Design a photovoltaic solar system for Hebron Governmental Hospital "Alia Hospital"

By

Student name:

Ibrahim Amlah

Supervisor: Name(s):

Prof. Dr. Sameer Khader

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الاهداء:

الى معلمنا و قدوتنا و حبيبنا و شفيعنا محمد صلى الله عليه وسلم.

الى من رسموا بدمائهم خارطة الوطن وطريق المستقبل و هندسوا.

بأجسادهم معاقل العز و الكرامة الى من هم اكرم منا جميعا الى شهداء الوطن الحبيب.

الى الذين عشقوا الحرية التي تفوح منها رائحة الياسمين وتواروا خلف القضبان ليفسحوا لنا النور الى اسرانا الابطال.

إلى أبي و أمي .... فلولاهما لما وُجِدتُ في هذه الحياة ، ومنهما تعلَّمت الصمود و حب الحياة ، مهما كانت الصعوبات .

الى خطيبتي........ رفيقة الكفاح و الظروف الصعبة التي لم تبخل بوقت أو جهد لمساعدتي و دعمي.

إلى جميع أخوتي و أهلي و الأقارب و الأصدقاء

إلى أساتذتي الأفاضل ....، فمنهم استقيتُ الحروف ، وتعلَّمت كيف أنطق الكلمات، وأصوغ العبارات، وأحتكم إلى القواعد في مجال.....

إلى الزملاء والزميلات، الذين كان لهم الفضل في دعمهم لي و لم يتوانوا للحظة في مدي بالبيانات و المعلومات اللازمة لإعداد رسالتي .

أهدي إليكم مشروعي.

داعيًا المولى -سبحانه وتعالى- أن تُكلَّل بالنجاح والقبول من جانب أعضاء لجنة المناقشة المُبجَّلين.

Abstract

Alternative energy is one of the most important fields of future energy, which helps reduce dependence on the public electricity network, and from here the idea of the project came, which is to design a solar energy system that works to cover the consumption of Hebron Governmental Hospital “Alia Hospital” as the weakness of the public electricity network that has proven Its shortcomings are in the continuous cut off of the electric current, which is the largest and controlled source of the electric current in Palestine. Therefore, it has been relied on electric generators to cover this deficit in the network, and one of its most important defects is the pollution resulting from the process of burning fuel in order to produce energy, which is promising It is not desirable in health care places, hence the idea of the project to design a solar energy system that reduces dependence on generators and works to cover the deficit in the network.

الملخص

تعد الطاقة البديلة هي احد اهم مجالات الطاقة المستقبلة و التي تساعد في تقليل الاعتماد على شبكة الكهرباء العامة و من هنا جاءت فكرة المشروع و هي تصميم نظام طاقة شمسية يعمل على تغطية استهلاك مستشفى الخليل الحكومي" مستشفى عالية" حيث ان ضعف شبكة الكهرباء العامة التي اثبتت عيوبها في القطع المستمر للتيار الكهربائي الذي يعد الاحتلال الاسرائيلي هو المصدر الاكبر له في فلسطين و المتحكم فيه ولذلك تم الاعتماد على مولدات الكهربائية في تغطية هذا العجز في الشبكة و التي من اهم عيوبها التلوث الناتج عن عملية احتراق الوقود من اجل انتاج الطاقة و التي تعد بالأمر غير المحبذ في اماكن الرعاية الصحية فمن هنا جاءت فكرة المشروع في تصميم نظام طاقة شمسية يقلل من الاعتماد غلى المولدات و يعمل على تغطية العجز الموجود في الشبكة.

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Overview

Photovoltaic offer consumers the ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells. The word photovoltaic comes from "photo," meaning light, and "voltaic," which refers to producing electricity. Therefore, the photovoltaic process is "producing electricity directly from sunlight." Photovoltaic are often referred to as PV, PV systems are often cost justified even when grid electricity is not very far away. When applications require larger amounts of electricity and are located away from existing power lines. photovoltaic systems can in many cases offer the least expensive.

1.1 Photovoltaic system type [1].

Photovoltaic system can generally be classified according to connection between PV system and grid:

1. On grid system

They are also called on-grid or utility interactive. Grid-tied systems are designed to operate in parallel with and interconnected with the electric utility grid.

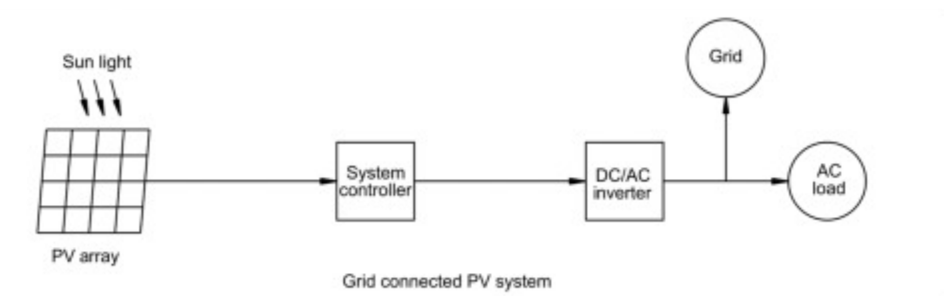


Fig.1.1: Grid connected PV system

2. off grid system

They are most common in remote locations without utility grid service , off-grid solar-electric systems can work anywhere. They are generally designed and sized to supply DC and/or AC electrical load.

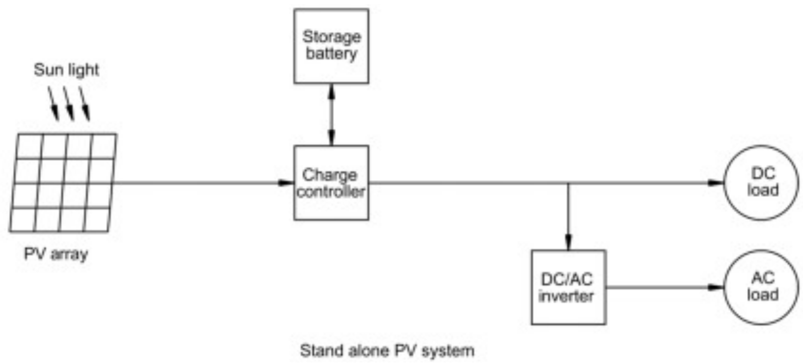


Fig.1.2: off grid system

1. Hybrid system

A Hybrid Solar Photovoltaic (PV) System is a combination of both the On-Grid and Off-Grid Solar PV Systems. Thus, it is connected to the grid while having localised power storage in the form of batteries as well.

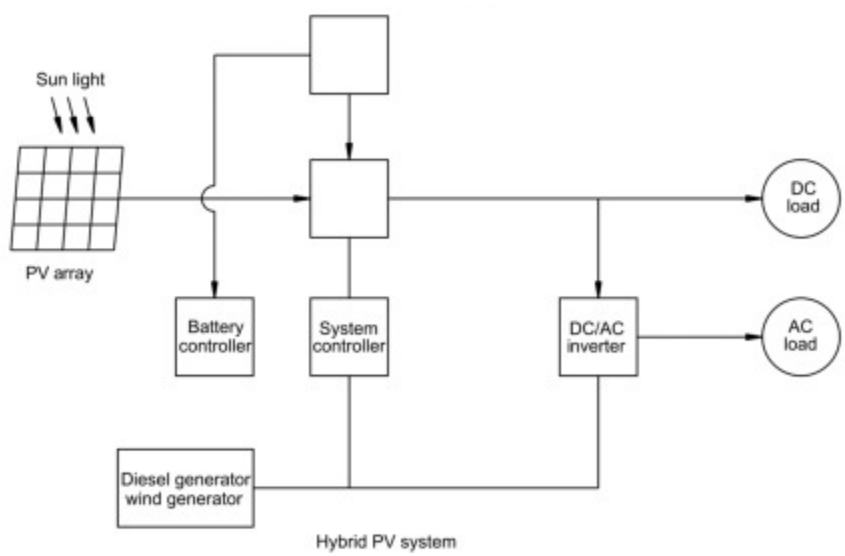


Fig.1.3: Hybrid system

1.2. Electricity in Palestine (Challenges and difficulties)

The energy sector acts as a key enabler across all industries. Access to a stable and reasonably priced energy supply is an important driver of economic growth: wastewater treatment plants, manufacturing sites, high tech-hubs, hotels, and many other facilities require reliable power in order to operate effectively. In addition, households require electricity for families to lead a comfortable life, schools need it to create a functional learning environment, and hospitals depend on it to provide a consistent quality of care for patients. [2]

1.3 Research problems

1) High electrical loads in public buildings and the hospital building in particular, which increases the electrical burden on the public network.
2) Constant and frequent power outages.
3) Constant need for electricity in operating rooms and intensive care units.

1.4 Project motivation

The importance of the project lies in promoting the use of alternative energy systems in public centers with high electrical consumption, reducing the use of traditional electrical generators, and providing a clean environment in health care centers.

1.5 Project Objectives

The main objectives of the project are to overcome the above-mentioned problems as follows:

- Study electrical loads and determine which loads have the highest energy consumption.
- Designing a solar energy system that covers the largest amount of electrical load consumption in the Alia Governmental Hospital building.
- Reducing dependence on traditional electricity generators, including reducing pollution resulting from these generators.

1.6 Time Schedule.

Illustrates the tasks that we did and how long it takes weekly for each task.

Table (1.1): First semester:

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

2

Chapter 2: Study the Site of Alia Governmental Hospital

Introduction
General study.
detail study hospital location.
Study the climatic nature of the site
Samaritan

2.1 Introduction

It is necessary to study the general site in which the solar energy system will be installed, as this study provides a clear vision of the nature of the general site and shows whether the installation of solar energy systems is effective or not.

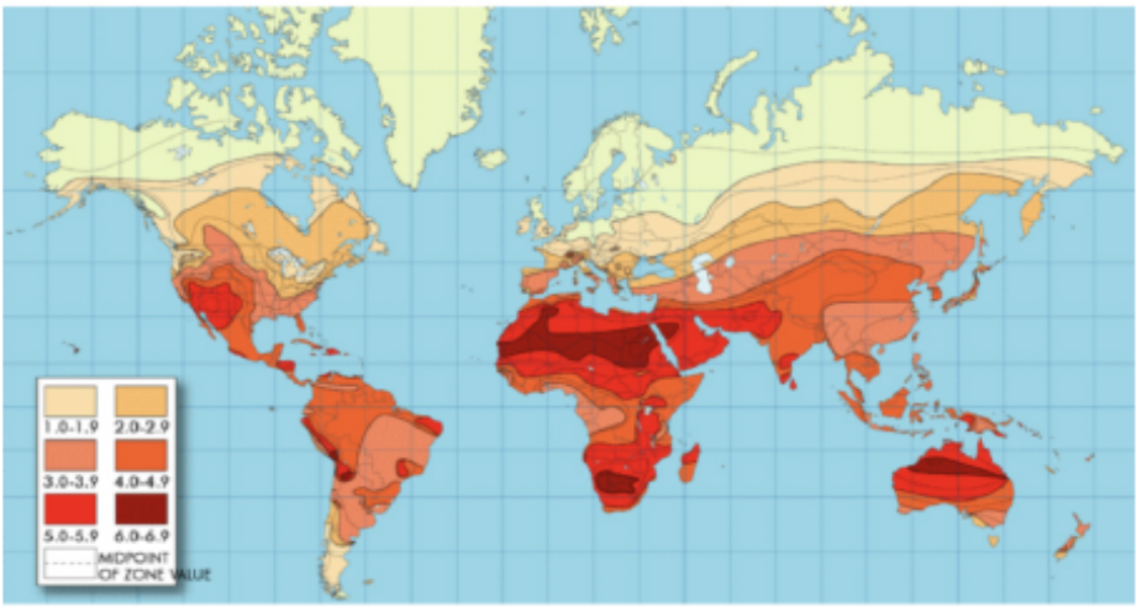


Fig.2.1: Peak Sun Hour Map [3]

Figure 2.1, The West Bank is among the countries that come in the second category in terms of peak hours.

2.2. General study.

In order to obtain an effective solar energy system design, it is necessary to study the general site in which the system will be installed. Through this chapter, we shed light on the study of all the conditions surrounding the solar system, the study of the site, and the study of the climatic nature of the site. figure two shows the hospital location in Hebron.

Fig.2.2: Aerial view of Alai Governmental Hospital "Google Maps"

2.3. detail study hospital location.

The mountainous nature of Hebron has given Alia Governmental Hospital an advantage, as the hospital building is located in a rising mountainous area, which helped it not to form any shadows from the neighboring buildings on the roof of the hospital building, as the roof of the hospital building is the best place to invest solar energy on it.

