

Palestine Polytechnic University

College of Engineering



Design an Off Grid Solar System for Umm Alamad Algharbia Village

By

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Submitted to the College of Engineering
in partial fulfillment of the requirements for the
Bachelor degree in Technology of power Engineering

Dec 2021

الإهداء:

إلى معلمنا وقائدنا وقادوتنا وحبیبنا وشفیعنا مجد صلی الله علیه وسلم.

إلى من هم أكرم منا جميعا إلى الشهداء الأبرار.

إلى الذين عشقوا الحرية التي تفوح منها رائحة الياسمين وتوارو خلف القضبان ليفسحوا لنا النور إلى أسرانا الأبطال.

إلى التي رأنا قلبها قبل عينيها واحتضنتنا أحشائها قبل يديها إلى التي تعجز الكلمات عن شكرها

إلى منبع الحنان وتاج الرأس ومن تنحني لها جباهنا، كيف لا والجنة تحت إقدامها أمهاتنا، الفضيلات.

إلى من وصلو النهار بالليل، و بذلو الغالي و النفيس من أجلنا، إلى مصدر فخرنا وعزنا، آبائنا الكرام.

إلى من يحملون في قلوبهم ذكرياتنا ويتقاسمون معنا أفراحنا وهمومنا ومن ساندونا،خوتنا وأخواتنا الأعزاء.

إلى من ضاقت السطور لذكرهم فوسعتهم قلوبنا، أصدقائنا الأعزاء.

إلى من علمونا حروفا من ذهب وكلمات من درر، إلى من جعلوا أفكارهم منارة تنير لنا الطريق، إلى محبي العلم والمعرفة،
أساتذتنا الاكارم

إلى من رسم معنا خطوات هذا النجاح، إلى من بذل جهده ووقته. وكان لنا مرشدا وناصحا وأخا إلى مشرفنا الحبيب
الدكتور نسيم قطيط

إلى صرحنا العظيم ومكمن فخرنا وصانع مجدنا إلى بيتنا الثاني التي قضينا فيها أجمل أيامنا جامعتنا الحبيبة.

إلى محفزنا الأول والأخير إلى قبلتنا ومقصد بوصلتنا إلى من احتضنتنا كل هذه السنين رغم أوجاعها إلى فلسطين
وجوهرتها القدس الشريف.

إلى الزملاء وكوادر جامعه بوليتكنك فلسطين.

Abstract

The process of converting solar energy into electrical energy through solar energy systems on and off the grid has contributed significantly to reducing the loads on international electrical networks, especially in developing countries. It also helped provide energy to remote areas far from city centers, hence the idea of the project based on the design of the system, which is a solar system separated from the grid serving the remote western village of Umm Al-Amad, which is located in a city that suffers from overload, especially in winter, in addition to The difficulties imposed by the reality of the Israeli occupation on this village to prevent electricity from reaching it from neighboring cities or even from the city's network itself. The project is divided into five off grid solar systems, with a total capacity of 75 kilowatts, and the cost of the project is approximately \$114,500.

المخلص

ان عملية تحويل الطاقة الشمسية إلى طاقة كهربائية من خلال أنظمة الطاقة الشمسية داخل وخارج الشبكة ساهمت بشكل كبير في تقليل الأحمال على الشبكات الكهربائية الدولية ، وخاصة في البلدان النامية. كما ساعدت في توفير الطاقة للمناطق النائية البعيدة عن مراكز المدن ، ومن هنا جاءت فكرة المشروع القائمة على تصميم النظام ، وهو نظام شمسي مفصول عن الشبكة يخدم قرية ام العمدة الغربية النائية التي تقع في مدينة تعاني من الحمل الزائد ، خاصة في فصل الشتاء ، بالإضافة إلى الصعوبات التي يفرضها واقع الاحتلال الإسرائيلي على هذه القرية لمنع وصول الكهرباء إليها من المدن المجاورة أو حتى من شبكة المدينة نفسها وينقسم المشروع الى خمس أنظمة شمسية معزولة عن الشبكة بقدرة كلية تبلغ 75 كيلو واط وبلغت تكلفة المشروع \$114500 تقريباً.

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<i>AH to the battery = AH from the batteryη coulomb</i>	(3. 2).....	19
<i>AH from pv = AH to the battery Dirt Efficiency</i>	(3. 3).....	19
<i>I_{pvt} = AH from pvG</i>	(3. 4).....	20
<i>Num of parallel panels = I_{pvt}I panel</i>	(3. 5).....	20
<i>N_{total} = N_s * N_p</i>	(3. 6).....	20
<i>days of storage = 9.43 – 1.9G + 0.11(G)2</i>	(3. 7).....	21
<i>usable storage needed =</i> <i>days of storage * amps from the battery</i>	(3. 8).....	21
<i>C_{normal} = Usable CapacityMDOD * T. DR</i>	(3. 9).....	21
<i>number of parallel bateries = total capacitybatterty capacity</i>	(3. 10).....	23
<i>number of series bateries = system voltagebatterty voltage</i>	(3. 11).....	23
<i>number of total bateries =</i> <i>number of parallel bateries * number of series bateries</i>	(3. 12).....	23
<i>PPV = YPVFPVGTGT,STC [1 + α_p(TC – TC,STC)]</i>	(4. 1).....	27
<i>KT = HaveH0, ave</i>	(4. 2).....	27
<i>G_{on} = G_{sc} [1 + 0.033 * cos360n365]</i>	(4. 3).....	28
<i>G_o = G_{on} * cosθZ</i>	(4. 4).....	28
<i>COSθZ = cosϕ * cosδ * cosω + sinϕ * sinδ</i>	(4. 5).....	28
<i>δ = 23.45 * sin(360° * 284n365)</i>	(4. 6).....	28
<i>H0 = 24πG_{on}[cosϕ * cosδ * cosωs + $\pi\omega$s180°sinϕ * sinδ]</i>	(4. 7).....	28
<i>cosωs = tanϕ * tanδ</i>	(4. 8).....	29
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$\eta mp = \eta mp, STC[1 + \alpha p T_c - T_c, STC]$	(4. 22).....	32
$T_c = T_a + T_c, NOCT - T_a, NOCT GTGT, NOCT[1 - \eta mp, STC 1 - \alpha p T_c, STC \tau \alpha] 1 +$ $(T_c, NOCT - T_a, NOCT) GTGT, NOCT \alpha \eta mp, STC \tau \alpha$	(4. 23)	32
$\delta = 23.45^\circ \sin(360^\circ 284 + n 365)$	(4. 24).....	33
$\omega = ts - 12hr. 15^\circ/hr$	(4. 25).....	33
$ts = tc + \lambda 15^\circ/hr - Zc + E$	(4. 26)	33
$E = 3.82(0.000075 + 0.001868 \cos B - 0.032077 \sin B - 0.014615 \cos 2B -$ $0.04089 \sin B)$	(4. 27).....	33
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$\cos \theta z = \cos \phi \cos \delta \cos \omega + \sin \phi \sin \delta$	(4. 30)	34
$G_{on} = G_{sc}(1 + 0.033 \cos 360n 365)$	(4. 31).....	34
$G_o = G_{on} \cos \theta z$	(4. 32).....	35
$\bar{G}_o = \frac{12}{\pi} G_{on} [\cos \phi \cos \delta (\sin \omega_2 - \sin \omega_1) + \frac{\pi(\omega_2 - \omega_1)}{180^\circ} \sin \phi \sin \delta]$	(4. 33).....	35
$KT = GGo$	(4. 34).....	35
$G_o = Gb + Gd$	(4. 35).....	35
$GT = Gb + Gd Ai Rb + Gd1 - Ai1 + \cos \beta 21 + f \sin 3 \beta 2 + Gpg(1 - \cos \beta 2)$	(4. 36).....	36
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Chapter One: Introduction.

- 1.1 Introduction.**
- 1.2 Problem definition.**
- 1.3 Project motivation.**
- 1.4 Project Objectives.**
- 1.5 Project Importance.**
- 1.6 Literature review.**
- 1.7 Time Schedule.**

1.1 Introduction:

There is no doubt that the Palestinian tendency to rely more on renewable energy sources comes in harmony and in line with the increasing global trends to exploit alternative energy sources. The trend in Palestine is focused on solar energy.

Therefore, the Palestinian National Authority has prepared plans and studies to increase reliance on alternative energy to reach 10% over the next ten years. While the European Union, for example, plans to reach this percentage to 20%.

Via head of the Energy and Natural Resources Authority, on energy problems in Palestine, represented by the inability of the amount of energy supplied to Palestine to cover the state's need in the West Bank and Gaza in particular, which forced the Energy Authority to resort to the renewable energy option, especially in (C) areas that are close to settlements and are under threat of confiscation by the occupation. The Palestinian Energy Authority aims to support and strengthen the resilience of the citizens in those areas and reduce the energy problem in the country. These projects also aim to rely even partially on clean energy that does not harm the environment and humans.

Accordingly, this project also aims to solve the problem of the lack of electric power in the village of Umm Al-Amad, close to the settlement of Ataniel, in addition to supporting and strengthening the resilience of the villagers. [1]

1.2 Problem definition:

1. The lack of an electricity network in the village.
2. The village outside the boundaries of the municipal council.
3. The far distance between the nearest place that provides services to the Southern Electricity Company from the village.
4. Obstructing the occupation to supply power to the village from the city grid.

1.3 Project motivation:

Serving the residents of my village who pay high costs for electricity by using small renewable energy projects. Support and strengthen the citizens' steadfastness in facing the occupation by providing the basics of their lives, including the electric power.

1.4 Project Objectives:

Designing an Off-grid solar system, to provide the village with sufficient electrical energy for the needs of the village residents.

1.5 Project Importance:

The importance of the project lies in providing the village and similar villages with renewable electric energy instead of supplying them from the city network far from these villages, and thus these villages will be provided with clean and environmentally friendly energy in addition to not increasing the load on the public network in the city, which leads to poor quality.

1.6 Literature review:

Projects implemented by the Palestinians to exploit solar energy to generate electricity:

The lighting project in the village of Amnisel, south of Yatta, Hebron Governorate, by installing a central solar system (solar cells) with a capacity of 13 kilowatts, which is the largest project implemented by the center to generate electricity through it. A central solar cell system to provide the entire village with electrical energy, as the village was

suffering from a shortage of infrastructure such as water and electricity, and the system was connected to a generator to help charge the batteries. [1]

The solar energy project for the "Al-Fakhit and Al-Taban" compounds in Masseter Yatta, south of Hebron. The project organizers explained that the project represents a quantum leap in the lives of the residents of these communities as the number of families living in these two communities reached 20 families, and 2.5 kilowatts per day were allocated for each family. [1]

A solar cell project was established to supply the village with 12 kilowatts. The solar energy produced during the day was stored and converted into electrical energy for use on a 24-hour basis when needed.

The Energy Research Center at An-Najah National University, in cooperation with the Spanish Ciba Foundation, implemented the Khirbet Tana lighting project with a solar cell system, and the project provides electricity to 14 families (about 100 people), and Khirbet Tana is located in the east of the village of Beit Furik, 6 kilometers away. It is currently inhabited by about 60 Palestinian families, with a population of no more than 400 people, most of whom depend on the fields of agriculture and livestock to manage their lives and daily income. They suffer from a lack of basic services such as water, electricity and telephone lines. Because of the ruin in the eastern isolation area. The ruin is surrounded on the north by the Israeli settlement of Getet, on the south by the Arab al-Rujman community, on the east by the Israeli settlement of "Mikhora" and the Israeli bypass road No. 508, and on the west by the villages of Yanun and Beit Furik. [1].

1.7 Time Schedule:

1.7.1 First schedule:

This table illustrates the tasks that I did and how long it takes weekly for each task:

Table (1. 1): First schedule:

Task \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Finding Project Idea															
Proposal															
Collecting data															
Documentation															
Print documentation															
Preparing for presentation															

1.7.2 Second schedule:

The following time table displays the project implementation-flow divided into fifteen weeks of the first semester as following.

Table (1. 2): Second schedule:

Tasks \ Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Treatment and rectify the reviews															
Studying manual of Homer Program															
Learn on the program project simulation															
Result															
Report															

2

Chapter Two: System Components.

- 2.1 Overview.**
- 2.2 Solar panels.**
- 2.3 Charge controller.**
- 2.4 Batteries.**
- 2.5 Inverter.**

2.1 Overview:

This chapter is an explanation of the main components and parts of the project, and how each type has been specifically selected, and this chapter relies heavily on separating the accounts (Ch3) regarding the selection of some parts of the project.

Off grid solar system consists of four main parts, which are as follows:

1- Solar panels

2-charge controller

3-Batteries

4-inverter

There are many of these pieces mentioned in the global market, but the best ones available in the Palestinian market will be chosen for several reasons, the most important of which are Importing parts from companies that have not been handled by Palestinian companies is a very expensive and time consuming process Also, the parts available in the Palestinian market are very good to meet the needs of off-grid systems, and certainly not the best in the world, but they are very, very good.

