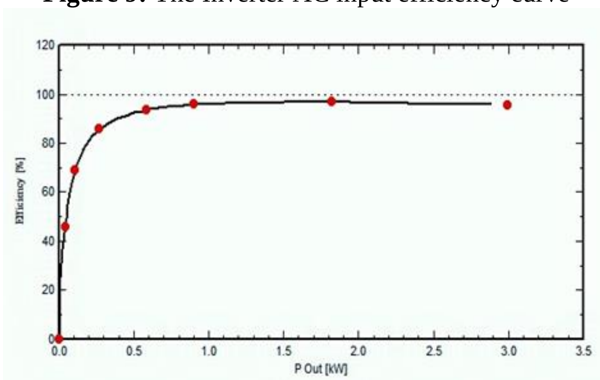


Figure 10: The Inverter DC output efficiency curve

5. Results

A PVSYST software package is used for the proposed site. All figures are generated by simulation processes. This paper discusses the results of simulations based on computational modeling and a comparison between 700 wp HJT solar panel and 675 wp si mono, model CWT675 - 132PM12 – V and CW Enerji manufacturer, both types with same numbers and working with same size of inverter and batteries . [3]

The output graphs from the simulation output: Performance Ratio and Solar Fraction for both types of solar panels are shown in Figure 11, According to the system summary, PV modules, inverters, installations, and loads have been calculated to determine their efficiency.

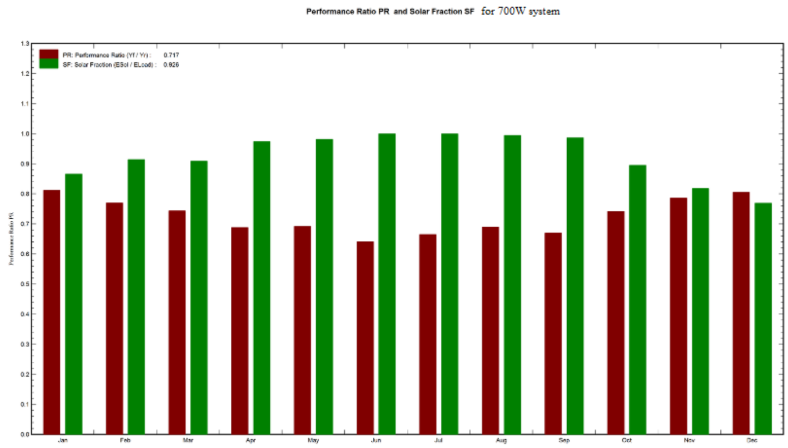
4

The Performance Ratio (PR) can be calculated by dividing the final PV system yield (Yf) by the reference yield (Yr).

$$PR = \frac{Yf}{\mathrm{Yr}} \quad ....(3)$$

Solar fraction (SF) describes the relationship between the amount of energy supplied to the load and the amount of energy required by the load, as follows:

$$\boldsymbol{SF} = \frac{\textbf{energy supplied to the load}}{\textbf{energy need by the load}} \quad ....(4)$$



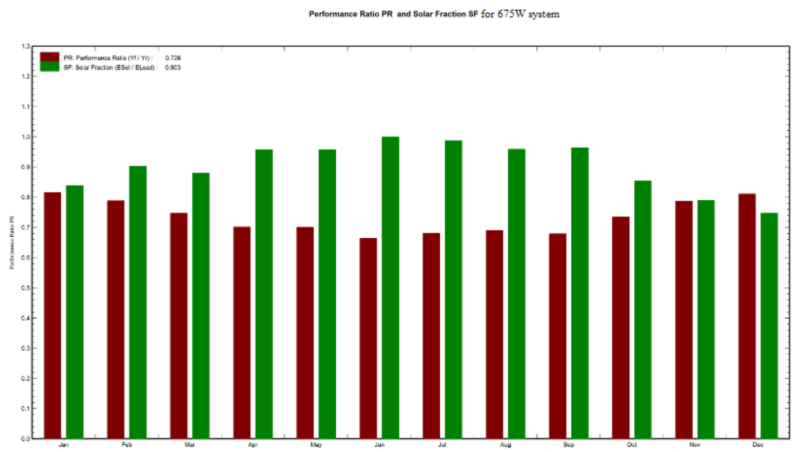


Figure 11: Performance Ratio and Solar Fraction for both types of solar panels.

The study indicates that the system using 700 wp with HJT is more efficient than the 675 wp system due to the main balance and results table that is generated from PVSYST software see Table 6 and Table 7 which are showed all the main results below.