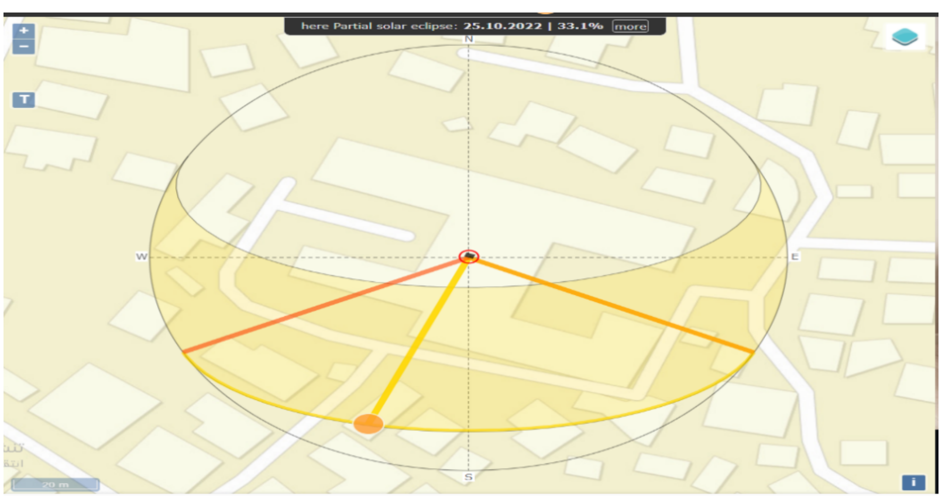


Fig.2.3: Sun path of the sun's movement "suncalc".

Figure 2.3 shows us the path of the sun's movement and the orientation of the buildings. The obtained data from the mentioned sun bath.

Table 2.1: the data I collected from the "Suncalc" program during the months of the year.

month	Sun tilt angle	Peak sun radiation at: hour
January	32.42	**11:44**
February	42.31	**11:53**
March	54.05	**11:50**
April	63.49	**12:41**
May	76.54	**12:36**
June	75.19	**12:38**
July	70.38	**12:44**
August	61.38	**12:45**
September	51.62	**12:36**
October	41.38	**12:27**
November	41.38	**11:23**
December	35.63	**11:30**

From table 2.1 it can be noted that the loges day is 21 June and at the shortest 21 the September.

2.4 Study the climatic nature of the site

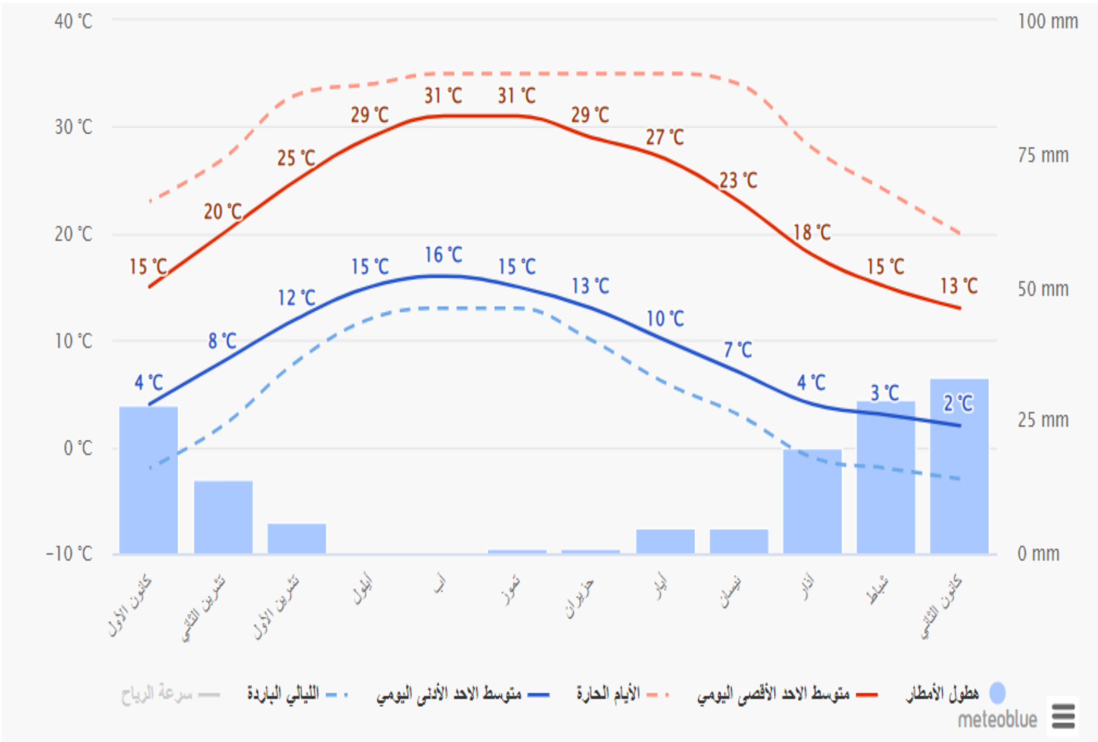


Fig.2.4: Average Temperatures

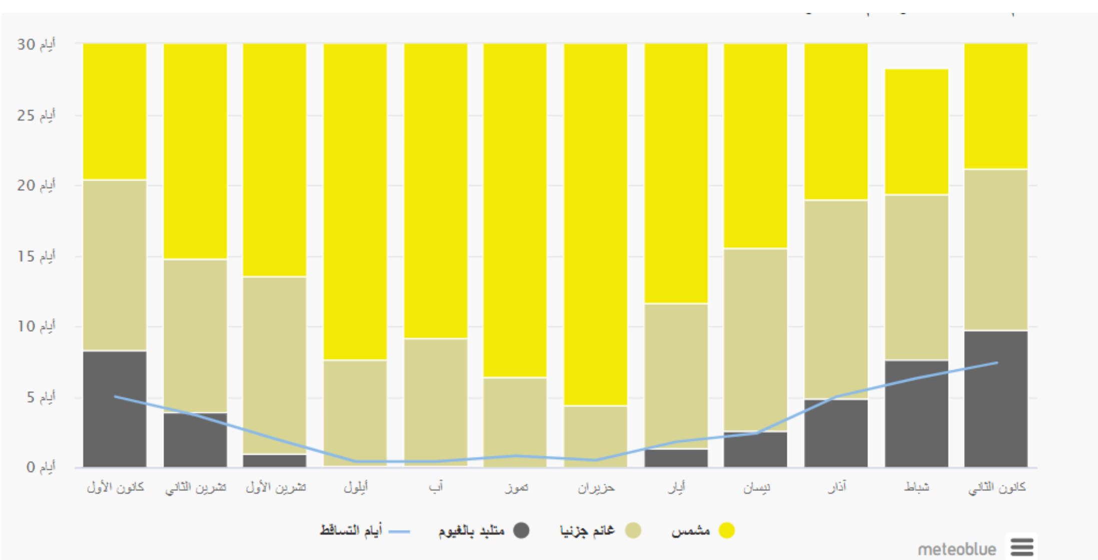


Fig.2.5: Sunny days

Figure 2.5 shows the sunny days, cloudy days, partly cloudy days, and rainy days over the course of the year.

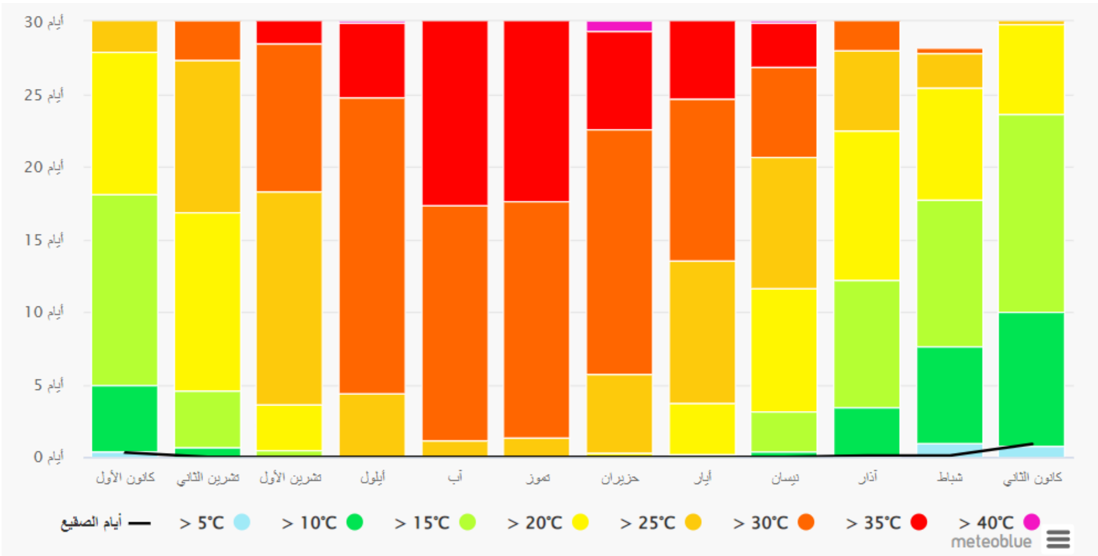


Fig.2.6: Temperature distribution throughout the year

From Figure 2.6, we notice that the highest temperature was recorded in the month of 6 and the lowest temperature was recorded in the month of 1.

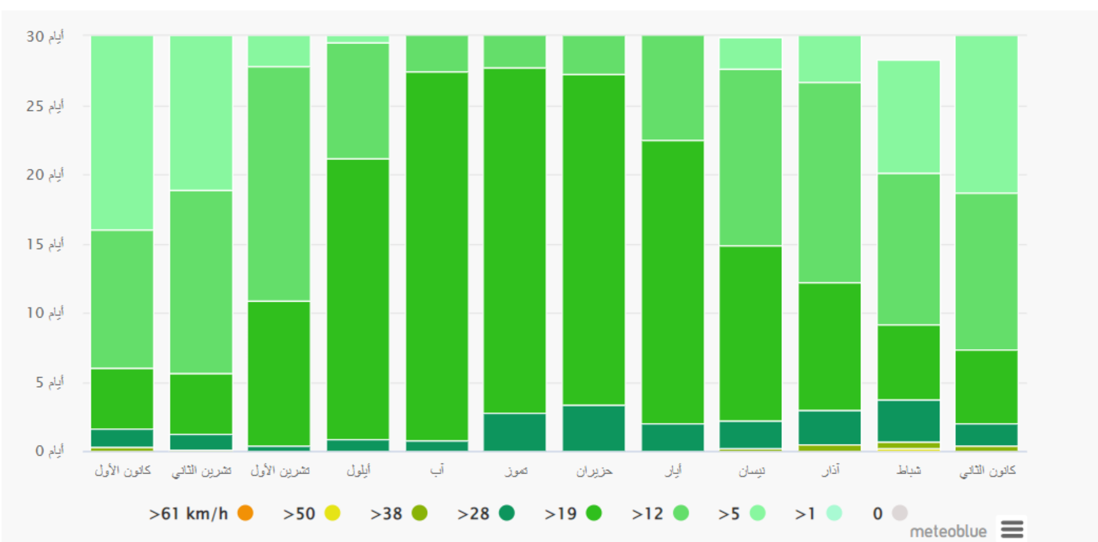


Fig.2.7: Wind speed throughout the year.

Figure 2.7 shows us that January, December and March are the months with the highest speed of holidays throughout the year.

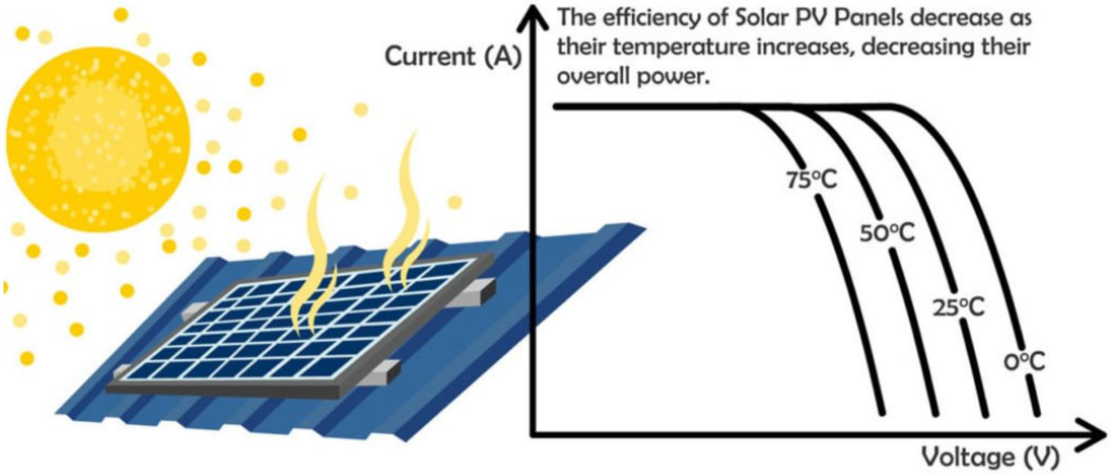


Fig.2.8. Temperature effect

It is necessary to know the effect of temperature on solar energy systems, as it becomes clear from Figure 2.8 that the increase or decrease in temperature directly affects the electrical voltage and to a small extent on the electrical current. 2.4 It shows us that the highest temperature is less than 40 degrees, but for a few days, while the rest of the days of the year have moderate temperatures below 30 degrees.