Components and definition of a system outside the network, the following picture shows the parts of this system and each part of it will be explained in detail below as shown in Figure (2.1):

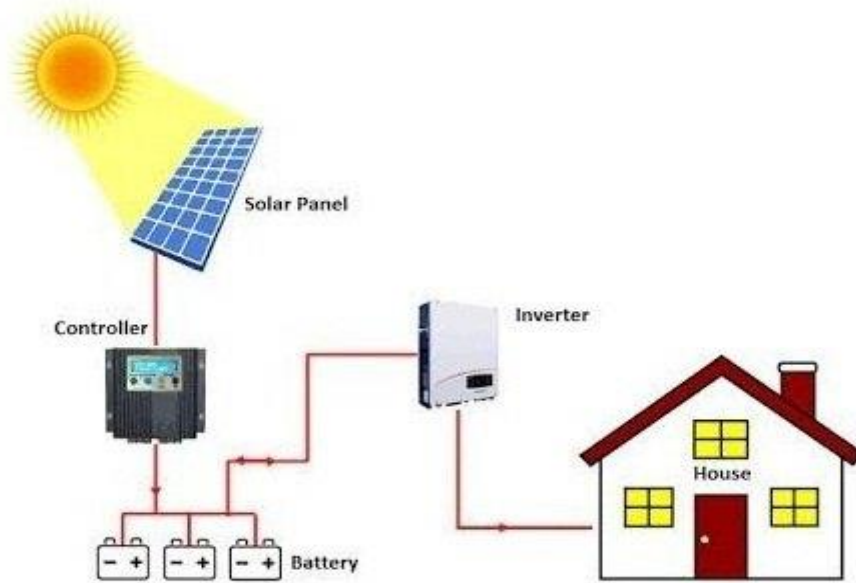


Figure (2. 1): Component of off grid solar system [2]

2.2 Solar panels:

Solar panels collect clean renewable energy in the form of sunlight and convert that light into electricity which can then be used to provide power for electrical loads. Solar panels are comprised of several individual solar cells which are themselves composed of layers of silicon, phosphorous (which provides the negative charge), and boron (which provides the positive charge). Solar panels absorb the photons and in doing so initiate an electric current. The resulting energy generated from photons striking the surface of the solar panel allows electrons to be knocked out of their atomic orbits and released into the electric field generated by the solar cells which then pull these free electrons into a directional current. This entire process is known as the Photovoltaic Effect. An average home has more than enough roof area for the necessary number of solar panels to produce enough solar electricity to supply all of its power needs excess electricity generated goes onto the main power grid, paying off in electricity use at night.

After many studies about the paintings available in Palestine, the following type was chosen (JKM535M-7TL4-V) as shown in Figure (2.2). It is widely available in

the Palestinian market, with high efficiency, and a lifespan of up to 25 years, as the efficiency of the board during this lifetime decreases from 98% to 84.5%.



Figure (2. 2): Picture of (JKM535M-7TL4-V) panels.

Data sheet of (JKM535M-7TL4-V) panels (page 57)

2.3 Charge controller:

Solar power system charge controller, also known as a charge regulator, is basically a solar battery charger connected between the solar panel and the battery as shown in Figure (2.3). Its job is to regulate the battery charging process to ensure the battery is properly charged or, most importantly, not overcharged. DC-coupled solar charge controllers have been around for decades and are used in nearly all small off-grid solar systems.

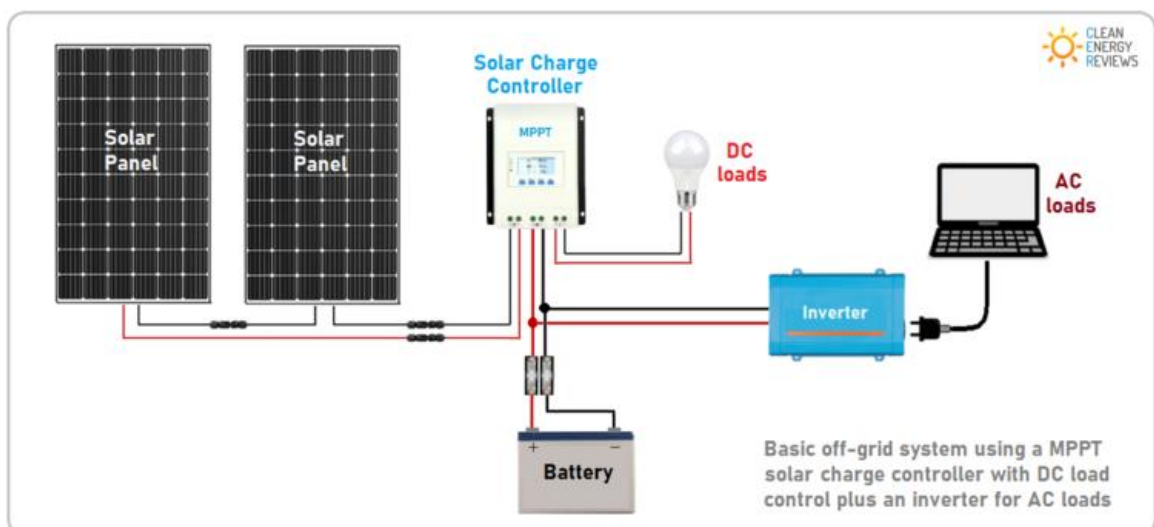


Figure (2. 3): location of charge controller in the System [3].

Modern solar charge controllers have advanced features to ensure battery system charging with high accuracy and efficiency and maintain battery security, in general, most of the smaller charge controllers from 12 volts to 24 volts to 40 amps are used in convoys, recreational vehicles and camping, and they have output terminals Built-in constant current download. While most of the larger and more advanced 60A + MPPT solar charge controllers do not have load output terminals and are specifically designed for a larger off-grid system with solar arrays and powerful off-grid inverters.

Solar charge controllers are rated according to the maximum input voltage (V) and the maximum charge current (A). These two classifications define the number of solar panels that can be attached as detailed below "Solar Charge Controller Sizing".

Current Amp (A) rating = Maximum charging current.

Voltage (V) rating = Maximum voltage (Voc) of the solar panel/s.

PWM and MPPT solar charge controllers

There are two main types of solar charge controllers, PWM and MPPT.

PWM Solar Charge Controllers as shown in Figure (2.4). MPPT solar charge controllers as shown in Figure (2.5).

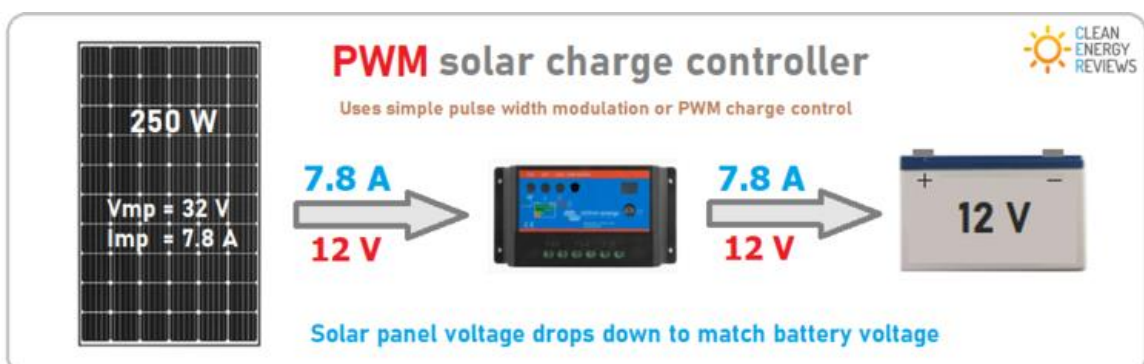


Figure (2. 4): PWM charge controller [3]

Simple PWM, or ‘pulse width modulation’ solar charge controllers have a direct connection from the solar array to the battery and use a basic ‘rapid switch’ to modulate or control the battery charging. The switch (transistor) is open until the battery reaches the absorption charge voltage. Then the switch starts to open and close rapidly (hundreds of time per second) to reduce the current and maintain a constant battery voltage. This works ok, but the problem is the solar panel voltage is pulled down to match the battery voltage. This in turn pulls the panel voltage away from its optimum operating voltage (V_{mp}) and reduces power and efficiency.

PWM solar charge controllers are a great low-cost option for small 12V systems where one or two solar panels are used, such as simple applications like solar lighting, camping and basic things like USB/phone chargers.

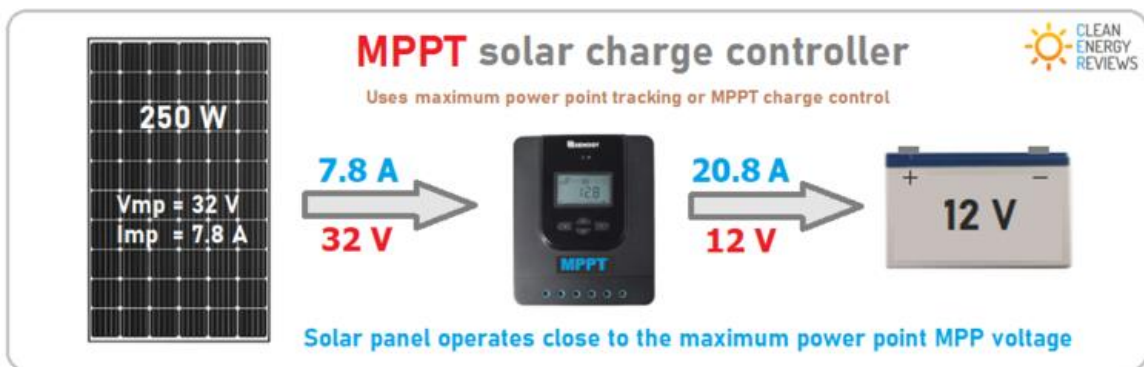


Figure (2. 5): MPPT solar charge controller [3].

An MPPT is basically an efficient DC to DC converter used to maximize the power output of a solar panel. The first MPPT was invented by a small Australian company called AERL way back in 1985, and this technology is now used in virtually all grid-connect solar inverters and many solar charge controllers.

The functioning principle of an MPPT solar charge controller is rather simple - due to the varying degree of sunlight (irradiance) landing on a solar panel throughout the day, the panel voltage and current continuously changes. In order to generate the most power, the maximum power point tracker sweeps through the panel voltage to find the ‘sweet spot’ or the best combination of voltage and

current to produce the maximum power. The MPPT is designed to continually track and adjust the voltage to generate the most power no matter what time of day or weather conditions. Note, generally only high-end MPPT controllers can detect partial shading, or are able to track multiple power points. Using this clever technology, the solar panel efficiency increases and the amount of energy generated can be up to 30% more than a PWM solar charge controller as shown in Figure (2.6).

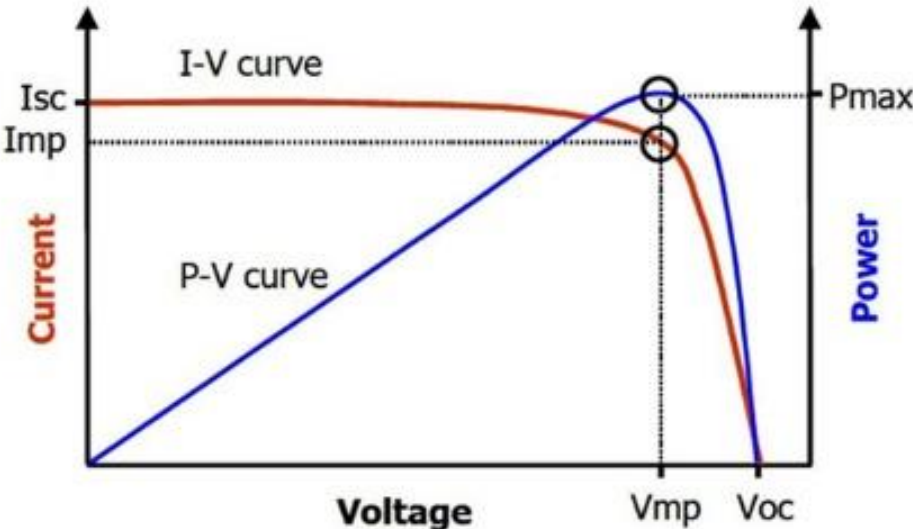


Figure (2. 6): Curve of MPPT charge controller [3].

According to the above information, a charge controller of the MBBT type was chosen, and based on the project accounts, a charge controller of the type Smart Solar MPPT 150/45-70 was chosen as shown in Figure (2.7).



Figure (2. 7): Smart Solar MPPT 150/45-70

Smart Solar MPPT 150/45-70 data sheet (page 59)

2.4 Batteries:

The Solar Signature Line is designed to deliver maximum sustained performance, long life and increased energy Trojan Solar AGM maintenance-free batteries can be counted on day in and day out as a reliable power source for a wide range of off-grid and grid applications Trojan's Solar Industrial line of deep cycle batteries are engineered specifically to support renewable energy systems with large daily loads where the batteries are cycled regularly [12]

Trojan SSIG 12 255 as shown in Figure (2.8).



Figure (2. 8): Trojan 12V Signature Flooded Battery SSIG 12 255 [4].

Batteries data sheet (page 61)

2.5 Inverter:

The next component in the solar system off-grid is the inverter. In nearly all off-grid solar systems, the inverter is battery dependent. The purpose of the inverter is to take the DC power stored in the batteries and convert it into usable AC power and send it to your loads so that it can be used in the same way as connecting it to the AC outlet in the place where the loads are to be run. The converters come in different sizes that can accommodate smaller loads or larger loads depending on the loads outside Network required. Another consideration is to ensure that the inverter can handle all the loads running simultaneously in the system. When all system loads in the system are added off the grid, it will determine the maximum amount that the inverter needs to handle.

Another important fact is that the inverter needs to match “voltage-wise” with the system in which it is being used. For instance, a 12-volt inverter cannot be used with a 24-volt battery bank – it must be used with a 12-volt battery bank. Unlike charge controllers, the voltage on an inverter cannot be changed as it is fixed and must be matched with the battery voltage of the system. Given that information, it’s important to choose an inverter wisely when designing a system especially if expanding the system are in the plans. Choosing an inverter is an important decision to make correctly in the beginning due to the cost associated with them.

The inverter used in the system designed is Three Phase SMA Off-Grid System - 20KW PV as shown in Figure (2.8) due to its availability in the Palestinian market and its suitability for the required design.