Table 6: All main results of the simulated system for 700wp HJT system

	GlobHor kWh/m²	**GlobEff** kWh/m²	**E_Avail** kWh	**EUnused** kWh	**E_Miss** kWh	**E_User** kWh	**E_Load** kWh	**SolFrac** ratio
January	100.7	135.2	525.1	0.00	74.7	483.2	557.8	0.866
February	113.1	136.0	523.5	6.65	43.1	460.8	503.8	0.915
March	144.2	154.8	582.6	17.19	50.6	507.2	557.8	0.909
April	176.1	173.0	641.6	20.30	13.8	526.0	539.8	0.974
May	195.6	178.6	648.0	15.51	10.5	547.3	557.8	0.981
June	215.4	190.3	682.4	29.53	0.0	539.8	539.8	1.000
July	210.7	189.5	675.8	19.90	0.0	557.8	557.8	1.000
August	190.6	182.0	650.0	10.01	3.1	554.7	557.8	0.994
September	170.5	180.2	653.0	35.30	7.3	532.6	539.8	0.987
October	133.2	152.7	564.2	4.80	58.6	499.2	557.8	0.895
November	100.7	127.7	486.0	3.74	98.1	441.8	539.8	0.818
December	90.1	121.1	469.5	2.90	128.5	429.3	557.8	0.770
Year	1840.9	1921.1	7101.7	165.84	488.1	6079.7	6567.8	0.926

Table 7: All main results of the simulated system for 675 wp SI MONO system

	GlobHor kWh/m²	**GlobEff** kWh/m²	**E_Avail** kWh	**EUnused** kWh	**E_Miss** kWh	**E_User** kWh	**E_Load** kWh	**SolFrac** ratio
January	100.7	135.2	506.3	0.00	90.0	467.8	557.8	0.839
February	113.1	136.0	502.3	0.64	49.2	454.6	503.8	0.902
March	144.2	154.8	554.6	16.96	66.7	491.1	557.8	0.880
April	176.1	173.0	605.4	6.27	22.8	517.0	539.8	0.958
May	195.6	178.6	606.1	2.23	23.4	534.4	557.8	0.958
June	215.4	190.3	632.7	2.56	0.0	539.8	539.8	1.000
July	210.7	189.5	625.5	1.10	7.1	550.7	557.8	0.987
August	190.6	182.0	603.7	2.80	23.0	534.8	557.8	0.959
September	170.5	180.2	609.4	7.90	19.5	520.3	539.8	0.964
October	133.2	152.7	532.5	0.00	81.3	476.5	557.8	0.854
November	100.7	127.7	464.5	0.29	113.5	426.3	539.8	0.790
December	90.1	121.1	452.2	0.16	141.1	416.8	557.8	0.747
Year	1840.9	1921.1	6695.3	40.91	637.7	5930.1	6567.8	0.903

6. Conclusion

The simulation of a stand-alone photovoltaic system has been performed using the PVSYST program, A PV panel's size and inverter type can be determined based on simulation results, this is in order to satisfy the load demand Sizing which is influenced significantly by the site's geographic location. System performance, losses, and detailed configuration diagrams have been produced. Using PVSYST software and watt-hour demand estimates, a PV system has been sized and theoretically simulated. 220 volts AC and 48 volts DC are used in the system. Generally, silicon heterojunction technology (HJT) solar cells have high open-circuit voltages (VOC), over 700 mV. A new record efficiency for silicon solar cells has been achieved with an efficiency of 24.03%. Combined with its low temperature coefficient, HJT technology will produce record-high energy per rated power across a wide range of climate zones. For this study, 700W HJT panels and 675W si-mono are simulated. The system requires 6 parallel panels for both systems, 1 series panel, and 6 total panels, It takes 19 m^2 for both to install these panels, Performance ratio and solar fraction of PVSYST software are 72% and 93% for system that using 700W HJT solar panels respectively. Whereas 73% and 90% for system that using 675W si-mono solar panels respectively, a 60Ah, 12V battery is selected. There were 9 batteries in total, 5 batteries in parallel, and 4 batteries in series. Additionally, it was found that the system with a single-phase, high-frequency 48V DC to 220V AC inverter (3kW, 220V) worked effectively in Basra Governorate in Iraq. The study indicates that the system using 700 wp with HJT is more efficient than the 675 wp system due to the main balance and results table that is generated from PVSYST software it was seen that the system using 700W HJT is higher energy supplied to the user which means its closer to the load demand than the 675W system, Moreover, the system using 700W is less missing energy than 675W system. All that is led to make High-efficiency Heterojunction Technology (HJT) have a number of advantages more than other types of panels. Basra's sunny climate and high temperatures suit these panels' high energy yield and efficiency. Thus, they can reduce costs and increase energy production. In addition, HJT technology aligns with sustainability goals, reduces environmental impact, and improves air quality. The technology facilitates infrastructure development and brings electricity to remote areas.

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