The study of the site is important because it helps us determine the procedures for installing the system and determine several requirements in order to choose the metal structure and determine if the site is suitable for installing the system.

3

Chapter 3: Study of electrical loads and consumption in the Alia hospital.

Introduction

Electric load consumption data.

The measured consumed energy

Calculation

3.1 Introduction:

In many countries of the world, Hospitals are major consumers of energy. In order to assess the potential for energy savings in such facilities, a study of electrical loads Is conducted on the campus of Hebron Governmental ALIA. The aim of this study Is to analyze the energy consumption of the different loads and sections in the hospital and identify the loads and sections with a maximum consumption rate of the existing loads and identify their operation regime and characters and sections that consume the most electrical energy among all hospital facilities. The ever-increasing energy costs and environmental concerns make rational use of energy and energy conservation efforts (mission) of great importance. Governmental and state-owned buildings in general, especially old ones, are good for conducting energy audits and suggesting solutions to conserve energy and promote efforts toward enhancing the environment in the region. Therefore, it is necessary to know the reasons responsible for the high energy consumption.

Through this chapter, a brief analysis and discussions should be conducted about the electrical consumption in the various hospital facilities and departments.

Initially, Studying the electrical loads in each department separately, as a result of this survey, the following data illustrates the consumption rates of electrical loads in the hospital.

Fig.3.1. Hospital departments.

3.2. Electric load consumption data.

Intensive care unit (ICU):

It is the most important department in the hospital, as patients in this department need special care, so it is imperative that there be an electrical system in the hospital that is commensurate with this importance. The current equipment is equipped with an internal UPS system. Table 3.1 shows the consumption of the section.

Table 3.1 ICU Section consumption.

	average consumption of the section (kWhr)	Consumption of luminaires (kWhr)
Consumption value	21.200	1.8

Department of General Surgery:

The department's consumption is concentrated in the air conditioning units distributed over 12 rooms, where each room contains an air conditioner with a volume of 2 tons.

Note that 2 tons = 7.0337 kilowatts. [4]

$$\text{Total capacity of air conditioning units} = \text{Number of air conditioning units} \times single\ unit\ capacity \qquad (3.1)$$

Total capacity of air conditioning unit $=12 \times 7{,}0337 = 84{,}4044\ k\text{Whr}$

Table 3.2 Department of General Surgery Section consumption.

	Consumption of units (kWhr)	Consumption of luminaires (kWhr)	Total consumption
Consumption value	84.4044	1.6	90.0044

Operations department:

It can be noticed that the energy consumption is only during the operations time, and from, which means it is impossible to determine the exact consumption of the section. It is necessary to mention the devices that consume energy and represented in the sterilization devices that work for two hours a day and that consume energy of 11 kilowatts per day the one. It is necessary to calculate the consumption value of the lighting units in the corridors of the section, which consume the energy of the 1kw/hr. The operating rooms contain several devices that work during the operation, which are anesthesia devices, an X-ray device, a planning device, a lighting unit, and an operating bed.

Department of Physical Therapy:

The department works for seven hours a day, as the consumption in this department is not considered large compared to the other departments. Table 3.3 The total consumption of the department is placed.

Table 3.3 Department of Physical Therapy Section consumption

	Section consumption (kWhr)
Consumption value	8.020

Emergency department:

By studying the consumption of this section, we noticed that this section does not have a high electrical consumption, as the consumption is concentrated in lighting units, two blood pressure testers, three electrocardiographs, and lighting units distributed over the section, such as the total consumption of 1 kw/hr. The department operates throughout the day

Outpatient Department:

In this department, there is no high electrical consumption, as this department works to conduct an examination of the patient. In this section, there is no high electrical consumption, as this section works to conduct an examination of the patient. Table 3.4 shows the amount of consumption of the section.

Table 3.4 Outpatient Department Section consumption

	Section consumption (kWhr)
Consumption value	2

finance department:

We worked on studying the loads in the section, as the loads in this section consist of computers, printers and lighting units. Table 3.5 shows the depreciation value in the section.

Table 3.5 Outpatient Department Section consumption

	Section consumption (kWhr)
Consumption value	2.5

pharmacy:

Consumption in the pharmacy is represented in lighting units in addition to a refrigerator for storing medicines, as the total consumption is equal to 840 watts hour from 8 to 3 hours. As for the rest of the day, consumption is limited to the refrigerator for storing medicines, which operates with an electrical capacity of 400 watts hour and works for a period of time. 16 hours.

maternity section:

The total consumption of this section is estimated at 1-kilowatt hour, in which consumption is focused on lighting units in addition to the nursery and the natural delivery room.

Department of Radiology and MRI:

This section is the most energy-consuming in the hospital building through the operation of tomography scanners, as the consumption in this section is from 0.5 to 50 kWhr. The radiology department consists of three X-ray devices with a capacity of 21 kilowatts, as the number of devices operating in this department is two, in addition to the tomography device, the power it consumes is 11.1 kilowatts, as it works for h hours per day because it is The only device in the department as this device is connected to a 12 kW UPS.

Magnetic resonance device This device needs high electrical energy as it consumes electrical energy of 20 kWhr and the department works for 7 hours a day as the magnetic resonance department is connected to the UBS system with an electrical capacity of 30 kilowatts and the UBS room contains three air-conditioning units The volume of one ton per unit, which means an electrical capacity of 10.5 kWhr.

We note from the information we collected from the department that the total consumption is 52.1 kWhr.

Lighting in the corridors:

The hospital corridors contain 187 lighting units with an average electrical capacity of 30 watts per unit, which means that the total consumption is 61.5 kWhr.

Sterilization devices in the hospital There are three sterilization devices in the hospital that operate over ten hours per day, with an electrical capacity of 35.56 kW for each sterilization unit, meaning that the total capacity in the event of all devices working reaches 178 kWhr, knowing that one unit is in operation.

Air conditioning units:

There are four air-conditioning units in the building. Only two units operate, and the other two units are standby units, with a total consumption of 13 kWhr.

electric lifts:

The building contains five old electric elevators, as there are two elevators with an electrical capacity of 11 kWhr and the other two elevators operate with an electrical capacity of 7 kWhr, and the fifth elevator operates with an electrical capacity of 5 kWhr, meaning that it needs a total energy equal to 41 A kWhr multiplied by a demand factor of 0.6 means that it needs 24.6 kWhr of energy. From the results we obtained previously, the following table shows the total consumption of the hospital.

blood bank:

There are many devices in this section that consume electrical energy and have a high consumption, and when we studied the existing loads, we found that most of the devices were connected directly with UPS systems, and we found that the average consumption of the section reaches 40 kWhr.

After studying the consumption of all electrical loads and devices in each section and determining the value of the total consumption for each section, since the values were taken in the month of 2 we converted these values into the monthly consumption and by specifying in the month of 2 as Table 3.1 shows the consumption values during the month of 2.

Table 3.6 Shows the consumption of hospital departments.

Section	Consumption amount (kW month)
ICU	**16560**
GENERAL SURGERY	**38563.2**
Operations	**360**
PHYSICAL THERAPY	**1684.2**
EMERGENCY	**720**
OUTPATIENT	**420**
FINANCE	**525**
PHARMACY	**380.4**
MATERNITY	**720**
RADIOLOGY & MRI	**37512**
LIGHTING	**44280**
AIR CONDITION	**9360**
ELECTRIC LIFTS	**17712**
blood bank	**16800**
TOTAL	**185596.8**

Suppliers can also reduce overall power consumption by choosing low power CPUs and screens in their more advanced devices. High power equipment such as autoclaves should have automatic monitoring at the plug level, so that technical staff can receive warnings when such equipment has exceeded a predetermined run time and can investigate. All of these strategies can be complemented with staff energy awareness programmers and good routines at the end of shifts for shutting off unnecessary equipment [5].

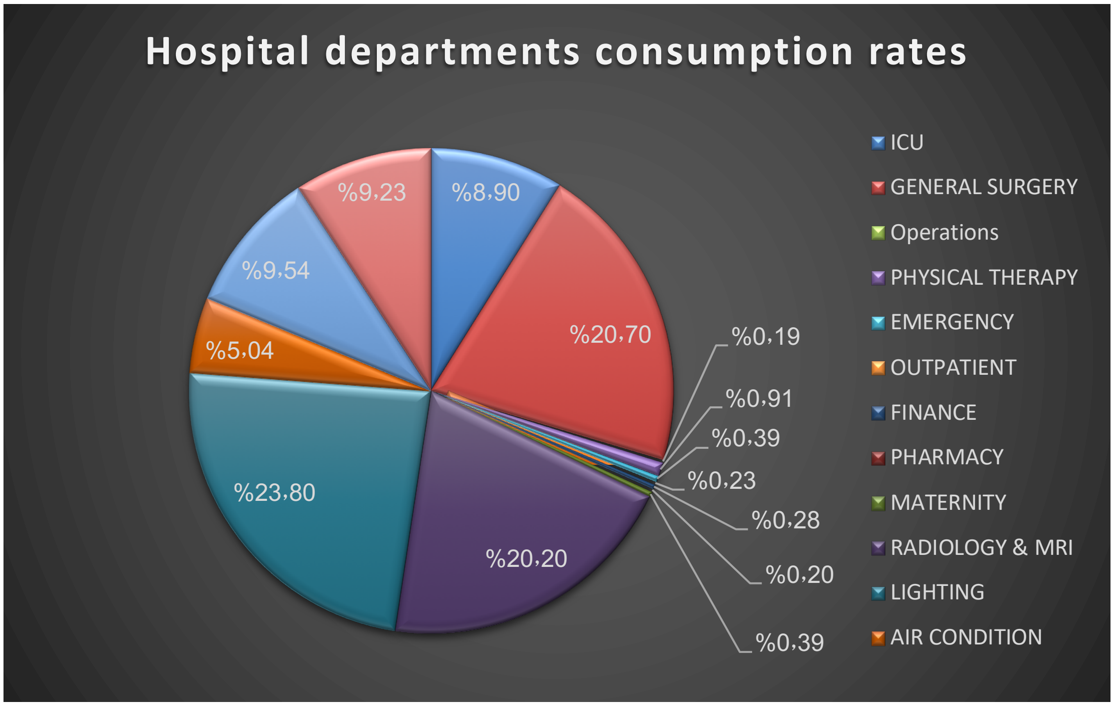


Fig.3.2: The consumption chart of hospital sections.

From Figure 3.2, we note the division of electrical loads, and we note that the highest consumption was recorded in the corridors lighting, and then the most consumption comes from the General Surgery Department, as the two departments constitute 64.5% of the total hospital consumption value. Hence, we will work on giving suggestions to reduce consumption.

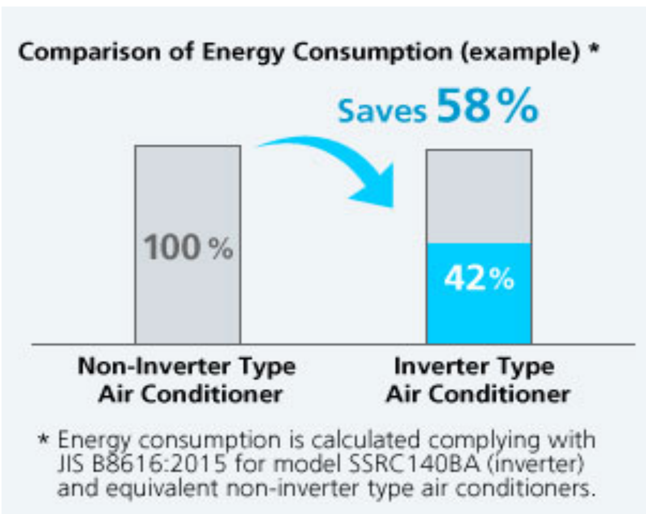
Lighting in the corridors:

The lighting in the hospital is the most energy consuming, as it constitutes 28.8% of the hospital consumption, and this is due to several reasons, which is the distribution of lighting inside the hospital in an unbalanced and inappropriate manner. Therefore, solutions must be proposed to treat this high consumption.