Figure (2. 9): XW Pro 8.5 kW Hybrid Inverter 230V PV [5]

Data sheet of the inverter (page 64)

3

Chapter Three: Design and Calculations.

- 3.1 Introduction.**
- 3.2 Loads calculations.**
- 3.3 Calculations for the number of panels.**
- 3.4 Calculations for the number of batteries.**
- 3.5 Electrical design for the system.**
- 3.6 Houses locations on map.**

3.1 Introduction.

This chapter explains the calculations for:

- Loads.
- Number of solar panels.
- The number of batteries.

and what follows it in terms of details of the factors that affect solar energy from receiving it through solar panels until converting it into electrical energy to operate both loads ac and dc.

In addition to an aerial photo of the village showing the locations of the houses, the distribution of units on them, and a design for one of the systems, and the remaining four are identical to the same design.

3.2 Loads calculations.

The village consists of 15 houses divided into five groups, each group consists of 3 houses, all with loads ranging from 4 to 5 kilowatts for one house, and accordingly the loads will be calculated on the basis of one of the houses to build one solar system and the rest are the same calculations and the same design.

Table (3. 1): houses consumption.

Houses	Consumption	Average
House 1	5.975 kWh/day	
House 2	4.5 kWh/day	4.925 kWh/day
House 3	4.3 kWh/day	
House 4	4.73 kWh/day	
House 5	4.9 kWh/day	4.91 kWh/day
House 6	5.1 kWh/day	
House 7	4.82 kWh/day	
House 8	4.46 kWh/day	4.66 kWh/day
House 9	4.7 kWh/day	

House 10	5 kWh/day	
House 11	4.42 kWh/day	4.67 kWh/day
House 12	4.61 kWh/day	
House 13	4.72 kWh/day	
House 14	4.3 kWh/day	4.64 kWh/day
House 15	4.9 kWh/day	

Table (3. 2): The table of one house loads.

Device	Device power	Daily hours per day	Device power per day	
5 lamps led	40w for lamp	6 hours	$5*0.04*6=1.2\text{kW.h/day}$	
Fans	100w for fan	8hours	$1*0.1*8=0.8\text{kW.h/day}$	
TV and receiver	90 w	10 hours	$1*0.9*10=0.9\text{kW.h/day}$	
Caustic clothes	100 w	0.16 hours	$1*1*0.16=0.16\text{kW.h/day}$	
Fridge (dc load)	36 w	24 hours	0.865kW.h/day	
Vacuum Cleaner	1000 w	0.25 hours	$1*0.25*1=0.25\text{kW.h/day}$	
Washing machine	1000 w	0.75 hours	$1*1*0.75=0.75\text{kW.h/day}$	
milk shake machine	500 w	0.5 hours	$1*0.5*0.5=0.25\text{kW.h/day}$	
Other devices	50 w	2 hours	$1*0.05*2 =0.1\text{kW.h/day}$	
Water pump	400 w	0.5 hours	$1*0.4*0.5=0.2\text{kW.h/day}$	
milk machine[6]	400 w	1.25 hours	$1.25*0.400*1=0.5\text{kW.h/day}$	
Total	4076 w		5.975kW. h/day	
			5.11 kW.h/day (AC)	0.865 kW.h/day (DC)

Total kW for the village:

$$4076 * 15 = 61.140 \text{ Kw.}$$

Total kW.h/day for the village:

$$5 * 15 = 75 \text{ kW.h/day. (Due to the table 3.1)}$$

3.3 Calculations for the number of panels.

$$\begin{aligned} AH \text{ from the battery} &= \frac{\text{Delivered Energy/Day}}{\text{Etta}_{inv} * \text{System Voltage}} && (3.1) \\ &= \frac{3 * 5000}{0.986 * 48} \\ &= 316.93712 \text{ AH} && [7] \end{aligned}$$

Where

- AH: The Capacity in Ampere Hour.
- Etta_{inv}: Inverter Efficiency.

$$\begin{aligned} AH \text{ to the battery} &= \frac{AH \text{ from the battery}}{\eta_{coulomb}} && (3.2) \\ &= \frac{316.93712}{0.9} \\ &= 352.152356 \text{ AH} \end{aligned}$$

Where

- AH: The Capacity in Ampere Hour.
- η Coulomb: battery coulomb Efficiency.

$$\begin{aligned} AH \text{ from pv} &= \frac{AH \text{ to the battery}}{\text{Dirt Efficiency}} && (3.3) \\ &= \frac{352.152356}{0.95} \\ &= 370.6867 \text{ AH} \end{aligned}$$

Where

- AH: The Capacity in Ampere Hour.
- Dirt Efficiency: Dirty Environment Efficiency.
- ❖ January is the worst month with 4.9kWh/m².day

$$\begin{aligned}
 I_{pvt} &= \frac{AH \text{ from pv}}{G} & (3.4) \\
 &= \frac{370.6867}{4.9} \\
 &= 75.6503451 \text{ A} & [8]
 \end{aligned}$$

$$\begin{aligned}
 \text{Num of parallel panels} &= \frac{I_{pvt}}{I_{panel}} & (3.5) \\
 &= \frac{75.6503451}{12.77} = 5.9 \\
 &= 6 \text{ strings}
 \end{aligned}$$

Where

- AH: The Capacity in Ampere Hour.
- I_{pvt} : Total Rated Current of Panels.
- G: Peak Hours of Sun Per Day in Hebron.
- I_{panel} : Rated Current of One Panel.

Since the rated voltage is 41.9 the system battery voltage is 48V, so we need two panels in series with $N_s=2$, therefore the total number of panels (modules) is

$$\begin{aligned}
 N_{total} &= N_s * N_p & (3.6) \\
 &= 2 * 6 \\
 &= 12 \text{ panels.}
 \end{aligned}$$

Where

- N_{total} : Number of total panels.
- N_s : Number of series panels.
- N_p : Number of parallel panels.

3.4 Calculations for the number of batteries.

$$\begin{aligned} \text{days of storage} &= 9.43 - 1.9(G) + 0.11(G)^2 && (3.7) \\ &= 9.43 - 1.9(4.9) + 0.11(4.9)^2 \\ &= 2.7611 \text{ days} \end{aligned}$$

$$\begin{aligned} \text{usable storage needed} &= \\ \text{days of storage} * \text{amps from the battery} &&& (3.8) \\ &= 3 * 316.93712 \\ &= 950.81136 \text{ AH @ 48 V} \end{aligned}$$

Where

- Ns: Number of series panels.
- Np: Number of parallel panels.
- G: Peak Hours of Sun per Day in Hebron.

$$\begin{aligned} C_{normal} &= \frac{\text{Usable Capacity}}{MDOD * (T.DR)} && (3.9) \\ &= \frac{950.81136}{0.8 * (1)} \\ &= 1188.5142 \text{ AH ... 444} \end{aligned}$$

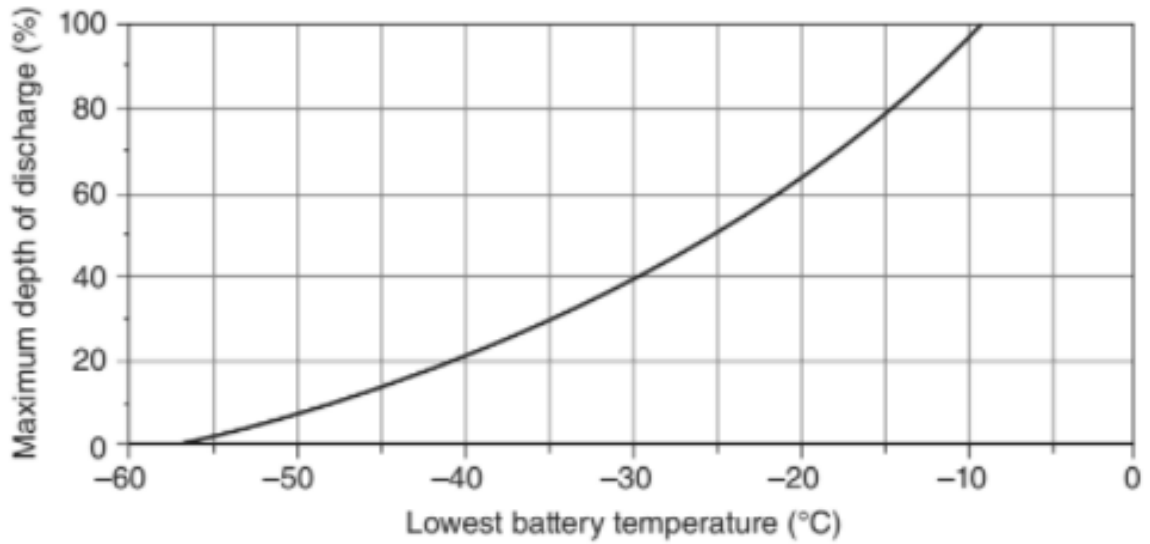


Figure (3. 1): MDOD due to changing in temperature [9]

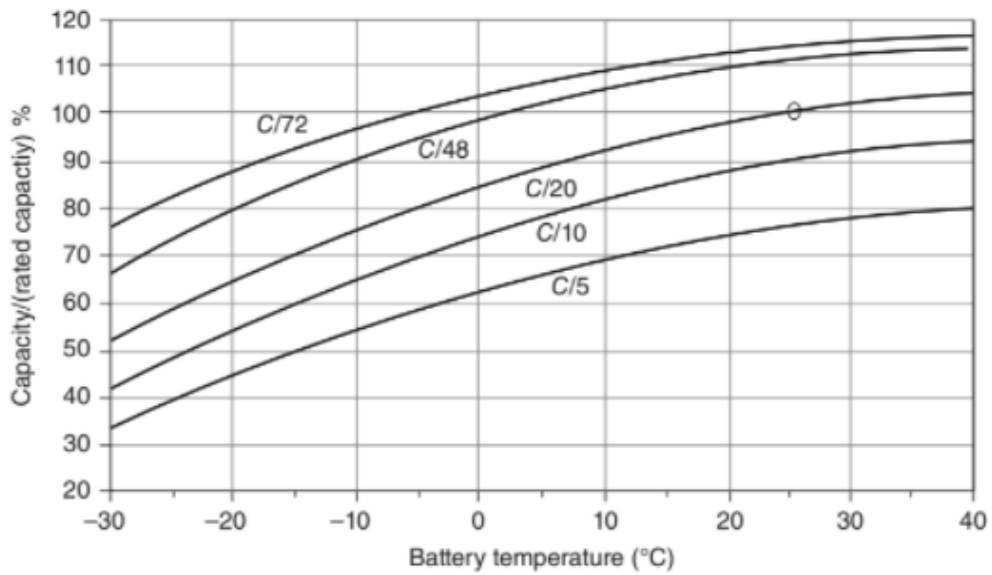


Figure (3. 2): battery capacity depends on discharge rate and temperature. [9]

❖ (Ratio is based on rated capacity at C/20 and 25 C)

Where

- C_{normal}: capacity for normal operation.
- MDOD: Maximum Depth of Discharging.
- T. DR: Discharging Rate Depends on Temperature.

$$\text{number of parallel bateries} = \frac{\text{total capacity}}{\text{batterty capacity}} \quad (3. 10)$$

$$= \frac{1188.5142 \text{ AH}}{250 \text{ AH}}$$

$$= 4.755$$

$$= 5 \text{ Bateries}$$

❖ number of series connected to produce 48V system voltage is

$$\text{number of series bateries} = \frac{\text{system voltage}}{\text{batterty voltage}} \quad (3. 11)$$

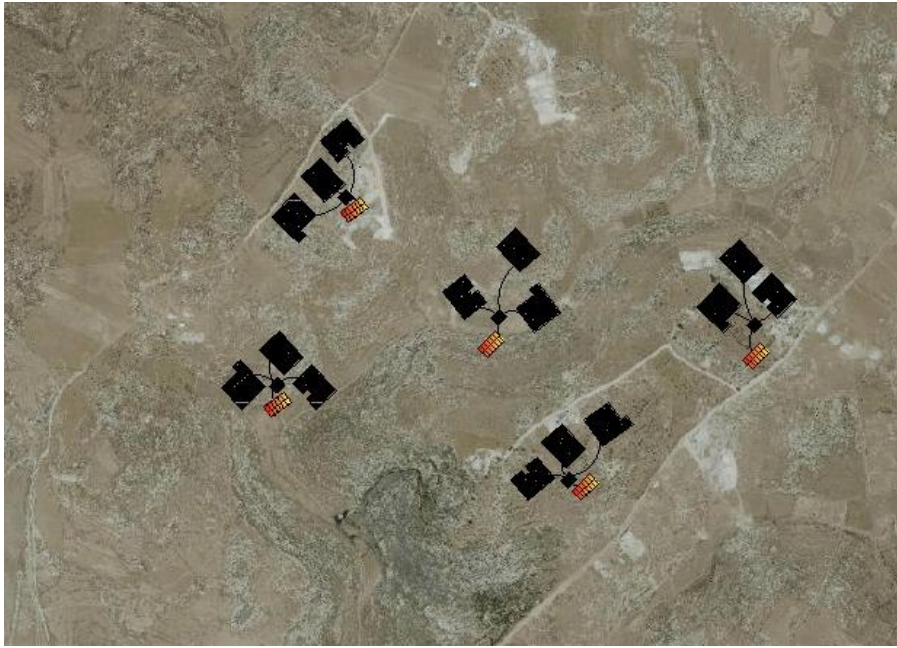
$$= \frac{48 \text{ V}}{12 \text{ V}}$$

$$= 4 \text{ bateries}$$

$$\text{number of total bateries} = \text{number of parallel bateries} * \text{number of series bateries} \quad (3. 12)$$

$$= 5 * 4$$

$$= 20 \text{ bateries}$$



b)

Figure (3. 4): Houses locations on map by AutoCAD program.