In the beginning, the lighting units must be distributed in a manner compatible with the neighborhood and the place, and after that it is necessary to use the visible lighting units and not to use the lighting units covered with the net, because it neglects to limit the amount of lighting reaching the place and reduce the amount of lighting that is used, and also it is necessary to use LED lighting units are considered the best currently and the least energy consuming.

GENERAL SURGERY:

The Department of General Surgery is one of the second highest departments in energy consumption, so it is necessary to determine the reason for the high energy consumption, as we find the reason for the high energy is the use of air conditioning units distributed over the rooms of the department. Therefore, a solution to this high consumption "must be followed through the use of air conditioning units Motor speed in non-inverter type air conditioners remains constant and temperature is adjusted by turning the motor ON and OFF, which consumes more energy. In inverter type air conditioners, temperature is adjusted by changing motor speed without turning the motor ON and OFF. Compared to non-inverter type air conditioners, air conditioners with inverters have less power loss and can save in energy" [6].



Department of Radiology and MRI:

medical imaging equipment is a class of high-energy consuming products widely used today in hospitals, imaging centers and radiological practices. Energy-efficient medical devices play a key role in reducing environmental impacts, but achieving higher rates of energy efficiency also requires better management of devices when they are not in use. MRIs are also used in imaging centers and radiological practices. There the contribution of the energy consumption of imaging equipment is much larger than 19%. [6]

Cylindrical MRI scanners generate a powerful magnetic field through a cryo-cooled superconductive magnet which has to operate 24h/d and cannot be turned off (only for emergency reasons). Therefore MRI scanners consume energy even when switched to off-mode to maintain the liquid helium at the temperature of 4 Kelvin. Nonetheless good environmental use behavior, such as switching the MRI scanner to off mode during night hours, can significantly reduce the yearly energy consumption by up to 21,8%, as determined by the COCIR study on MRI (www.cocir. org). The graph represents daily energy consumption and savings of a MRI scanner compared to a situation where the scanner is left in ready-to-scan mode for all 24 hours.

In order to reduce the consumption of X-ray devices, it is preferable to replace these devices, as their feet give them a low energy utilization factor, so it is better for suppliers to use new devices with a high energy benefit factor and low energy consumption.

General tips to reduce energy consumption in hospitals:

how changing energy delivery systems to an "on-demand" model could dramatically reduce energy consumption in hospitals. This design applies mainly to ventilation energies (electrical and thermal), but our results suggest that it has theoretical potential also in the area of hospital equipment. Putting this into practice, however, will require suppliers to build in functions which allow their equipment to safely enter a low-power standby mode and to power up quickly when needed. Automatic power-down functions need to be equipment specific; for example, if a piece of lab equipment has no sample loaded, then it should go into standby after some minutes. Many of these power saving functions are now incorporated into other portable IT devices such as smartphones. Most hospital equipment with display screens should at least have functions which turn off the screen after 10-20 minutes without user input. For equipment types such as patient monitors this may not be desirable; in such cases the screen should at least have backlighting and go into low light mode.[7]

Suppliers can also reduce overall power consumption by choosing low power CPUs and screens in their more advanced devices. High power equipment such as autoclaves should have automatic monitoring at the plug level, so that technical staff can receive warnings when such equipment has exceeded a predetermined run time and can investigate. All of these strategies can be complemented with staff energy awareness programmes and good routines at the end of shifts for shutting off unnecessary equipment.

3.3 The measured consumed energy

The following is a study of the hospital consumption for the past five years. according to the records of referring to the records of the Hebron Electricity Company, where table2- table 5 illustrate the annual consumption of the energy for the mentioned period.

Table 3.7: Monthly consumption for 2013

Consumption in 2013	
Month	**Consumption (kW month)**
January	25128
February	25402
March	25592
April	25847
May	26148
June	26783
July	27122
August	27488
September	27750
October	27997
November	28209
December	285580
Total	322024

Table 3.8 " Monthly consumption for 2014"

Consumption in 2014	
Month	**Consumption (kW month)**
January	28747
February	29007
March	29238
April	29483
May	29688
June	29950
July	30419
August	30943
September	31572
October	32038
November	32317
December	32593
Total	365995

Table 3.9: Monthly consumption for 2015

Consumption in 2015	
Month	**Consumption (kW month)**
January	**32881**
February	**33157**
March	**33407**
April	**33663**
May	**33875**
June	**34275**
July	**34683**
August	**35233**
September	**35658**
October	**36396**
November	**36536**
December	**36771**
Total	**452931**

Table 3.10: Monthly consumption for 2016

Consumption in 2016	
Month	**Consumption (kW month)**
January	**37028**
February	**37293**
March	**37553**
April	**37802**
May	**38068**
June	**38667**
July	**39219**
August	**39922**
September	**40464**
October	**41047**
November	**41461**
December	**41779**
Total	**470303**

Table 3.11: Monthly consumption for 2017

Consumption in 2017	
Month	**Consumption (kW month)**
January	**42036**
February	**42398**
March	**42696**
April	**42988**
May	**43776**
June	**43956**
July	**43956**
August	**45444**
September	**63101**
October	**46719**
November	**47140**
December	**47429**
Total	**508683**

Table 3.12: Monthly consumption for 2018

Consumption in 2018	
Month	**Consumption (kW month)**
January	**47777**
February	**48129**
March	**48438**
April	**48767**
May	**49131**
June	**49736**
July	**50332**
August	**50994**
September	**51747**
October	**52441**
November	**53018**
December	**53301**
Total	**603811**

Table 3.13: Monthly consumption for 2019

Consumption in 2019	
Month	Consumption (kW month)
January	34800
February	35300
March	34500
April	32100
May	36300
June	51600
July	63800
August	74100
September	68600
October	66600
November	51900
December	28800
Total	578400

Table 3.14: Monthly consumption for 2020

Consumption in 2020	
Month	Consumption (kW month)
January	34300
February	38300
March	33700
April	32900
May	28000
June	43400
July	52300
August	83900
September	73200
October	73600
November	56700
December	27300
Total	577600

Table 3.15: Monthly consumption for 2021

Consumption in 2021	
Month	**Consumption (kW month)**
January	27500
February	41500
March	33500
April	29000
May	33900
June	47100
July	49200
August	70000
September	77100
October	55400
November	43700
December	34500
Total	542400

Table 3.16: Monthly consumption for 2022

Consumption in 2022	
Month	**Consumption (kW month)**
January	11500
February	21800
March	30120
April	39320
May	46440
June	56760
July	71680

Table 3.17: Annual consumption of the hospital.

Annual consumption	
Consumption amount (kW/years)	**Year**
322024	**2013**
365995	**2014**
452931	**2015**
470303	**2016**
508683	**2017**
603811	**2018**
578400	**2019**
577600	**2020**
542400	**2021**

3.4 Calculation

Referring to table 8, the average energy consumption

$$average\ consumption = \frac{Total\ consumption\ over\ the\ past\ nine\ years}{The\ number\ of\ years}\ . \qquad (2)$$

$$= \frac{3266147}{8} = 362905{,}2222 Kw/years$$

Avoid we the rate of increase in hospital consumption is equal to:

$$Consumption\ increase = \frac{current\ year\ consumption}{Previous\ year's\ consumption}. \qquad (3)$$

$$= \frac{542400}{362905{,}2222} = 1{,}494\ \ increase,$$

Energy by calculating the rate of increase =
542400 * ١,٤٩٤ = ٨١٠673,8123 Kw/years

4

Chapter 4: Photovoltaic system design

4.1 Overview

This chapter mainly revolves around the design of the PV system for the buildings of Hebron Governmental Hospital based on the average annual loads and then depending on the available space according to the conventional equations.

4.2 PV system design

4.2.1 Introduction

Palestine is located between (29° 15" - 33.15") north latitude and (34.15" – 35" 14") which is the ideal location for using solar energy. Hebron is located at 31.4 latitude and 35.1 longitude. The daily average solar radiation ranges between (2.83 to 7.5) kWh per square meter Maximum radiation available in June and July and minimum in December and January The design scheme for Hebron Governmental Hospital Building has been proposed.

Monthly global solar insolation and daily average bright sunshine hour in Hebron city are presented in the table 4.1 these values are a 22-year ago Average solar insolation from the PVsyst software.

Table 4.1 : Monthly global solar insolation at Hebron using PV syst[23]

Month	Solar insolation (KWh/m2)
January	3.097
February	3.607
March	4.735
April	5.322
May	7.052
June	7.48
July	7.65
August	7.19
September	6.44
October	5.35

November	4.1
December	2.835
Total PSH/Year	64.808
Average insolation	5.401 (KWh/m2)

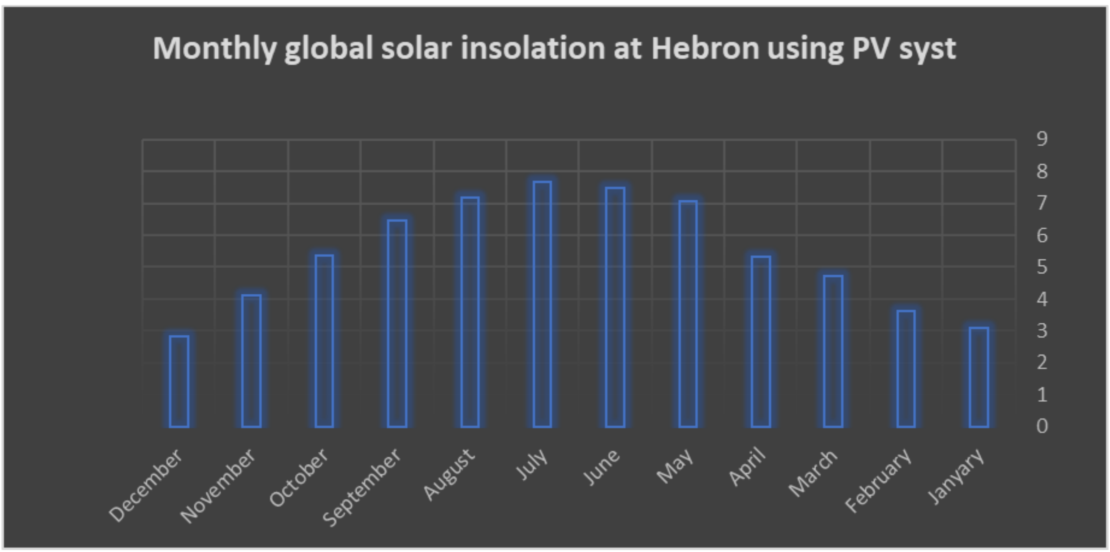


Figure 4.1: history Monthly global solar insolation at Hebron using PV syst.

4.2.2 PV System Design for Hebron Governmental Hospital

The total area of the roof in Figure 4.1 for the buildings is 3200 m² of architectural level, but there are three areas that cannot be used for photovoltaic panels, and these areas are stairs of the building and places of air conditioning units and places resulting in shade, and therefore the exceptional areas of the design are (1755) square meters and so the actual usable area is only 1,444 square metres, the PV system is designed for rooftop installation.

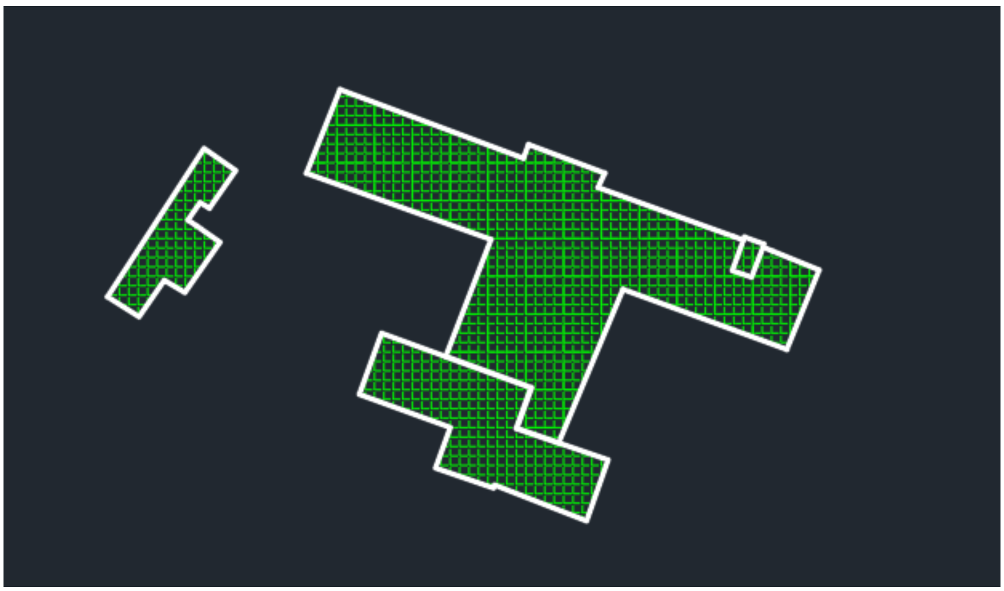


Figure 4.2: The area of the roof Hebron Governmental Hospital building.

Figure 4.3 The area marked in yellow is the actual area that can be used.

Since the sun does not shine perpendicularly on every point of the earth, for maximum efficiency the PV modules are tilted with an angle which depends on the location of the installation. In the northern hemisphere, solar panels should be tilted to face south and vice versa. An easy way to determine the tilt angle is the latitude of the location. If a place has a latitude X north, then panels should be tilted with X° angle from the horizontal base to face south [24].

4.2.3 Module Accommodations on Roof Area and Load Analysis.

To calculate module accommodations on the roof of C-Building, a satellite picture of the roof with dimensions is taken, as shown below. Aerial photography lab in Palestine polytechnic university. The Hebron Governmental Hospital building is not parallel to the north-south pole in either side. The facing angle is calculated from the same lap and was found to be 32°, but the collectors must be south facing which means the azimuth angle is zero, since the building is in the northern half of the world and to achieve the maximum beam insolation on a collector [25].

Figures 4.4: A satellite picture for roof of Hebron Governmental Hospital.

For the PV-system sizing the total consumption Measured for the building is 810.67 MWh/year that is obtained in chapter 3. And all calculation depend on this value even though this value is the maximum of all load estimated methods, because the loads in the Hebron Governmental Hospital building may growth in the future, and as mentioned in the very beginning in this chapter The number of hours at peak sun daily for Hebron city is 5.4 hour/day.

The modules that proposed to uses for a high efficiency that maximizes the output power. Poly crystalline type, with an efficiency of about (21.4%. The PV cells generate low voltage direct current that is coupled to the building's electricity supply via an inverter with efficiency of 98.2%, and the efficiency for conversion will calculated.

Power loss at $\%(\frac{\Delta P}{°C})$ = 0.0⋅4% per degree above 25 $C°$ from data sheet in AppendixA.1

NOCT = 47°, (Data sheet)

T_{CELL}= T_{amp} + $\frac{NOCT-20}{0,8}$ * 1 SUN. (4.1)

T_{CELL} = 20 + $\frac{45-20}{0,8}$ * 1 SUN = 54.125 °C.

$P_{dc\,,\,PTC}$ = 1KW * (1 - $\%(\frac{\Delta P}{°C})$ * (T_{CELL} - 25°C) = 0.985 kW.

$\eta_{temp} = \frac{\text{Pdc PTC}}{1KW} = \frac{0,885KW}{1KW} = 0,985$

$(Which\ mean\ the\ losses\ by\ the\ temprtture\ will\ be\ 11,5\,\%)$.

$\eta_{inverter} =$ 98,7% from datasheet in Appendix A.3.

$(Which\ wean\ the\ losses\ by\ the\ inverter\ will\ be\ 1,4\,\%)$.

$\eta_{mismatching} =$ 96% in PV modules datasheet

$(Which\ wean\ the\ losses\ by\ the$ mismatching $between\ collectors\ will\ be\ 4\,\%)$.

$\eta_{dust\ collectors}$ = 96% [2] $(Which\ wean\ the\ losses\ by\ the\ inverter\ will\ be\ 4\,\%)$.

$\eta_{conversion}$= η_{temp}*$\eta_{inverter}$ * $\eta_{mismatching}$ * $\eta_{dust\ collectors}$ (4.2)

$\eta_{conversion}$ = 0.885 * 0.987 * 0.96 * 0.96 = 86.8%

$$\text{Energy (KW/year)} = \text{Pac(KW)} * \text{(h/day at peak sun)} * 365\ \text{day/year} \qquad (4.3)$$

$$P_{ac} = \frac{energy\left(\frac{KWhr}{year}\right)}{\frac{h}{day} at\ peak\ sun * 365\ {day}/{year}} = \frac{810673812,3}{5,401 * 365} = 411,224\ KW_{AC},$$

$$P_{DC} = \frac{P_{ac}}{\eta_{\text{conversion}}} = \frac{411{,}224K}{86{,}8\%} = 473355KW_{peak\ (DC)}$$

$$\eta_{PV} = 21{,}46\%\ from\ datasheet\ in\ [Appendix\ A, 1]$$

$$\text{number of PV panel} = \frac{\text{P}_{\text{DC(PV)}}}{\text{P}_{\text{panel}}} = \frac{473355\text{K}}{550} = 860{,}06 \text{ panel,}$$

$$\text{P}_{\text{dc,stc}} = \frac{1\text{kW}}{\text{m}^2} \text{ at 1 sun} \times \text{Area} \times \eta_{PV} \rightarrow Area = \frac{473355\ KW}{\frac{1\ KW}{m^2} \times 0{,}2146} = 2205{,}66\ m^2$$

The latitude of Hebron id 31.4°north; the tilt angle for the PV modules at site is 31°. The width of the PV module selected for installation is 2m, and if the total shade length of the module is X as shown in Figure 4.4.

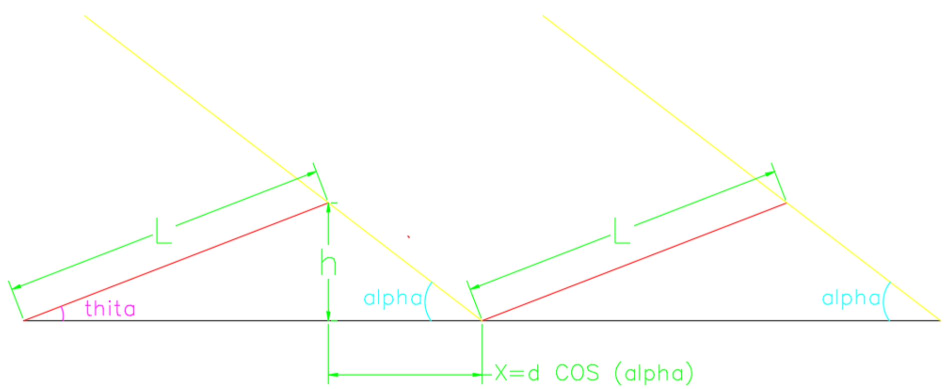


Figure 4.5: The inclination of the PV panels.

@ thita = 31°

$$d = \frac{\text{h}}{\tan(\text{alpha})} = \frac{\text{L}\ \sin(\text{thita})}{\tan(\text{alpha})} = \frac{2 \times \sin(31)}{\tan(31)} = 1{,}71 \text{ m,}$$

$$\text{X} = \text{d COS(Azimuth)} = 1{,}71 \times \cos(25) = 1{,}55 \text{ m ,}$$

@ thita = 27°

$$d = \frac{h}{\tan(alpha)} = \frac{L\ \sin(thita)}{\tan(alpha)} = \frac{2\ \times\ \sin(27)}{\tan(31)} =\ 1{,}51\ m,$$

$$X = d\ COS(Azimuth)\ =\ 1{,}51\ \times\ \cos(25)\ =\ 1{,}36\ m\ ,$$

The change in the inclination value of the solar panel from 31°to 27°does not significantly affect the production of panels, as the inclination angle is set at 31°for the winter months, because the angle of inclination of the sun is low, and making the inclination angle of the photovoltaic modules to 27°does not significantly affect because most of the production It is in the summer months and the hours of the day are longer and the angle of inclination of the sun is greater, i.e. closer to 90°.than the winter months which are close to 30 degrees

We have three areas where the split PV panels can be installed on the roof of the old building, the roof of the kidney building and the roof of the emergency building.

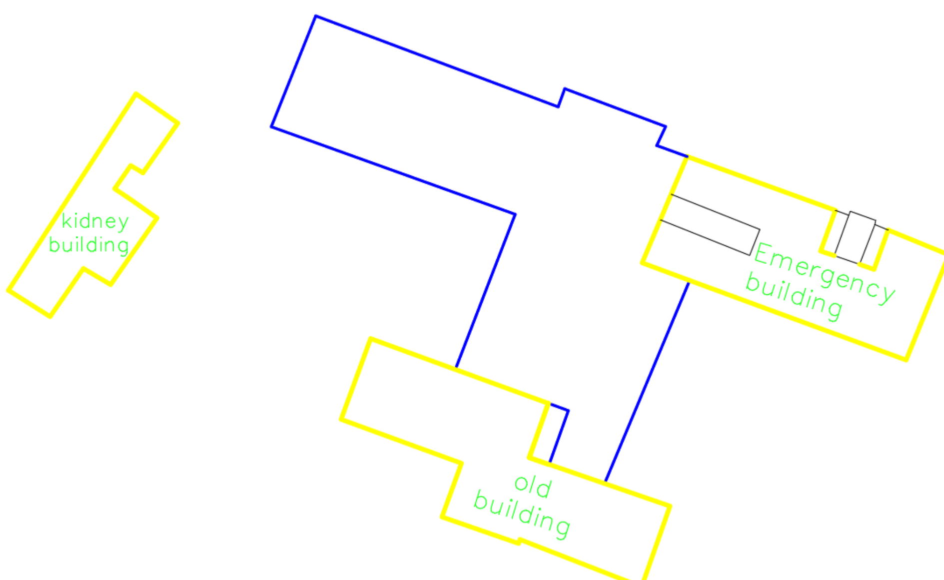


Figure 4.6: Distribution of the roofs on which the PV system will be installed.

4.2.4.1 Emergency building

In the beginning, we take the emergency building, which constitutes an area of $625m^2$, where the actual area for installing the panels is $233m^2$, and this is done after removing the shadows and the spacing between the panels.

First case: (Multi string inverter)

$A_{Net} = P_{dc}/(1kW/m^2) \times \eta_{PV}$ → Pdc = 50 kw (4.4)

Where:

η_{PV}: efficiency of PV [Appendix A]

# of PV = P_{dc} / P_{PV} (4.5)

$$= \frac{50000}{550} = 91\ panel$$

Where:

# of PV: Number of PV.

P_{PV}: PV module peak rated output Power. [Appendix A]

Maximum voltage produced by the photovoltaic panels at a temperature of -5 ° C.

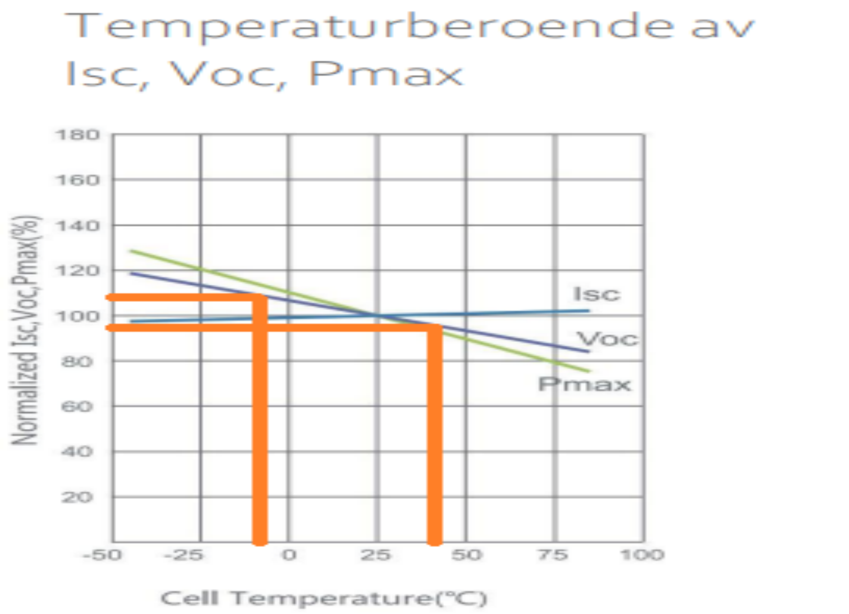


Fig. 4.7: Effect of heat on the solar panel used

Note that the increase in the open circuit voltage is 10%.

→ $V_{OC,\ -5} = V_{OC} * 110\% = 59.16 * 110\% = 65.076$ V.

Where:

V_{OC} : open circuit voltage at 25° C.

$V_{OC,\ -5}$: open circuit voltage at -5° C.