4

Chapter Four: Calculations and economic.

- 4.1 PV array power output calculation.**
- 4.2 Clearness index calculations.**
- 4.3 The maximum battery charge power.**
- 4.4 The maximum battery discharge power.**
- 4.5 The PV cell temperature.**
- 4.6 The radiation incident on the PV array.**

4.1 PV array power output calculation.

All equations above are from homer program manual [11]

HOMER uses the following equation to calculate the output of the PV array:

$$P_{PV} = Y_{PV} F_{PV} \frac{G_T}{G_{T,STC}} [1 + \alpha_p (T_C - T_{C,STC})] \quad (4.1)$$

Where:

Y_{PV} : is the rated capacity of the PV array, meaning its power output under Standard test conditions [kW].

F_{PV} : is the PV derating factor [%]

G_T : Is the solar radiation incident on the PV array in the current time step [kW/m²].

$G_{T,STC}$: Is the incident radiation at standard test conditions [1 kW/m²].

α_p : Is the temperature coefficient of power [%/°C].

T_C : Is the PV cell temperature in the current time step [°C].

$T_{C,STC}$: Is the PV cell temperature under standard test conditions [25 °C].

4.2 Clearness index calculations.

$$K_T = \frac{H_{ave}}{H_{0,ave}} \quad (4.2)$$

Where:

K_T : Monthly average clearness index.

H_{ave} : is the monthly average radiation on the horizontal surface of the earth [kWh/m²/day].

$H_{0,ave}$: is the *extraterrestrial horizontal radiation*, meaning the radiation on a horizontal surface at the top of the earth's atmosphere [kWh/m²/day].

$$G_{on} = G_{sc} [1 + 0.033 * \cos \frac{360n}{365}] \quad (4.3)$$

Where:

G_{on} : Intensity of solar radiation.

G_{sc} : is the solar constant [1.367 kW/m²].

n : is the day of the year [a number between 1 and 365].

$$G_o = G_{on} * \cos \theta_z \quad (4.4)$$

Where

θ_z : is the zenith angle.

$$\cos \theta_z = \cos \phi * \cos \delta * \cos \omega + \sin \phi * \sin \delta \quad (4.5)$$

Where

ϕ : is the latitude.

δ : is the solar declination.

ω : is the hour angle.

$$\delta = 23.45 * \sin(360^\circ * \frac{284n}{365}) \quad (4.6)$$

Where:

n : is the day of the year [a number between 1 and 365].

$$H_0 = \frac{24}{\pi} G_{on} [\cos \phi * \cos \delta * \cos \omega_s + \frac{\pi \omega_s}{180^\circ} \sin \phi * \sin \delta] \quad (4.7)$$

Where:

H_0 : is the average extraterrestrial horizontal radiation for the day [kWh/m²/day].

ω_s : is the sunset hour angle.

$$\cos \omega_s = \tan \phi * \tan \delta \quad (4. 8)$$

$$H_{0,ave} = \frac{\sum_{n=1}^N H_0}{N} \quad (4. 9)$$

Where:

$H_{0,ave}$: is the average extraterrestrial horizontal radiation for the month [kWh/m²/day].

N : is the number of days in the month.

4.3 The Maximum battery charge power.

$$P_{batt,amax,kbm} = \frac{KQ_1e^{-k\Delta t} + QKc(1-e^{-k\Delta t})}{1-e^{-k\Delta t} + c(K\Delta t - 1 + e^{-k\Delta t})} \quad (4. 10)$$

Where:

Q_1 : is the available energy [kWh] in the storage at the beginning of the time step.

Q : is the total amount of energy [kWh] in the storage at the beginning of the time step.

c : is the storage capacity ratio [unit less].

K : is the storage rate constant [h⁻¹].

Δt : is the length of the time step [h].

$$P_{batt,amax,mar} = \frac{(1-e^{-\alpha_c\Delta t}) * (Q_{max} - Q)}{\Delta t} \quad (4. 11)$$

Where:

α_c : is the storage's maximum charge rate [A/Ah].

Q_{max} : is the total capacity of the storage bank [kWh].

$$P_{batt,amax,mcc} = \frac{N_{batt} * I_{max} * V_{nom}}{1000} \quad (4. 12)$$

Where:

N_{bott} : is the number of batteries in the storage bank.

I_{max} : is the storage's maximum charge current [A].

V_{nom} : is the storage's nominal voltage [V].

$$P_{batt,amax} = \frac{MIN (P_{batt,amax,kbm} * P_{batt,amax,mar} * P_{batt,amax,mcc})}{\eta_{bott}} \quad (4. 13)$$

Where:

$\eta_{batt,c}$: is the storage charge efficiency.

4.4 The Maximum Battery Discharge Power.

$$P_{batt,dmax,kbm} = \frac{-KcQ_{max} + KQ_1 e^{-k\Delta t} + QKc(1 - e^{-k\Delta t})}{1 - e^{-k\Delta t} + c(K\Delta t - 1 + e^{-k\Delta t})} \quad (4. 14)$$

Where:

Q_1 : is the available energy [kWh] in the storage at the beginning of the time step.

Q : is the total amount of energy [kWh] in the storage at the beginning of the time step.

Q_{max} : is the total capacity of the storage bank [kWh].

c : is the storage capacity ratio [unit less].

K : is the storage rate constant [h^{-1}].

Δt : is the length of the time step [h].

$$P_{batt,dmax,mcc} = \eta_{batt,d} * P_{batt,dmax,kbm} \quad (4.15)$$

Where:

$\eta_{batt,c}$: is the storage Discharge charge efficiency.

$$P_{out} = V_0 * I - R_0 * I^2 \quad (4.16)$$

$$I_{Pout,max} = V_0 / (2R_0) \quad (4.17)$$

4.5 The PV Cell Temperature.

$$\tau\alpha G_T = \eta_c G_T + U_L(T_c - T_a) \quad (4.18)$$

Where:

τ : is the solar transmittance of any cover over the PV array [%]

α : is the solar absorptance of the PV array [%]

G_T : is the solar radiation striking the PV array [kW/m²]

η_c : is the electrical conversion efficiency of the PV array [%]

U_L : is the coefficient of heat transfer to the surroundings [kW/m² °C]

T_c : is the PV cell temperature [°C]

T_a : is the ambient temperature [°C]

$$T_c = T_a + G_T \left(\frac{\tau\alpha}{U_L} \right) \left(1 - \frac{\eta_c}{\tau\alpha} \right) \quad (4. 19)$$

$$\frac{\tau\alpha}{U_L} = \frac{T_{c,NOCT} - T_{a,NOCT}}{G_{T,NOCT}} \quad (4. 20)$$

Where:

$T_{c,NOCT}$: Is the nominal operating cell temperature [°C]

$T_{a,NOCT}$: Is the ambient temperature at which the NOCT is defined [20°C]

$G_{T,NOCT}$: Is the solar radiation at which the NOCT is defined [0.8 kW/m²]

$$\eta_c = \eta_{mp} \quad (4. 21)$$

Where:

η_{mp} : Is the efficiency of the PV array at its maximum power point [%]

$$\eta_{mp} = \eta_{mp,STC} [1 + \alpha_p (T_c - T_{c,STC})] \quad (4. 22)$$

Where:

$\eta_{mp,STC}$: Is the maximum power point efficiency under standard test conditions [%]

α_p : is the temperature coefficient of power [%/°C]

$T_{c,STC}$: Is the cell temperature under standard test conditions [25°C]

$$T_c = \frac{T_a + (T_{c,NOCT} - T_{a,NOCT}) \left(\frac{G_T}{G_{T,NOCT}} \right) \left[1 - \frac{\eta_{mp,STC} (1 - \alpha_p T_{c,STC})}{\tau\alpha} \right]}{1 + (T_{c,NOCT} - T_{a,NOCT}) \left(\frac{G_T}{G_{T,NOCT}} \right) \left(\frac{\alpha_p \eta_{mp,STC}}{\tau\alpha} \right)} \quad (4. 23)$$

4.6 The Radiation Incident on the PV Array.

$$\delta = 23.45^\circ \sin\left(360^\circ \frac{284+n}{365}\right) \quad (4.24)$$

Where:

n: is the day of the year [a number 1 through 365]

$$\omega = (t_s - 12hr) \cdot 15^\circ/hr \quad (4.25)$$

Where:

t_s : is the solar time [hr.]

$$t_s = t_c + \frac{\lambda}{15^\circ/hr} - Z_c + E \quad (4.26)$$

Where:

t_c : is the civil time in hours corresponding to the midpoint of the time step [hr]

λ : is the longitude [°]

Z_c : is the time zone in hours east of GMT [hr]

E: is the equation of time [hr]

$$E = 3.82(0.000075 + 0.001868\cos B - 0.032077\sin B - 0.014615\cos 2B - 0.04089\sin B) \quad (4.27)$$

Where:

B is given by:

$$B = 360^\circ \frac{(n-1)}{365} \quad (4.28)$$

$$\begin{aligned} \cos\theta = \sin\delta \sin\phi \cos\beta - \sin\delta \cos\phi \sin\beta \cos\gamma + \cos\delta \cos\phi \cos\beta \cos\omega \\ + \cos\delta \sin\phi \sin\beta \cos\gamma \cos\omega + \cos\delta \sin\beta \sin\gamma \sin\omega \end{aligned} \quad (4. 29)$$

Where:

θ : Is the angle of incidence [°].

β : Is the slope of the surface [°].

γ : Is the azimuth of the surface [°].

ϕ : Is the latitude [°].

δ : Is the solar declination [°].

ω : Is the hour angle [°].

$$\cos\theta_z = \cos\phi \cos\delta \cos\omega + \sin\phi \sin\delta \quad (4. 30)$$

Where:

θ : Is the zenith angle [°]

$$G_{on} = G_{sc} \left(1 + 0.033 \cos \frac{360n}{365}\right) \quad (4. 31)$$

Where:

G_{on} : Is the extraterrestrial normal radiation [kW/m²]

G_{sc} : is the solar constant [1.367 kW/m²]

n : is the day of the year [a number 1 through 365]

$$G_o = G_{on} \cos\theta_z \quad (4. 32)$$

Where:

G_o : Is the extraterrestrial horizontal radiation [kW/m²]

θ_z : is the zenith angle [°]

$$\bar{G}_o = \frac{12}{\pi} G_{on} [\cos\phi \cos\delta (\sin\omega_2 - \sin\omega_1) + \frac{\pi(\omega_2 - \omega_1)}{180^\circ} \sin\phi \sin\delta] \quad (4. 33)$$

Where:

\bar{G}_o : Is the extraterrestrial horizontal radiation averaged over the time step [kW/m²]

G_o : Is the extraterrestrial normal radiation [kW/m²]

ω_2 : is the hour angle at the beginning of the time step [°]

ω_1 : is the hour angle at the end of the time step [°]

$$K_T = \frac{\bar{G}}{\bar{G}_o} \quad (4. 34)$$

Where:

\bar{G} : is the global horizontal radiation on the earth's surface averaged over the time step [kW/m²]

$$\bar{G}_o = \bar{G}_b + \bar{G}_d \quad (4. 35)$$

Where:

\bar{G}_b : Is the beam radiation [kW/m²]

\bar{G}_d : Is the diffuse radiation [kW/m²]

$$\bar{G}_T = (\bar{G}_b + \bar{G}_d A_i) R_b + \bar{G}_d (1 - A_i) \left(\frac{1 + \cos \beta}{2} \right) \left[1 + f \sin^3 \left(\frac{\beta}{2} \right) \right] + \bar{G}_{p_g} \left(\frac{1 - \cos \beta}{2} \right) \quad (4.36)$$

Where:

β : Is the slope of the surface [°]

p_g : Is the ground reflectance, which is also, called the albedo [%]

5

Chapter Five: Homer pro program simulation and results.

- 5.1 Location of the village.**
- 5.2 Solar radiation and temperature.**
- 5.3 The AC loads and dc loads data.**
- 5.4 PV Data.**
- 5.5 Storage Data.**
- 5.6 Inverter Data.**
- 5.7 Electrical results.**
- 5.8 Economic result.**

5.1 Location of the village.

The figure (5.1) as shows location of the village near the settlement of Otnael, according to what was previously mentioned, indicated on the map of the Homer Bro program.

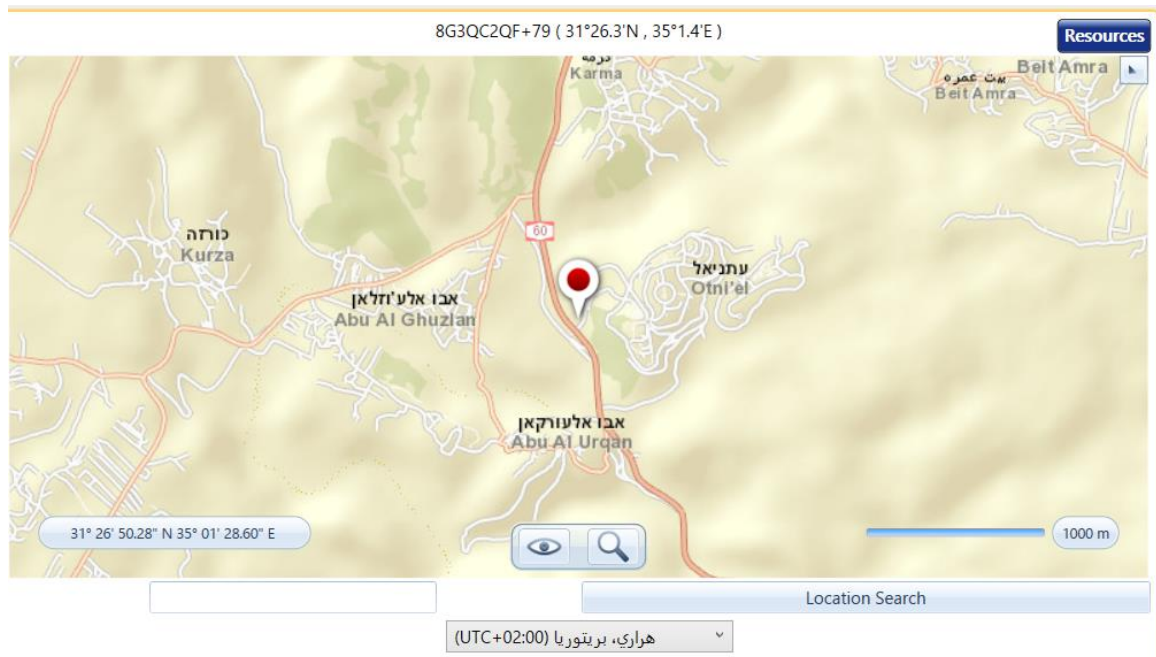


Figure (5. 1): location of the village.

5.2 Solar radiation and temperature.

The rate of solar radiation from the Homer program, whose data was included from the Internet, according to the project site on the map.

The Figure (5.2) as shows the average daily solar radiation for each month separately

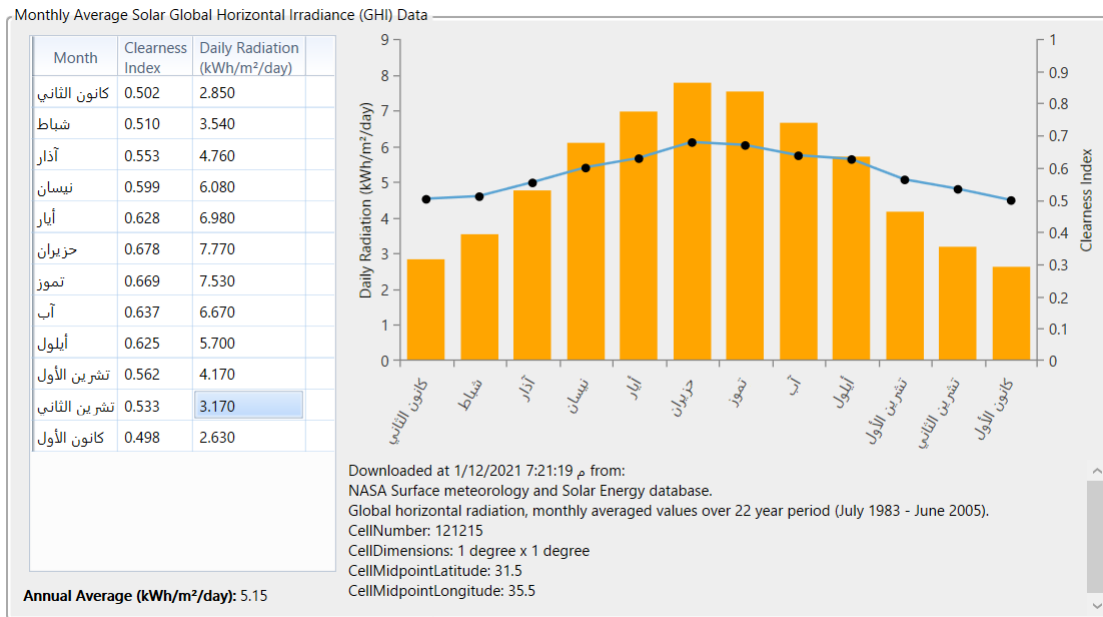


Figure (5. 2): average daily solar radiation.

The rate of temperature from the Homer program, whose data was included from the Internet, according to the project site on the map.

The Figure (5.3) as shows the average daily temperatures for each month separately.

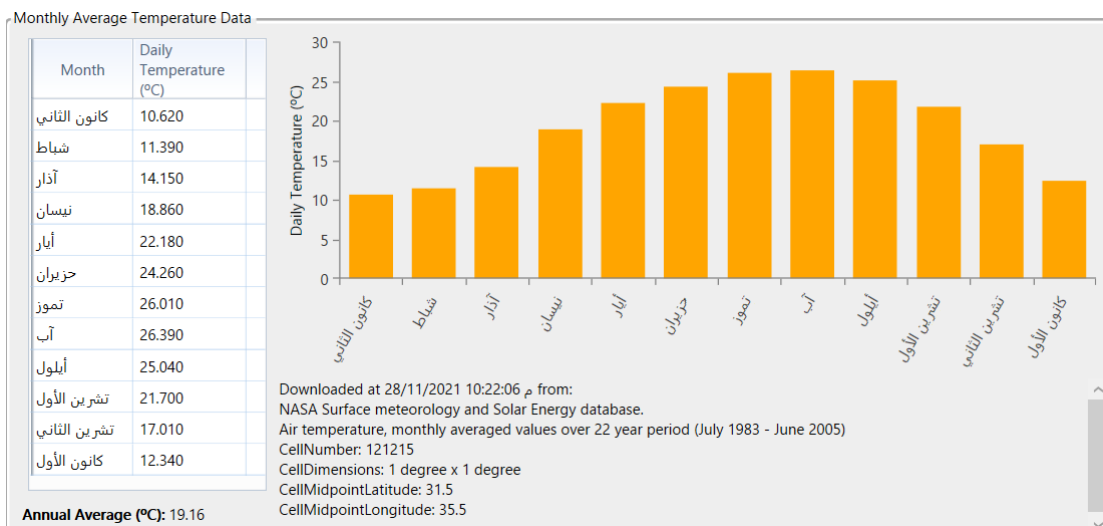


Figure (5. 3): average daily temperatures.

5.3 The AC loads and dc loads data.

5.3.1 AC loads.

The AC loads hour by hour per day during 12 months of the year and these values are packed based on the values of the worst month of the year which is January as it is considered the most energy consuming month in the region Figure (5.4) as shows AC load data contains daily profile, seasonal profile and yearly profile hour by hour.

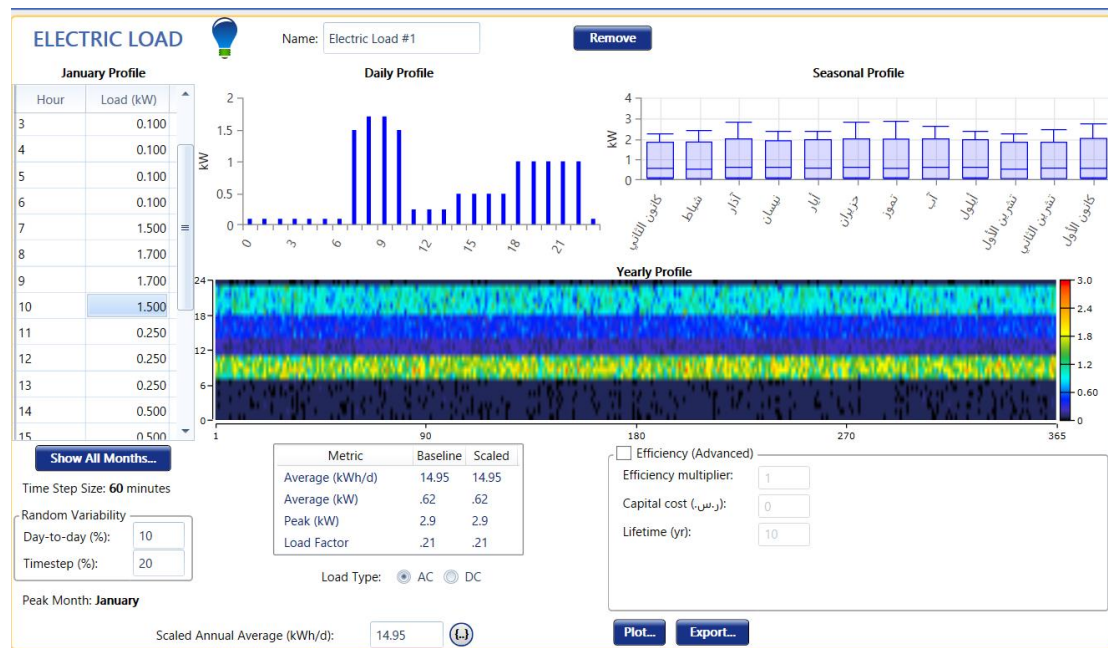


Figure (5. 4): AC Load data.

Table (5. 1): AC Data.

hour	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec
0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
7	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
8	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
9	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
10	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
11	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
12	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25

13	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
14	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
15	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
16	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
17	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
18	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1
23	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

The Figure (5.5) as shows the daily energy consumption in the village in January, hour by hour.

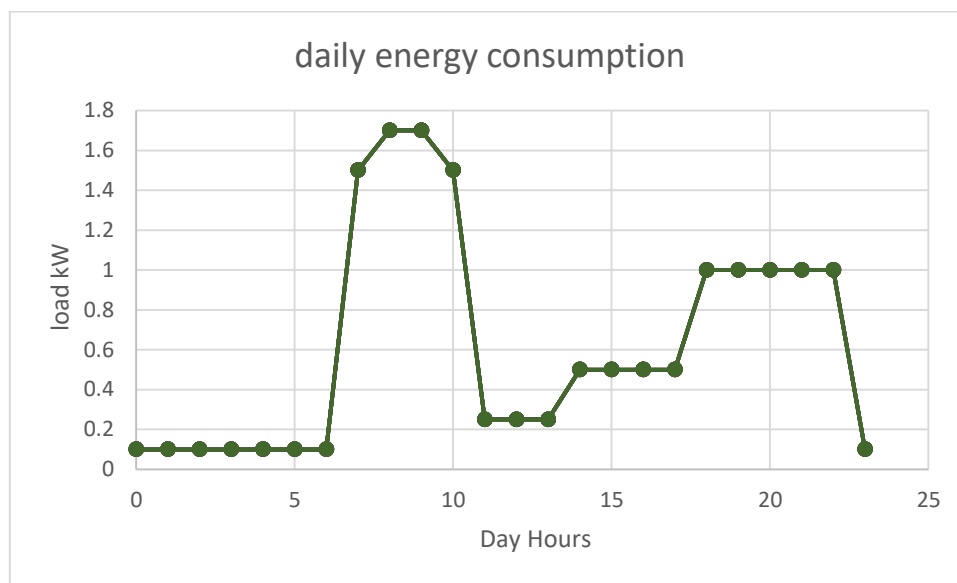


Figure (5. 5): daily energy consumption.

The image taken, in the Figure (5.6) as shows the hourly energy consumption in the village throughout the days of the year, hour by hour based on the daily load packed above, and the Figure (5.7) as shows scaled data monthly averages

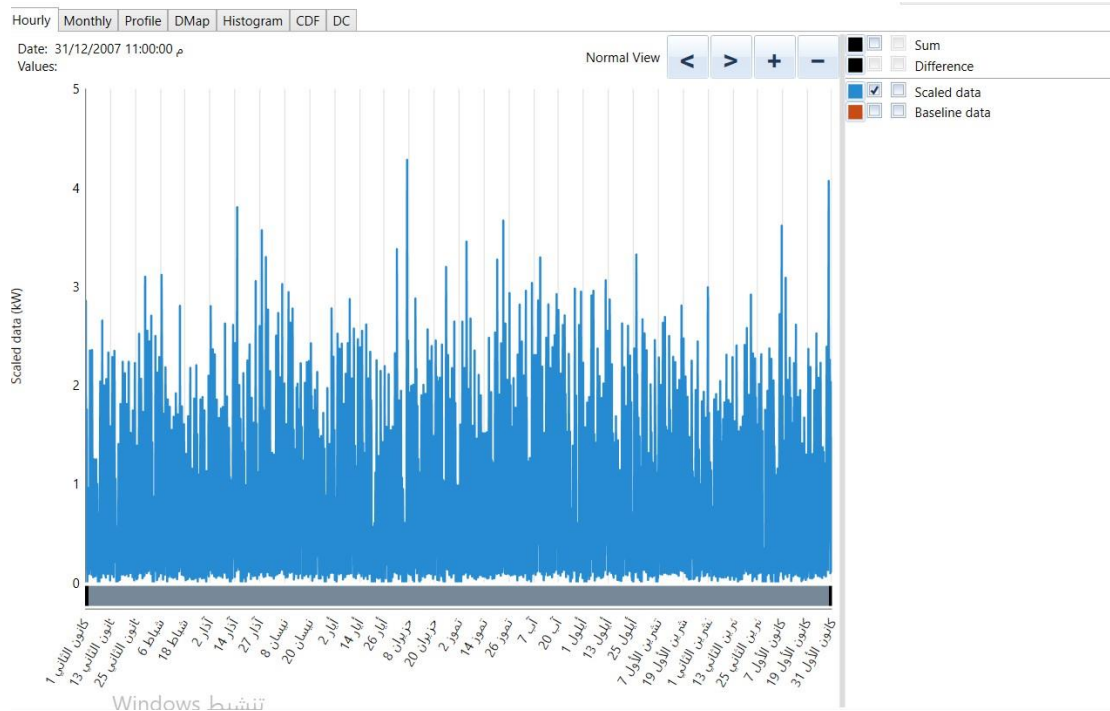


Figure (5. 6): hourly energy consumption.