Note that the decrease in the open circuit voltage is 5%.

→ $V_{OC,\ 40} = V_{OC} * 95\% = 59.16 * 95\% = 56.202$V.

# of module on each string per inverter = $V_{dcinv,\ max}$ / Vdc PV (4.6)

$= \frac{800}{65{,}076} = 12{,}29 \approx 12$ module/MPPT.

# of module on each string per inverter = $V_{dcinv,\ min}$ / $V_{dcPV,\ min}$. (4.7)

$$= \frac{390}{56,202} = 7 \text{ module/mppt.}$$

Where:

$V_{dcinv,\ max}$: maximum voltage at input side in inverter [Appendix B]

$V_{dcinv,\ min}$: minimum voltage at input side in inverter. [Appendix B]

Maximum current produced by the photovoltaic panels at a temperature of 40° C.

Note that the increase in the short circuit current is ±2%.

→ $I_{sc,\ 40} = I_{SC} * 102\%$ A
(10)

= 11.45 * 102% = 11.679 A.

Where :

I_{SC} : short circuit current at 25° C. [Appendix A]

$I_{SC,\ 40}$: oshort circuit current at 40° C.

→ $I_{sc_{min,\ -5}} = I_{SC} * 98\% = 11.45 * 98\% = 11.221$ A.

Where :

I_{SC} : short circuit current at 25° C. [Appendix A]

$I_{sc,\ 40}$: short circuit current at -5° C.

$$\#\ of\ string\ for\ each\ inverter = \frac{\text{Isc,inv}}{\text{Isc,40}} = \frac{33}{11,679} = 2,8 = 2\ string/\text{mppt} \quad (4.8)$$

Where:

Isc, inv: short circuit current in pv side inverter [Appendix B]

$Number\ of\ module\ in\ array = 2 \times 12 = 24\ module/MPPT.$

$Number\ of\ module\ in\ array = 2 \times 8 \times \#\text{of MPPT} = 2 \times 12 \times 2 = 48 module.$

$Number\ of\ array = \frac{91}{48} = 1{,}9 \approx 2\ array.$

Number of inverter $|_{25KW}$ = 2 inverter.

$P_{ac} = P_{DC} \times \eta_{conversion} = 50000 \times 86{,}8\% = 43{,}4\ KW,$

$$\text{Energy}\ (\frac{\text{KWhr}}{\text{year}}) = P_{ac} \times 5{,}401\ \frac{\text{h}}{\text{day}}\ \text{at peak sun} \times 365\ \frac{\text{day}}{\text{year}}$$

$$= 43{,}4\ \text{KW} \times 5{,}401 \times 365 = 85557{,}241\ \frac{\text{KWhr}}{\text{year}} = 85{,}557\ \frac{\text{MWhr}}{\text{year}},$$

$$\%\ \text{of Energy coverd} = \frac{85{,}557}{510{,}8} = 16{,}75\%$$

4.2.4.2 Cables[دكتور ماهر]

For the DC side the cable should have a minimum current rating of:

$I_{DC\ Cable} = n \times I_{sc} \times 1.25 = 2 \times 11.45 \times 1.25 = 28.6$ A

- where n is the number of similar voltage strings connected in parallel and ISC is the PV module short circuit current.
- For high system voltages, such as in grid connected PV, double insulated cable should be used for safety reasons.
- For the PV the cable should have a minimum voltage rating of:

$$V_{DC\ Cable} = m \times V_{OC} \times 1.15$$

$$= 12 \times 59.16 \times 1.15 = 816.4\ V$$

• where m is the number of similar current modules connected in series and VOC is the module open circuit voltage.

AC cable with 2*16 mm^2 is selected for the connected between the inverter and grid.

4.2.4.3 Fuses / Miniature Circuit breakers (MCB)

• Fuses, Miniature Circuit Breakers (MCBs DC/AC) and switches serve similar functions in PV systems because both are used to isolate sections of the system for maintenance or in the event of emergency or malfunction.

• **string DC fuse:**

$I_{DC\ Fuse} = I_{sc} \times 1.25 = 11.45 \times 1.25 = 14.3A$ **but rating standard is 20A**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 12 = 851.904$ V **but rating standard is 1000 V.**

• **String DC circuit breaker:**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 12 = 851.904$ V **but rating standard is 1000 V.**

$I_{DC\ CB} = I_{sc} \times 1.25 = 11.45 \times 1.25 = 14.3A$ **but rating standard is 20A**

• **Array DC circuit breaker:**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 12 = 851.904$ V **but rating standard is 1000 V.**

$I_{DC\ CB} = I_{sc} \times 1.25 \times N_{string} = 11.45 \times 1.25 \times 4 = 57.25A$ **but rating standard is 60A**

4.2.4.4 DC surge arrester and lightening arrester:

SMA inverter has implementation of a surge arrester inside the inverter (internal protection inside the inverter), also based on the IEC the selection of the addition surge to ensure is needed the over voltage protection with 1000 V and 15 KA and lightening arrester is needed to protect the system from any Lightning may occur and it will solidly connected to the earth.

4.2.4.5 Inverter AC circuit breaker:

The maximum output current from inverter is 36.2 A and the stander rating is 40 A with 400 V.

4.2.4.6 Economic Feasibility study

This section shows the calculation of the cost of generated energy by the Grid The PV System The feasibility study evaluates the project's potential for success; therefore, perceived objectivity is an important factor in the credibility of the study for potential investors and lending institutions. The purpose of the economic feasibility is to determine the positive economic benefits to the organization that the proposed system will provide. It includes quantification and identification of all the benefits expected. This assessment typically involves a cost benefits analysis.

In order to get a complete design for solar system the economic study is essential to identify the costs of installation of project in detail to study if the project is profitable or not.

The prices of all components are got from the local market of Hebron to get the most accurate.

Table 4.2: Price list of each component in the system from ULTRA SUN company

Component	specification	quantity	Price ($)	Total Price ($)
Photovoltaic panel	550 watt	91	260	23660
Inverter	25 kW SMA	2	7120	14240
String Fuse	20 A , 1000 V	8	8.5	68
DC circuit breaker (for string)	20 A, 1000 V	8	63.5	508
DC circuit breaker (for Array)	60 A, 1000 V	2	67	134
DC surge arrester	15KA, 1000 V	2	122	244
AC circuit breaker (after each inverter)	40 A, 1000V	2	17	34
Min circuit breaker (for the system)	80 A, 1000 V	1	34	34
DC cable	6 mm^2	(R&M) (depends on	500	500

		connection & shape of the building)		
AC cable	21 mm^2	200	750	750
Grounding grid establishing	–	-		135
System Installation & operation Grid connection	–	-		8570
Electrical company fee	–	-		150
Maintenance	–	-		300
Total				49327

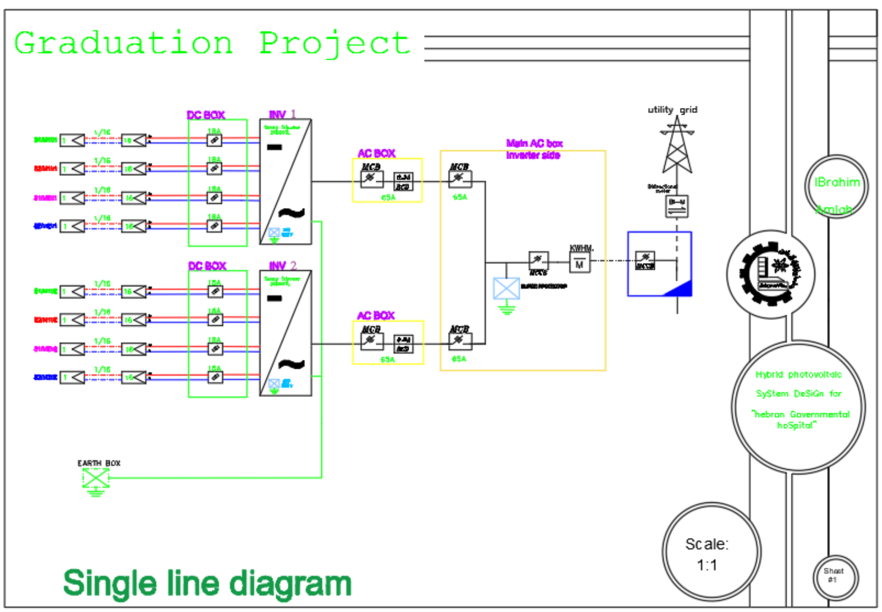


Figure 4.8: single line diagram (Multi string inverter)

Second case:(Central Inverter)

We use a central inverter where we connect all the system to this inverter, as we have chosen an inverter of the type "PVI-CENTRAL50-US-480".

# of module on each string per inverter = $V_{dcinv,\ max} / V_{dc\ PV}$

$= \frac{600}{65,076} = 9,2 \approx 9$ module.

# of module on each string per inverter = $V_{dcinv,\ min}$ / $V_{dcPV,\ min}$.

$= \frac{330}{56,202} = 5,87 \approx 5$ module.

Where :

$V_{dcinv,\ max}$: maximum voltage at input side in inverter.[Appendix D]

$V_{dcinv,\ min}$: minimum voltage at input side in inverter.[Appendix D]

Maximum current produced by the photovoltaic panels at a temperature of 40° C.

$\# \ of \ string \ for \ each \ inverter \ = \frac{Isc_{inv}}{Isc_{40}} = \frac{170}{11,679} = 14,5 = 14 \ string$

Where:

Isc, inv: short circuit current in pv side inverter [Appendix D]

Number of PV = # of string * # of module on each string per inverter

= 14 * 9 = 126 module.

This type of inverter bears 126 PV panels, but our system consists of 91 panels, so we will use 9 PV panels in a row and we will use 10 string on parallel, which will give us a current of 110 amps less than the maximum current that the inverter can withstand.

$$\text{Energy}\ (\frac{\text{KWhr}}{\text{year}}) = P_{ac} \times 5{,}401\ \frac{h}{\text{day}}\ \text{at peak sun} \times 365\ \frac{\text{day}}{\text{year}}$$

$$= 43{,}4\ \text{KW} \times 5{,}401 \times 365 = 85557{,}241\ \frac{\text{KWhr}}{\text{year}} = 85{,}557\ \frac{\text{MWhr}}{\text{year}},$$

$$\%\ \text{of Energy coverd} = \frac{85{,}557}{510{,}8} = 16{,}75\%$$

4.2.4.2 Cables[دكتور ماهر]

For the DC side the cable should have a minimum current rating of:

$I_{DC\ Cable} = n \times I_{sc} \times 1.25 = 2 \times 11.45 \times 1.25 = 28.6$ A

• where n is the number of similar voltage strings connected in parallel and ISC is the PV module short circuit current.

• For high system voltages, such as in grid connected PV, double insulated cable should be used for safety reasons.

• For the PV the cable should have a minimum voltage rating of:

$V_{DC\ Cable} = m \times V_{OC} \times 1.15 = 9 \times 59.16 \times 1.15 = 612.3$ V

• where m is the number of similar current modules connected in series and VOC is the module open circuit voltage.

AC cable with 4*25 mm^2 is selected for the connected between the inverter and grid.

4.2.4.3 Fuses / Miniature Circuit breakers (MCB)

• Fuses, Miniature Circuit Breakers (MCBs DC/AC) and switches serve similar functions in PV systems because both are used to isolate sections of the system for maintenance or in the event of emergency or malfunction.

• **string DC fuse:**

$I_{DC\ Fuse} = I_{sc} \times 1.25 = 11.45 \times 1.25 = 14.3$A **but rating standard is 20A**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 9 = 638.9$ V **but rating standard is 1000 V.**

- **String DC circuit breaker:**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 9 = 638.9$ V **but rating standard is 1000 V.**

$I_{DC\ CB} = I_{sc} \times 1.25 = 11.45 \times 1.25 = 14.3A$ **but rating standard is 20A**

- **Array DC circuit breaker:**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times \ = 638.9$ V **but rating standard is 1000 V.**

$I_{DC\ CB} = I_{sc} \times 1.25 \times N_{string} = 11.45 \times 1.25 \times 10 = 143.125$ A **but rating standard is 160A**

4.2.4.4 DC surge arrester and lightening arrester:

SMA inverter has implementation of a surge arrester inside the inverter (internal protection inside the inverter), also based on the IEC the selection of the addition surge to ensure is needed the over voltage protection with 1000 V and 15 KA and lightening arrester is needed to protect the system from any Lightning may occur and it will solidly connected to the earth.

4.2.4.5 Inverter AC circuit breaker:

The maximum output current from inverter is 72.5 A and the stander rating is 75 A with 400 V.