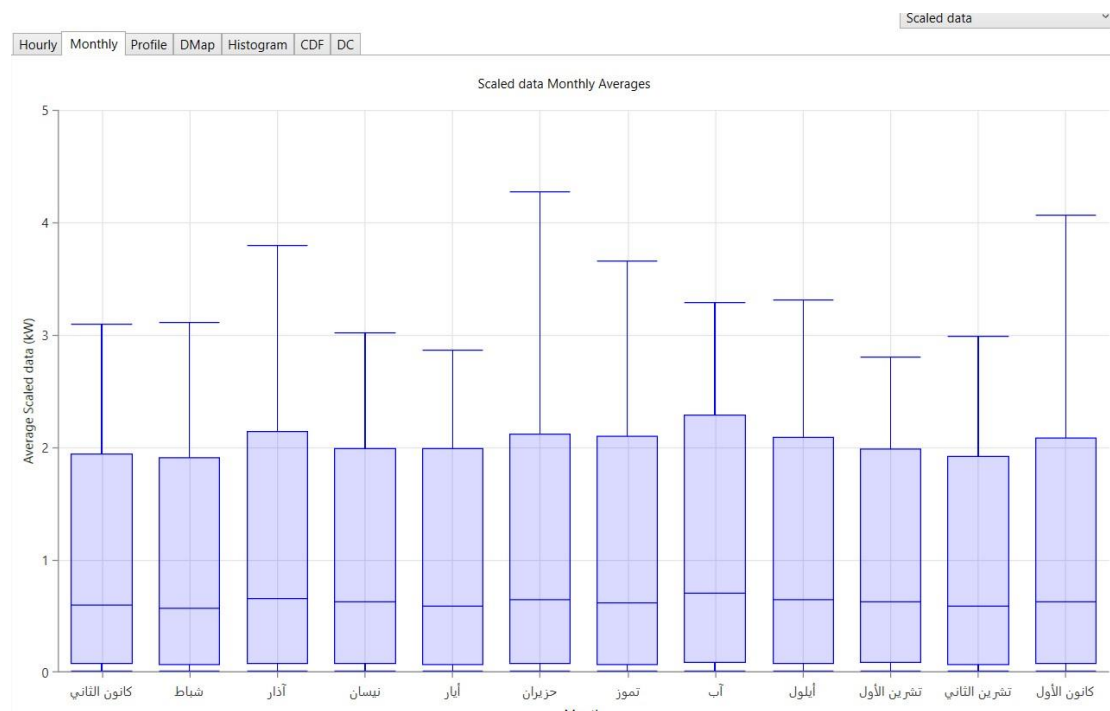


Figure (5. 7): scaled data monthly averages.

5.3.2 DC load data.

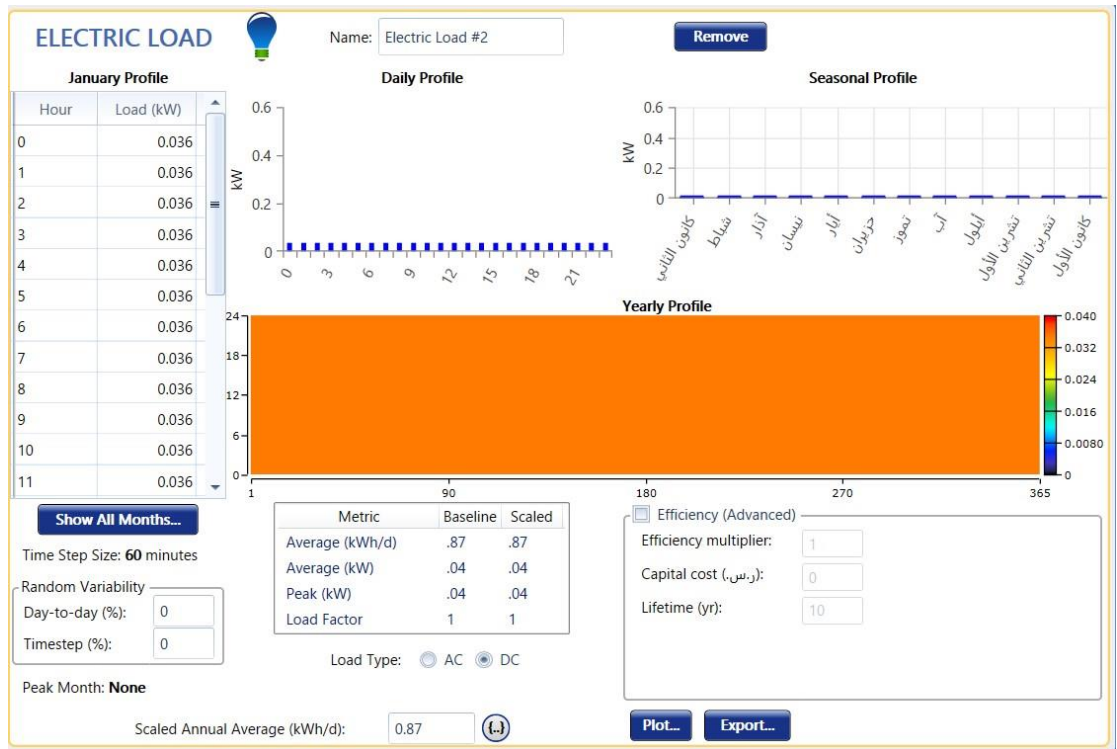


Figure (5. 8): DC load data.

5.4 Pv data.

The values and data of the solar panels were entered into the program as shown in the figure below.

This section includes price, efficiency and panel capacity.

Add/Remove Jinko JKM535-60

PV Name: Jinko JKM535-60 Abbreviation: Jinko60

Properties

Name: **Jinko JKM535-60**
Abbreviation: **Jinko60/535**
Panel Type: **Flat plate**
Rated Capacity (kW): **7**
Temperature Coefficient: **-0.410**
Operating Temperature (°C): **45.00**
Efficiency (%): **16.8**
Manufacturer: **Jinko Solar**
[Data Sheet for JKM275-60](#)
Notes:
60 Poly-crystalline cells.
Jinko Solar's Eagle 60 PERC cell line can range in nominal maximum power from 255 to

Capacity (kW)	Capital (ريال)	Replacement (ريال)	O&M (ريال/year)
0.535	460.30	0.00	0.00

Lifetime time (years): 25.00

Site Specific Input

MPPT Advanced Input Temperature

Explicitly model Maximum Power Point Tracker

Lifetime (years): 15.00

Size (kW)	Capital (ريال)	Replacement (ريال)	O&M (ريال/year)
1	0.00	0.00	0.00

Search Space

Size (kW)
1

Use Efficiency Table?

Efficiency (%): 95


Input Percentage (%) Effi

[Click here to add new item](#)

Figure (5. 9): PV Data.

5.5 Storage Data.

The values and data of the batteries have been entered into the program and include the values as shown in the figure below.

STORAGE  Name: Abbreviation:

Properties

Kinetic Battery Model
Nominal Voltage (V): 12
Nominal Capacity (kWh): 3.09
Maximum Capacity (Ah): 257
Capacity Ratio: 0.503
Rate Constant (1/hr): 0.339
Roundtrip efficiency (%): 80
Maximum Charge Current (A): 45
Maximum Discharge Current (A): 300
Maximum Charge Rate (A/Ah): 1

Batteries

Quantity	Capital (ر.س.)
<input type="text" value="1"/>	<input type="text" value="1,338.75"/>
Lifetime	

Figure (5. 10): Storage data.

5.6 Inverter Data.

The Figure (5.11) as shows the XW Pro 8.5 M inverter was selected from the program, , and the price of the inverter was determined, this price includes the price of the charge controller based on the program's algorithm as well.

The screenshot shows the 'CONVERTER' software interface. At the top, there is a dropdown menu for 'XW Pro 8.5' and a 'Complete Catalog' button. Below this, the 'Properties' section displays the selected inverter's name and abbreviation, along with a link to technical data. The 'Costs' section contains a table with columns for Capacity (kW), Capital (E.S.), and Replacement (E.S.). The 'Inverter Input' section includes input fields for Lifetime (years) and Efficiency (%), and a checked checkbox for 'Parallel with AC generator?'.

Figure (5. 11): Inverter Data.

The results related to electrical production as Figure (5.12) shows.

Production	kWh/yr	%
Jinko JKM535-60	11,813	100
Total	11,813	100

Consumption	kWh/yr	%
AC Primary Load	5,475	94.5
DC Primary Load	316	5.45
Total	5,791	100

Quantity	kWh/yr	%
Excess Electricity	5,084	43.0
Unmet Electric Load	0	0
Capacity Shortage	0.158	0.00270

Quantity	Value
Renewable Fraction	100
Max. Renew. Penetration	14,957

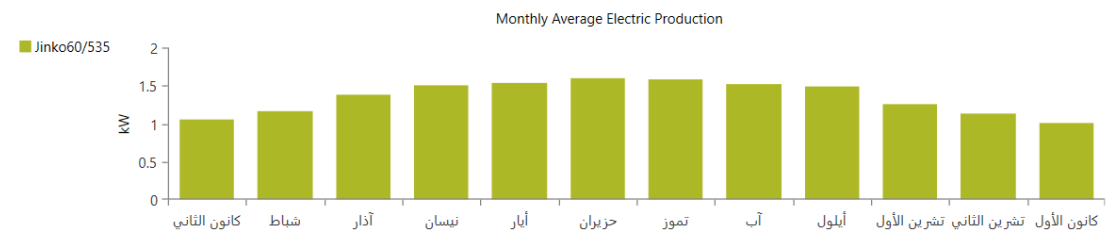


Figure (5. 12): results related to electrical.

5.7 Electrical results.

The results regarding the batteries the Figure (5.13) as shows.

The system needs 84.1 hours of storage in the worst conditions.

Those are equal to 4 days of storage.

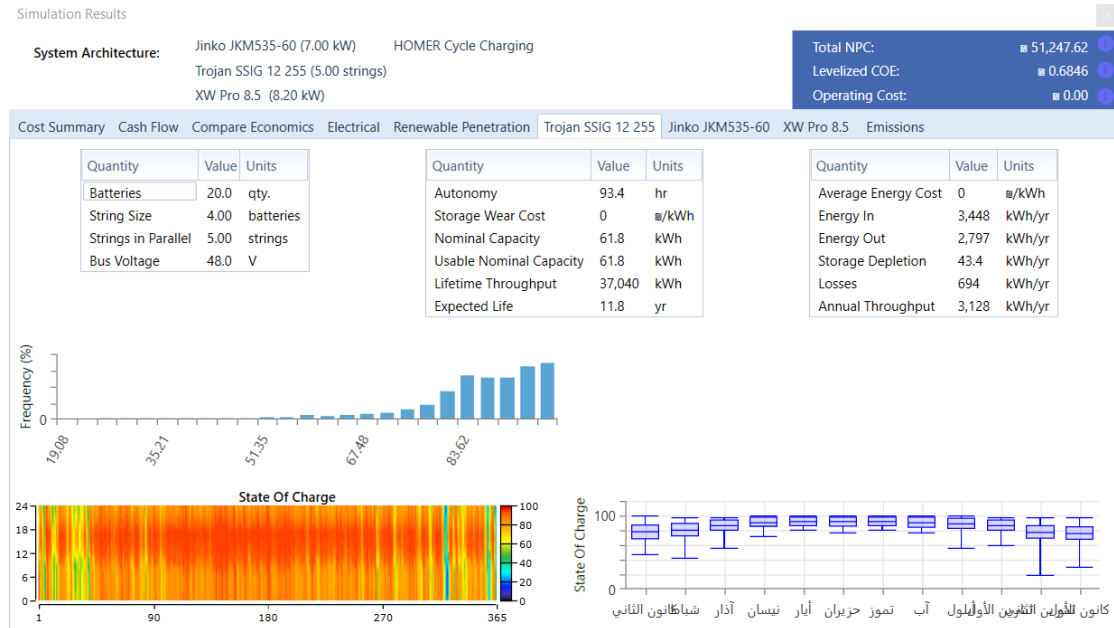


Figure (5. 13): Electrical results.

The results related to the solar panels the Figure (5.14) as shows.

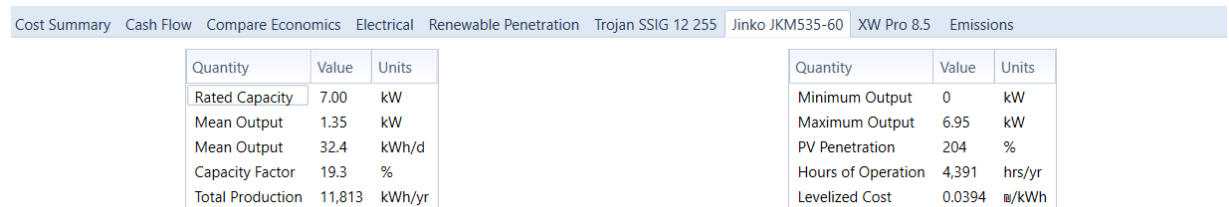


Figure (5. 14): results of solar panels.

The results related to the inverter the Figure (5.15) as shows.

Quantity	Inverter	Units
Capacity	8.20	kW
Mean Output	0.625	kW
Minimum Output	0	kW
Maximum Output	4.28	kW
Capacity Factor	7.62	%

Quantity	Inverter	Units
Hours of Operation	8,669	hrs/yr
Energy Out	5,475	kWh/yr
Energy In	5,763	kWh/yr
Losses	288	kWh/yr

Figure (5. 15): results of the inverter.

5.8 Economic result

As for the economic results, the Homer program presented many acceptable and unacceptable scenarios and chose the least expensive ones based on the program's work algorithm based on the values entered by the user Figure (5.16) as shows.