4.2.4.6 Economic Feasibility study

This section shows the calculation of the cost of generated energy by the Grid The PV System The feasibility study evaluates the project's potential for success; therefore, perceived objectivity is an important factor in the credibility of the study for potential investors and lending institutions. The purpose of the economic feasibility is to determine the positive economic benefits to the organization that the proposed system will provide. It includes quantification and identification of all the benefits expected. This assessment typically involves a cost benefits analysis.

In order to get a complete design for solar system the economic study is essential to identify the costs of installation of project in detail to study if the project is profitable or not.

The prices of all components are got from the local market of Hebron to get the most accurate.

Table 4.3: Price list of each component in the system from ULTRA SUN company(2)

Component	specification	quantity	Price ($)	Total Price ($)
Photovoltaic panel	550 watt	90	260	23660
Inverter	50 kW SMA	1	15000	15000
String Fuse	20 A , 1000 V	9	8.5	76.5
DC circuit breaker (for string)	20 A, 1000 V	9	63.5	571.5
DC circuit breaker (for Array)	160 A, 1000 V	1	200	200
DC surge arrester	15KA, 1000 V	1	122	122
AC circuit breaker (after each inverter)	75 A, 1000V	1	55	55
DC cable	6 mm^2	(R&M) (depends on connection & shape of the building)	500	500
AC cable	25 mm^2	200	800	8000
Grounding grid establishing	–	-		135
System Installation & operation Grid connection	–	-		8570
Electrical company fee	–	-		150
maintenance	–	-		400
Total				57440

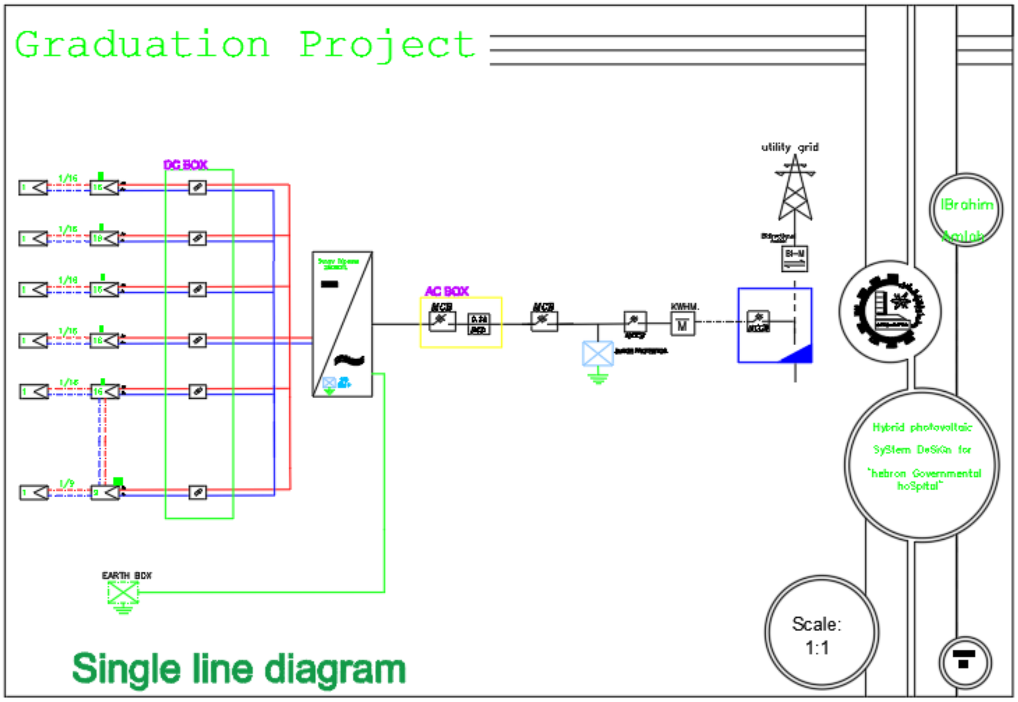


Figure 4.9: single line diagram (Central inverter)

We use the multi string system because it gives me more flexibility and less cost.

In the beginning, we take the emergency building, which constitutes an area of 273m2, where the actual area for installing the panels is 120.5m2, and this is done after removing the shadows and the spacing between the panels.

First case: (Multi string inverter)

$A_{Net} = P_{dc}/(1kW/m^2) \times \eta_{PV}$ → $P_{dc} = 25.86$ kW (4.4)

Where:

η_{PV}: efficiency of PV [Appendix A]

# of PV = P_{dc} / P_{PV} (4.5)

$$= \frac{25840}{550} = 46\ panel$$

Where:

# of PV : Number of PV.

P_{PV} : PV module peak rated output Power.[Appendix A]

Maximum voltage produced by the photovoltaic panels at a temperature of -5 ° C.

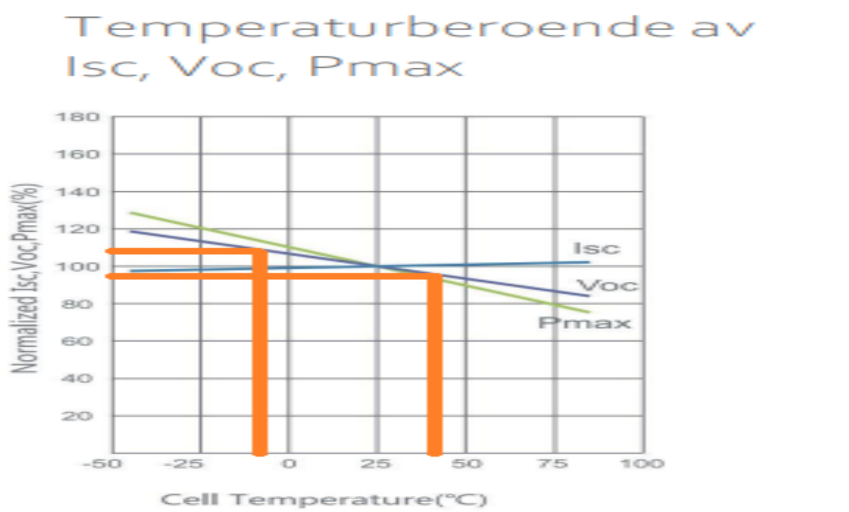


Fig. 4.10:Effect of heat on the solar panel used

Note that the increase in the open circuit voltage is 10%.

→ $V_{OC,\ -5}$ = V_{OC} ∗ 110% = 59.16 ∗ 110% = 65.076 V.

Where :

V_{OC} : open circuit voltage at 25° C.

$V_{OC,\ -5}$: open circuit voltage at -5° C.

Note that the decrease in the open circuit voltage is 5%.

→ $V_{OC, 40} = V_{OC} * 95\% = 59.16 * 95\% = 56.202V$.

# of module on each string per inverter = $V_{dcinv, max}$ / Vdc PV (4.6)

$= \frac{600}{65,076} = 9,22 \approx 9$ module/MPPT.

# of module on each string per inverter = $V_{dcinv, min}$ / $V_{dcPV, min}$. (4.7)

$= \frac{180}{56,202} = 3$ module/mppt.

Where :

$V_{dcinv, max}$: maximum voltage at input side in inverter. [Appendix E]

$V_{dcinv, min}$: minimum voltage at input side in inverter. [Appendix E]

Maximum current produced by the photovoltaic panels at a temperature of 40° C.

Note that the increase in the short circuit current is ±2%.

→ $I_{sc, 40} = I_{SC} * 102\%$ (10)

$= 11.45 * 102\% = 11.679$ A.

Where :

I_{SC} : short circuit current at 25° C. [Appendix A]

$I_{SC, 40}$: oshort circuit current at 40° C.

→ $Isc_{min,\ -5} = I_{SC} * 98\% = 11.45 * 98\% = 11.221$ A.

Where :

I_{SC} : short circuit current at 25° C. [Appendix A]

$Isc_{,\ 40}$: oshort circuit current at −5° C.

$$\#\ of\ string\ for\ each\ inverter\ = \frac{\text{Isc,inv}}{\text{Isc,40}} = \frac{33}{11{,}679} = 2{,}8 = 2\ string/\text{mppt} \quad (4.8)$$

Where:

Isc, inv: short circuit current in pv side inverter [Appendix B]

$Number\ of\ module\ in\ array = 2 \times 12 = 24\ module/MPPT.$

$Number\ of\ module\ in\ array = 2 \times 8 \times \#\text{of MPPT} = 2 \times 12 \times 2 = 48 module.$

$Number\ of\ array = \frac{46}{48} = 0{,}953 \approx 1\ array.$

Number of inverter $|_{25KW}$ = 1 inverter.

$P_{ac} = P_{DC} \times \eta_{conversion} = 25860 \times 86{,}5\% = 22{,}4\ KW,$

$$\text{Energy}\ (\frac{\text{KWhr}}{\text{year}}) = P_{ac} \times 5{,}401\ \frac{\text{h}}{\text{day}}\ \text{at peak sun} \times 365\ \frac{\text{day}}{\text{year}}$$

$$= 22{,}4\ \text{KW} \times 5{,}401 \times 365 = 44158{,}576\ \frac{\text{KWhr}}{\text{year}} = 44{,}158\ \frac{\text{MWhr}}{\text{year}},$$

$$\%\ \text{of Energy coverd} = \frac{44{,}158}{510{,}8} = 8{,}6\%$$

4.2.4.2 Cables[دكتور ماهر]

For the DC side the cable should have a minimum current rating of:

$I_{DC\ Cable} = n \times I_{sc} \times 1.25 = 2 \times 11.45 \times 1.25 = 28.6$ A

• where n is the number of similar voltage strings connected in parallel and ISC is the PV module short circuit current.

• For high system voltages, such as in grid connected PV, double insulated cable should be used for safety reasons.

• For the PV the cable should have a minimum voltage rating of:

$V_{DC\ Cable} = m \times V_{oc} \times 1.15 = 12 \times 59.16 \times 1.15 = 816.4$ V

• where m is the number of similar current modules connected in series and VOC is the module open circuit voltage.

AC cable with 2*16 mm^2 is selected for the connected between the inverter and grid.

4.2.4.3 Fuses / Miniature Circuit breakers (MCB)

• Fuses, Miniature Circuit Breakers (MCBs DC/AC) and switches serve similar functions in PV systems because both are used to isolate sections of the system for maintenance or in the event of emergency or malfunction.

• **string DC fuse:**

$I_{DC\ Fuse} = I_{sc} \times 1.25 = 11.45 \times 1.25 = 14.3$A **but rating standard is 20A**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 12 = 851.904$ V **but rating standard is 1000 V.**

• **String DC circuit breaker:**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 12 = 851.904$ V **but rating standard is 1000 V.**

$I_{DC\ CB} = I_{sc} \times 1.25 = 11.45 \times 1.25 = 14.3$A **but rating standard is 20A**

• **Array DC circuit breaker:**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 12 = 851.904$ V **but rating standard is 1000 V.**

$I_{DC\ CB} = I_{sc} \times 1.25 \times N_{string} = 11.45 \times 1.25 \times 4 = 57.25A$ **but rating standard is 60A**

4.2.4.4 DC surge arrester and lightening arrester:

SMA inverter has implementation of a surge arrester inside the inverter (internal protection inside the inverter), also based on the IEC the selection of the addition surge to ensure is needed the over voltage protection with 1000 V and 15 KA and lightening arrester is needed to protect the system from any Lightning may occur and it will solidly connected to the earth.

4.2.4.5 Inverter AC circuit breaker:

The maximum output current from inverter is 36.2 A and the stander rating is 40 A with 400 V.

4.2.4.6 Economic Feasibility study

This section shows the calculation of the cost of generated energy by the Grid The PV System The feasibility study evaluates the project's potential for success; therefore, perceived objectivity is an important factor in the credibility of the study for potential investors and lending institutions. The purpose of the economic feasibility is to determine the positive economic benefits to the organization that the proposed system will provide. It includes quantification and identification of all the benefits expected. This assessment typically involves a cost benefits analysis.

In order to get a complete design for solar system the economic study is essential to identify the costs of installation of project in detail to study if the project is profitable or not.

The prices of all components are got from the local market of Hebron to get the most accurate.