Component	Capital (,ر.س.)	Replacement (,ر.س.)	O&M (,ر.س.)	Fuel (,ر.س.)	Salvage (,ر.س.)	Total (,ر.س.)
Jinko JKM535-60	■ 6,022.62	■ 0.00	■ 0.00	■ 0.00	■ 0.00	■ 6,022.62
Trojan SSIG 12 255	■ 26,775.00	■ 0.00	■ 0.00	■ 0.00	■ 0.00	■ 26,775.00
XW Pro 8.5	■ 18,450.00	■ 0.00	■ 0.00	■ 0.00	■ 0.00	■ 18,450.00
System	■ 51,247.62	■ 0.00	■ 0.00	■ 0.00	■ 0.00	■ 51,247.62

Figure (5. 16): system components costs.

The program simulated 56 scenarios for the system, 14 of them were available, and in the end, only one of the solutions was chosen because it is the least expensive among all the others.

The Figure (5.17) (a) as shows, some of the possible solutions were more expensive than other solutions. Some solutions, for example, contain 20 batteries, some contain 40 batteries, and others contain more than that. The first solution was chosen based on the economic paradox, as the first solution was the least expensive among them all.

As the Figure (5.17) (a) and (b) shows, some of the possible solutions were more expensive than others. Some solutions for example have 20 batteries, some have 24, and some have more. The first solution was chosen on the basis of economic inconsistency, the first solution being the least expensive of them all.

For example, in the solutions as Figure (5.17) (a) and (b) shows, the cost of the system was about 185123 ILS, and some solutions cost less than that and some are higher than that. In the end, the least expensive solution was chosen, which cost about 51248 ILS, based on the economic comparison The Figure (5.17) (b) as shows.

	Jinko60/535 (kW)	SSIG 12 255	XW Pro (kW)	COE (₪)	NPC (₪)	Initial capital (₪)	Elec Prod (kWh/yr)	Elec Cons (kWh/yr)
	7.00	20	8.20	0.685	51,248	51,248	11,813	5,791
	7.00	20	8.20	0.685	51,248	51,248	11,813	5,791
	7.00	20	8.20	0.685	51,248	51,248	11,813	5,791
	7.00	20	8.20	0.685	51,248	51,248	11,813	5,791
	7.00	24	8.20	0.756	56,603	56,603	11,813	5,791
	7.00	24	8.20	0.756	56,603	56,603	11,813	5,791
	7.00	32	8.20	0.899	67,313	67,313	11,813	5,791
	7.00	40	8.20	1.04	78,023	78,023	11,813	5,791
	7.00	60	8.20	1.40	104,798	104,798	11,813	5,791
	7.00	80	8.20	1.76	131,573	131,573	11,813	5,791
	7.00	120	8.20	2.47	185,123	185,123	11,813	5,791

a)

Jinko60/535 (kW)	SSIG 12 255	XW Pro (kW)	Initial capital (₪)
7.00	20	8.20	51,248
7.00	20	8.20	51,248
7.00	20	8.20	51,248
7.00	20	8.20	51,248
7.00	24	8.20	56,603
7.00	24	8.20	56,603
7.00	32	8.20	67,313
7.00	40	8.20	78,023
7.00	60	8.20	104,798
7.00	80	8.20	131,573
7.00	120	8.20	185,123

b)

Figure (5. 17): possible solutions and economic comparison.

6

Chapter sex: Recommendations and final results.

6.1 Structure.

6.2 Final results.

6.3 Recommendations.

6.1 Structure.

The system rack is designed from galvanized steel and installed on a concrete floor where the details of wind speed and weather conditions such as snow and rain have been taken into account in the design Figure (6.1) as shows.

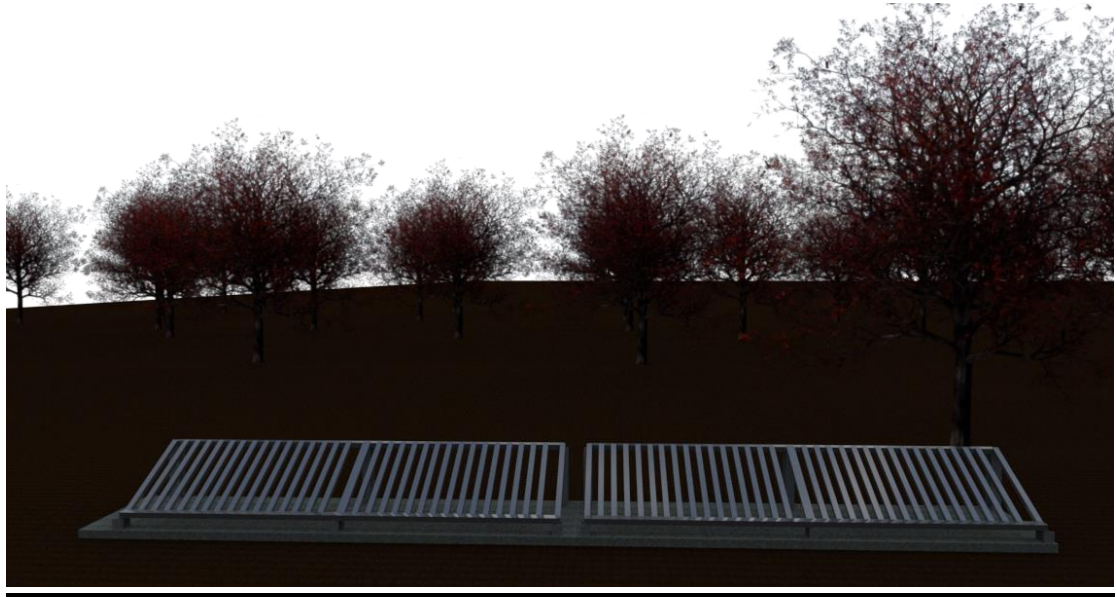


Figure (6. 1): Structure Design.

Steel costs (500 kg) were calculated and were 2000 ILS

And the costs of concrete (6 cups) were 2000 ILS

Taking into account the costs of manpower 3500 ILS

- ❖ The costs of building the electrical system in terms of manpower are as follows:

$$cost_{NHW} = cost_{BOS} * cost_{O\&M} \quad (6.1)$$

$$= (0.10 * 51248) + (0.05 * 51248)$$

$$= 13131 \text{ ILS}$$

The pvsyst program was used to determine tilt angle Figure (6.2) as shows.

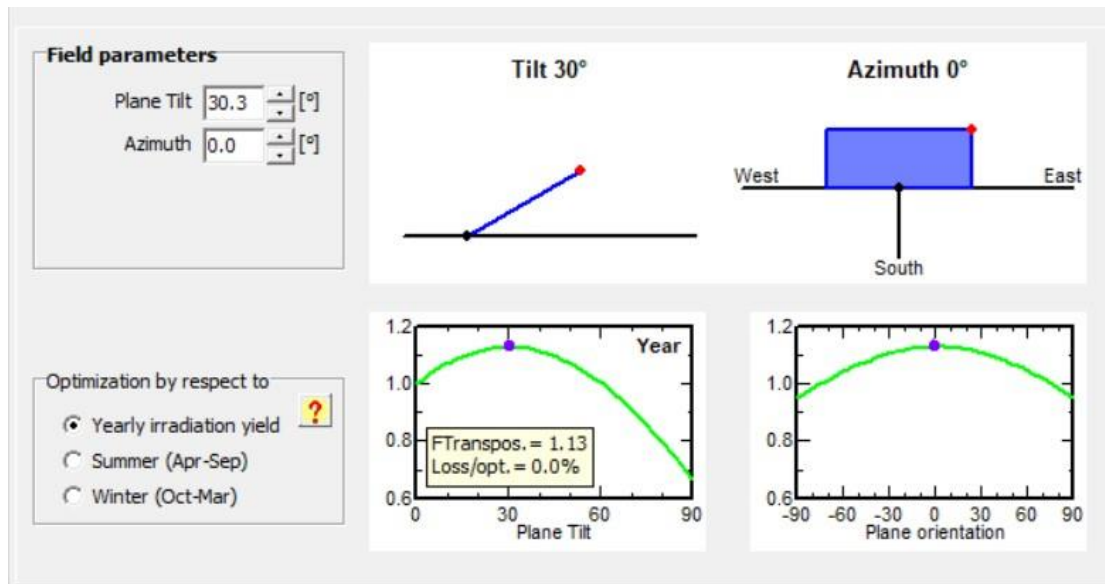


Figure (6. 2): determining tilt angle by pvsyst program.

Based on the location data that was entered into the program, tilt angle of 30 degrees was chosen in order to avoid the largest possible losses due to the shadow (the angle was chosen based on the annual rate, not the quarterly average) as Figure (6.3) shows.

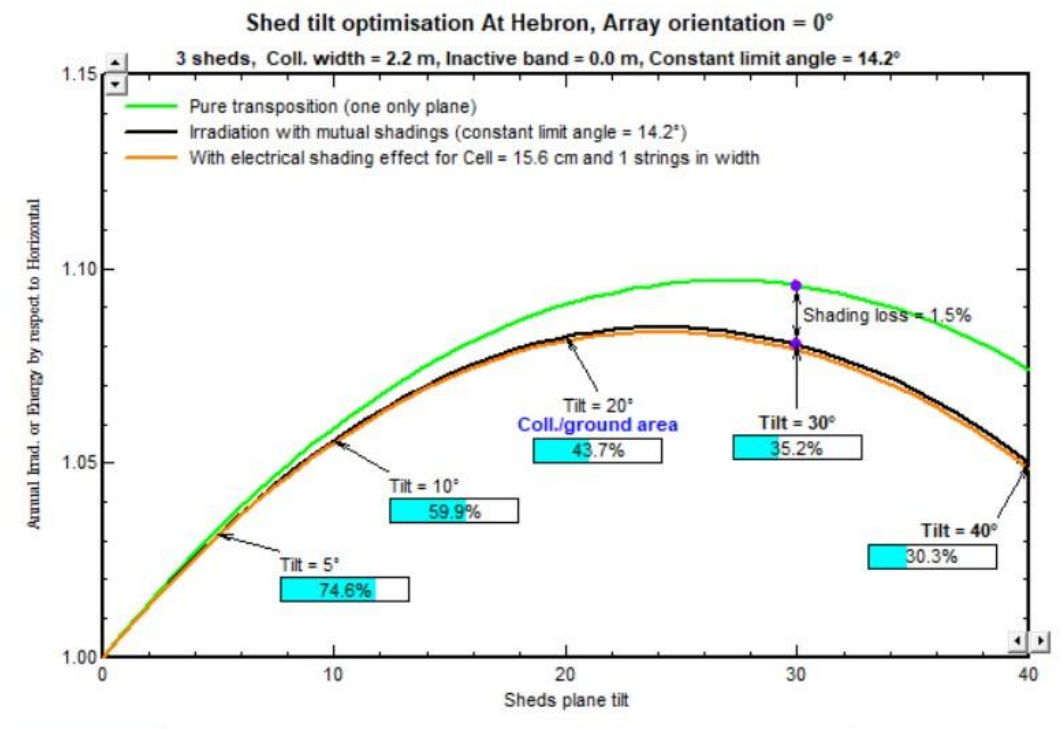


Figure (6. 3): shadow effect by pvsyst program.

And based on the values entered into the program, the optimal distances and details were chosen to build the structure of the system as Figure (6.4) shows.

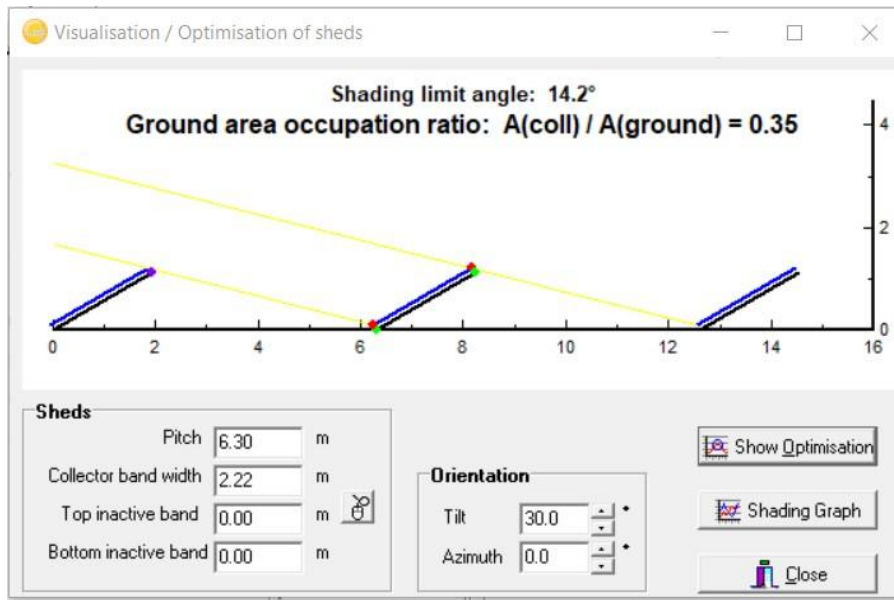


Figure (6. 4): details of structure by pvsyst program.

Based on the details taken from the program, the structure of the project was determined, taking into account the area of the land on which the project structure is located, as Figure (6.5) shows.

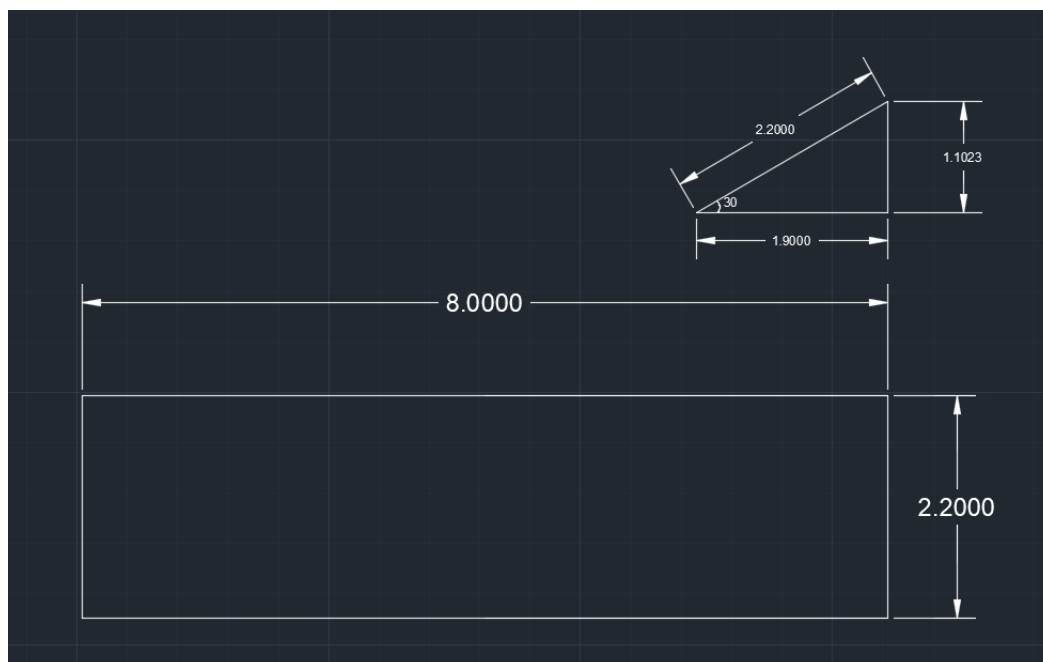


Figure (6. 5): Horizontal and front projection of the structure by AutoCAD program.

After studying many scenarios, it was chosen to build two structures for the system on a land area of 40 square meters

6.2 Final results.

Table (6. 1): Electrical results.

Pannels	Load consumption		Batteries				Invertert			
	AC load	Dc load	Quantity	String size	Strings parallel	Bus voltage	Autonomy	Days of storage	Capacity	Energy out
11813 kWh/yr	5475 kWh/yr	316 kWh/yr	20	4	5	48	93.4	4	8.2 kW	5475 kWh/yr
—	Total = 5791 kWh/yr		—					—		

Table (6. 2): Economic results.

Pannels	6022	ILS
Batteries	26775	ILS
Inverter	18450	ILS
Steel	2000	ILS
Concrete	2000	ILS
Manpower due to (steel & concrete)	3500	ILS
$cost_{BOS} + cost_{O\&M}$	13131	ILS
TOTAL	71878	ILS

As explained previously, the project consists of five solar units separated from the grid. Calculations and simulations have been made for one of these five units, and the other is completely identical to the case studied. The results and costs that have been reached are for one unit and accordingly the final cost becomes:

$$5 * 71878 = 359390 \text{ ILS (+ OR - 10\%).}$$

6.3 Recommendations.

1. Maintaining the cleanliness of the solar panels constantly to obtain the highest efficiency
2. Avoid building or placing high equipment in front of the panels to avoid any shadows on them
3. Building a room for electrical equipment such as inverters and batteries, and providing the necessary cooling for them.
4. Taking into account the mechanism of arranging the solar panels so that the largest possible amounts of cables connecting them are shortened.

References:

- [1] (Palestinian News and Information Agency)
https://info.wafa.ps/ar_page.aspx?id=9073 . (8/2/2020)
- [2] [UTL Optional Off-Grid Hybrid Solar System \(1KWp\), Capacity: 1KWp - 5KWp, Rs 65000 /kilowatt | ID: 22193817391 \(indiamart.com\)](#) (12/2/2020).
- [3]<https://www.cleanenergyreviews.info/blog/mppt-solar-charge-controllers>
(12/2/2020).
- [4] <https://sunwatts.com/2-7-kwh-trojan-12v-signature-flooded-battery-ssig-12-255/>
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- [5]<https://solar.schneider-electric.com/product/xw-pro-solar-hybrid-inverter/>
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- [6]<https://arabic.alibaba.com/product-detail/milk-suction-machine-prices-cow-milking-machine-1077189802.html> (15/3/2020).
- [7] <https://dergipark.org.tr/en/download/article-file/679294>**Authors**
Maher Al-Maghalseh (12/25/2021)
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- [9]<https://www.wiley.com/enus/Renewable+and+Efficient+Electric+Power+Systems+%2C+2nd+Edition-p-9781118633502> (16/3/2020)
- [10] <https://geomolg.ps/L5/index.html?viewer=A3.V1> (10/4/2020)
- [11] <https://www.homerenergy.com/products/pro/docs/index.html> (30/11/2021)

Appendix A

SPECIFICATIONS

Module Type	JKM515M-7TL4-V		JKM520M-7TL4-V		JKM525M-7TL4-V		JKM530M-7TL4-V		JKM535M-7TL4-V	
	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
Maximum Power (Pmax)	515Wp	383Wp	520Wp	387Wp	525Wp	391Wp	530Wp	394Wp	535Wp	398Wp
Maximum Power Voltage (Vmp)	41.50V	38.35V	41.60V	38.46V	41.70V	38.56V	41.80V	38.66V	41.90V	38.72V
Maximum Power Current (Imp)	12.41A	9.99A	12.50A	10.06A	12.59A	10.13A	12.68A	10.20A	12.77A	10.28A
Open-circuit Voltage (Voc)	49.04V	46.19V	49.14V	46.28V	49.24V	46.38V	49.34V	46.47V	49.44V	46.57V
Short-circuit Current (Isc)	13.14A	10.61A	13.23A	10.69A	13.32A	10.76A	13.41A	10.83A	13.50A	10.90A
Module Efficiency STC (%)	20.37%		20.56%		20.76%		20.96%		21.16%	
Operating Temperature(°C)	-40°C~+85°C									
Maximum system voltage	1500VDC (IEC)									
Maximum series fuse rating	25A									
Power tolerance	0~+3%									
Temperature coefficients of Pmax	-0.35%/°C									
Temperature coefficients of Voc	-0.28%/°C									
Temperature coefficients of Isc	0.048%/°C									
Nominal operating cell temperature (NOCT)	45±2°C									

تنشيط Windows

Appendix B

Model No.	150/45
Electrical Data	
Max. Solar Input Power	650 / 1300 / 1950 / 2600 W
Max. Solar Panel Open Circuit Voltage	150 V
Max. Solar Panel Short Circuit Current	50 A
Nominal System (Battery) Voltage	12 / 24 / 36 / 48 V
Self-Consumption	≤ 35 mA
Peak Conversion Efficiency	98.00 %

Appendix C

12 VOLT

PHYSICAL SPECIFICATIONS

MODEL NAME	TERMINAL TYPE *	DIMENSIONS * INCHES (mm)			WEIGHT † LBS. (kg)	HYDROLINK OR SPWK	HANDLES
		LENGTH	WIDTH	HEIGHT †			
SSIG 12 255*	6	14.97 (380)	6.91 (176)	14.67 (373)	123 (56)	SPWK	Braided Rope

ELECTRICAL SPECIFICATIONS

VOLTAGE	CAPACITY * AMP-HOURS (Ah)					ENERGY (kWh)
	10-Hr	20-Hr	48-Hr	72-Hr	100-Hr	
12	211	229	237	247	255	3.06

CHARGING INSTRUCTIONS

CHARGER VOLTAGE SETTINGS (AT 77°F/25°C)			
SYSTEM VOLTAGE	12V	24V	48V
Maximum Charge Current (% of C ₂₀ Rate)*	13%		
Maximum Absorption Phase Time (hours)	4		
Absorption Voltage **	14.70	29.40	58.80
Float Voltage	13.50	27.00	54.00
Equalization Voltage	16.20	32.40	64.80

Do not install or charge batteries in a sealed or non-ventilated compartment. Constant under or overcharging will damage the battery and shorten its life as with any battery.
 *If charging time is limited contact Trojan Technical Support for assistance.
 **In cases where controller has a bulk voltage setting, use absorption voltage setting above.

RECYCLE RESPONSIBLY



CHARGING TEMPERATURE COMPENSATION

ADD	SUBTRACT
0.005 volt per cell for every 1°C below 25°C 0.0028 volt per cell for every 1°F below 77°F	0.005 volt per cell for every 1°C above 25°C 0.0028 volt per cell for every 1°F above 77°F

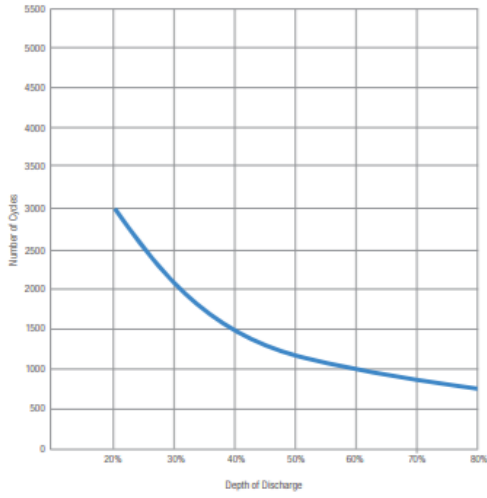
OPERATIONAL DATA

OPERATING TEMPERATURE	SELF DISCHARGE
-4°F to 113°F (-20°C to +45°C). At temperatures below 32°F (0°C) maintain a state of charge greater than 60%.	5 – 15% per month depending on storage temperature conditions.

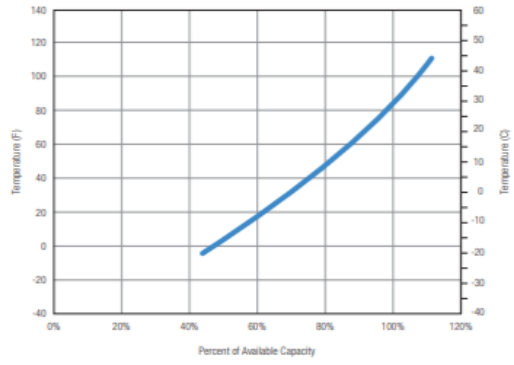
STATE OF CHARGE MEASURE OF OPEN-CIRCUIT VOLTAGE

PERCENTAGE CHARGE	SPECIFIC GRAVITY	CELL	12 VOLT
100	1.277	2.122	12.73
90	1.258	2.103	12.62
80	1.238	2.083	12.50
70	1.217	2.062	12.37
60	1.195	2.040	12.24
50	1.172	2.017	12.10
40	1.148	1.993	11.96
30	1.124	1.969	11.81
20	1.098	1.943	11.66
10	1.073	1.918	11.51

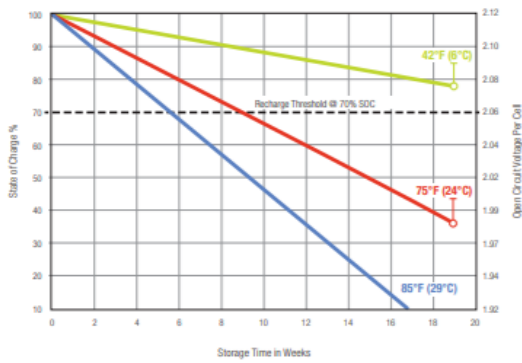
DOD VS CYCLE LIFE IN A STATIONARY APPLICATION



PERCENT CAPACITY VS. TEMPERATURE



SELF DISCHARGE VS. TIME*



EXPECTED LIFE VS. TEMPERATURE

Chemical reactions internal to the battery are driven by voltage and temperature. The higher the battery temperature, the faster chemical reactions will occur. While higher temperatures can provide improved discharge performance the increased rate of chemical reactions will result in a corresponding loss of battery life. As a rule of thumb, for every 10°C increase in temperature the reaction rate doubles. Thus, a month of operation at 35°C is equivalent in battery life to two months at 25°C. Heat is an enemy of all lead acid batteries, FLA, AGM and gel alike and even small increases in temperature will have a major influence on battery life.

*PERIODIC CHARGE

FREQUENCY

Provide a periodic freshening charge to maintain a SOC greater than the threshold of 70%.

Appendix D

Technical Specifications

Conext™ XW Pro 8.5 kW 230V (IEC)	
Inverter AC output (standalone)	
Output power (continuous) at 25°C	6800 W
Overload 30 min/60 sec at 25°C	8500 W / 12000 W
Output power (continuous) at 40°C	6000 W
Maximum output current 60 seconds (rms)	53 A
Output frequency	50/60 Hz
Output voltage	230 V +/- 3%
AC Output Frequency	50.0 +/- 0.1 Hz
Total harmonic distortion at rated power	< 5 %
Idle consumption search mode	< 7 W
Input DC voltage range	40 to 64 V (48 V nominal)
Maximum input DC current	180 A
Charger DC output	
Maximum output charge current	140 A
Output charge voltage range	40 – 64 V (48 V nominal)
Charge control	Three stage, two stage, boost, external BMS, custom
Charge temperature compensation	Battery temperature sensor included
Power factor corrected charging	0.98
Compatible battery types	Flooded (default), Gel, AGM, Lithium ion, custom
AC input	
AC 1 (grid) input current (selectable limit)	3 – 60 A (56 A default)
AC 2 (generator) input current (selectable limit)	3 – 60 A (56 A default)
Automatic transfer relay rating/typical transfer time	60 A/8 ms
AC input voltage range	165 - 280 V
AC input frequency range (bypass/charge mode)	45 – 55 Hz (default) 40 – 68 Hz (allowable)
AC grid-tie output	
Grid sell current (selectable)	0 to 27 A
Grid sell power	5000 W
Efficiency	
Peak	95.0%