Table 4.4: Price list of each component in the system from ULTRA SUN company(3)

Component	specification	quantity	Price ($)	Total Price ($)
Photovoltaic panel	550 watt	46	260	11960
Inverter	25 kW SMA	1	7120	7120
String Fuse	20 A , 1000 V	4	8.5	34
DC circuit breaker	20 A, 1000 V	4	63.5	254

(for string)				
DC circuit breaker (for Array)	60 A, 1000 V	2	67	134
DC surge arrester	15KA, 1000 V	1	122	122
AC circuit breaker (after each inverter)	40 A, 1000V	1	17	17
Min circuit breaker (for the system)	80 A, 1000 V	1	34	34
DC cable	6 mm^2	(R&M) (depends on connection & shape of the building)	500	500
AC cable	21 mm^2	200	750	750
Grounding grid establishing	–	-		135
System Installation & operation Grid connection	–	-		4285
Electrical company fee	–	-		150
maintenance	–	-		300
Total				25795

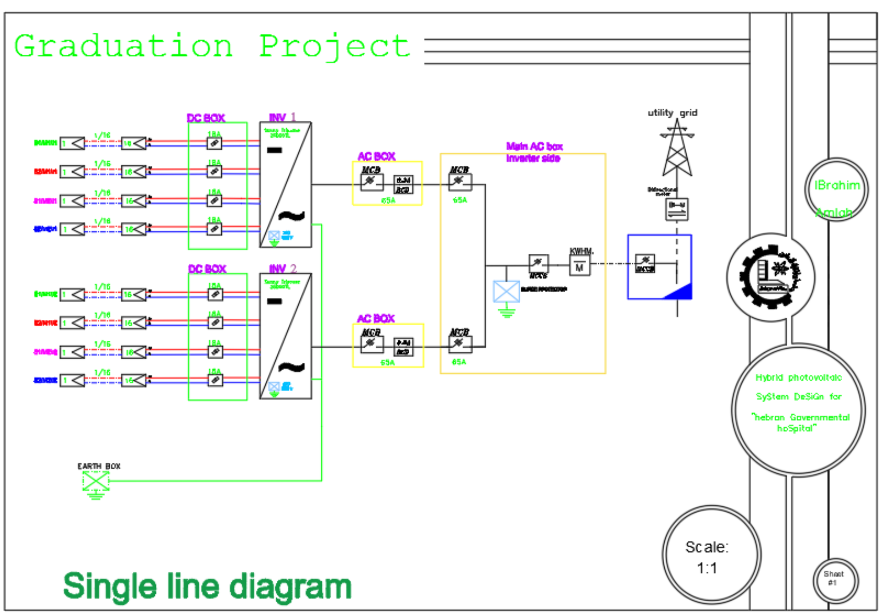


Figure 4.11: single line diagram (Multi string inverter)

Now we take the Kala building, which has an area of 400 square meters, where the actual area for installing the panels is 180 square meters, and this is done after removing the shadows and the spacing between the panels.

$A_{Net} = P_{dc}/(1kW/m^2) \times \eta_{PV}$ → $P_{dc} = 38.63$ kW (4.4)

Where:

η_{PV}: efficiency of PV [Appendix A]

# of PV = P_{dc} / P_{PV} (4.5)

$$= \frac{38630}{550} = 70 \ panel$$

Where:

# of PV : Number of PV.

P_{PV} : PV module peak rated output Power. [Appendix A]

Maximum voltage produced by the photovoltaic panels at a temperature of -5 ° C.

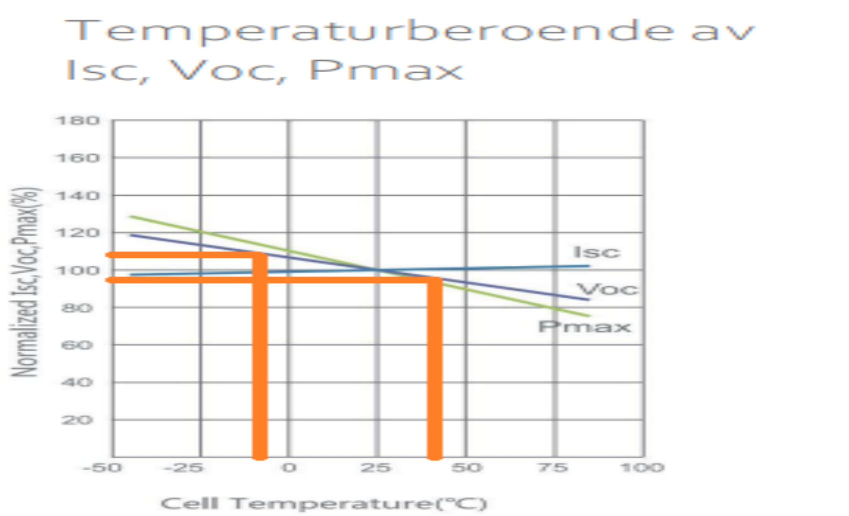


Fig. 4.12:Effect of heat on the solar panel used

Note that the increase in the open circuit voltage is 10%.

→ $V_{OC,\ -5} = V_{OC} * 110\% = 59.16 * 110\% = 65.076$ V.

Where :

V_{OC} : open circuit voltage at 25° C.

$V_{OC,\ -5}$: open circuit voltage at −5° C.

Note that the decrease in the open circuit voltage is 5%.

→ $V_{OC,\ 40} = V_{OC} * 95\% = 59.16 * 95\% = 56.202$V.

# of module on each string per inverter = $V_{dcinv,\ max}$ / Vdc PV (4.6)

$= \frac{600}{65,076} = 9,22 \approx 9$ module/MPPT.

# of module on each string per inverter = $V_{dcinv,\ min}$ / $V_{dcPV,\ min}$. (4.7)

$= \frac{180}{56,202} = 3$ module/mppt.

Where :

$V_{dcinv,\ max}$: maximum voltage at input side in inverter. [Appendix E]

$V_{dcinv,\ min}$: minimum voltage at input side in inverter. [Appendix E]

Maximum current produced by the photovoltaic panels at a temperature of 40° C.

Note that the increase in the short circuit current is ±2%.

→ $Isc_{,\ 40} = I_{SC} * 102\% = 11.45 * 102\% = 11.679$ A. (10)

Where :

I_{SC} : short circuit current at 25° C. [Appendix A]

$I_{SC,\ 40}$: oshort circuit current at 40° C.

→ $Isc_{min,\ -5}$ = I_{SC} * 98% = 11.45* 98% = 11.221 A.

Where :

I_{SC} : short circuit current at 25° C. [Appendix A]

$Isc_{,\ 40}$: oshort circuit current at -5° C.

P_{AC} = P_{dc} * conversion efficiency = 38.63 * 0.865 = 33.4 kW.

E_{ac} = G * P_{AC} = 5.4 * 33.4 = 180.44 kWh/d

Battery capacity (CB)

Select a 48 V voltage for the system

DC Energy (E_{dc}) = $\frac{\text{Eac}}{inverter\ efficiency} = \frac{180,44}{0,97} = 186\ kWh$

Ah to load :

CB = $\frac{\text{Edc}}{V} = \frac{186}{48} = 3875\ Ah$

Ah for PV = $\frac{3875}{0,96\ dirt} = 4036\ Ah$

Storage days

S.d = 3 day.

Discharge time =3*24=72 hours

Actual battery capacity

Total storage= Ah to load*storage days= 4036 * 3 = 12108 Ah @ 48V

Minimum temperature=-5 C

From curve at (T=-5 C) from the curve C/72

Capacity derating = 100%

MDOD%=100%

CB =12108 Ah

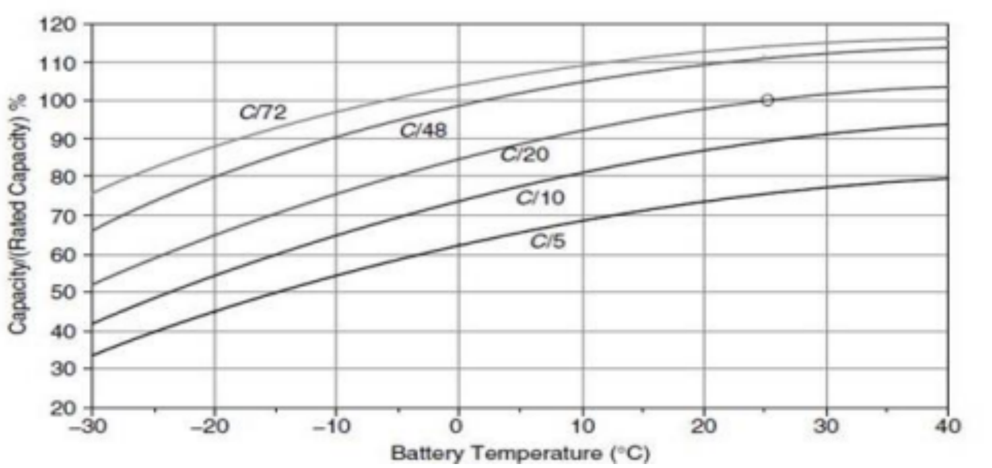


Fig4.13:Rated capacity and battery temperature curve

Batteries connection

#of string = $\frac{Total\ Ah}{Ah\ per\ battery} = \frac{12108}{400} = 30$

#of batteries = $\frac{system\ voltage}{battery\ voltage} = \frac{48}{24} = 2\ baterries,$

#of batteries **=** 2 * 30 = 60 *baterries,*

Ah/string = IR * G *derating efficiency=11.44 * 5.4*1=61.7 Ah/string.day.

#of string = $\frac{Ah\ per\ day}{Ah\ per\ day\ string} = \frac{3875}{61{,}7} = 62\ string,$

#of PV/string = $\frac{system\ voltage}{pv\ \ voltage} = \frac{48}{59} = 0{,}813 = 1\ PV$

$P_{ac} = P_{DC} \times \eta_{conversion} = 38630 \times 86{,}5\% = 33{,}4\ KW,$

$$\text{Energy}\ (\frac{\text{KWhr}}{\text{year}}) = P_{ac} \times 5{,}401\ \frac{\text{h}}{\text{day}}\ \text{at peak sun} \times 365\ \frac{\text{day}}{\text{year}}$$

$$= 33{,}4\ \text{KW} \times 5{,}401 \times 365 = 65873\ \frac{\text{KWhr}}{\text{year}} = 65{,}873\ \frac{\text{MWhr}}{\text{year}},$$

$$\%\ \text{of Energy coverd} = \frac{65{,}873}{510{,}8} = 12{,}8\%$$

4.2.4.2 Cables[دكتور ماهر]

For the DC side the cable should have a minimum current rating of:

$I_{DC\ Cable} = n \times I_{sc} \times 1.25 = 10 \times 11.45 \times 1.25 = 114.5\ A$

• where n is the number of similar voltage strings connected in parallel and ISC is the PV module short circuit current.

• For high system voltages, such as in grid connected PV, double insulated cable should be used for safety reasons.

• For the PV the cable should have a minimum voltage rating of:

$V_{DC\ Cable} = m \times V_{OC} \times 1.15 = 2 \times 59.16 \times 1.15 = 136.7\ V$

• where m is the number of similar current modules connected in series and VOC is the module open circuit voltage.

AC cable with $2*16\ mm^2$ is selected for the connected between the inverter and grid.

4.2.4.3 Fuses / Miniature Circuit breakers (MCB)

• Fuses, Miniature Circuit Breakers (MCBs DC/AC) and switches serve similar functions in PV systems because both are used to isolate sections of the system for maintenance or in the event of emergency or malfunction.

- **string DC fuse:**

$I_{DC\ Fuse} = I_{sc} \times 1.25 = 11.45 \times 1.25 = 14.3A$ **but rating standard is 20A**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 2 = 136.7\ V$ **but rating standard is 500 V.**

- **String DC circuit breaker:**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 12 = 136.7\ V$ **but rating standard is 500 V.**

$I_{DC\ CB} = I_{sc} \times 1.25 = 11.45 \times 1.25 = 14.3A$ **but rating standard is 20A**

- **Array DC circuit breaker:**

$V_{rating} = 1.2 \times V_{oc} \times N_{PV} = 1.2 \times 59.16 \times 2 = 136.7\ V$ **but rating standard is 500 V.**

$I_{DC\ CB} = I_{sc} \times 1.25 \times N_{string} = 11.45 \times 1.25 \times 10 = 143$ **but rating standard is 160A**

4.2.4.4 DC surge arrester and lightening arrester:

SMA inverter has implementation of a surge arrester inside the inverter (internal protection inside the inverter), also based on the IEC the selection of the addition surge to ensure is needed the over voltage protection with 1000 V and 15 KA and lightening arrester is needed to protect the system from any Lightning may occur and it will solidly connected to the earth.

4.2.4.5 Inverter AC circuit breaker:

The maximum output current from inverter is 36.2 A and the stander rating is 40 A with 400 V.

4.2.4.6 Economic Feasibility study

This section shows the calculation of the cost of generated energy by the Grid The PV System The feasibility study evaluates the project's potential for success; therefore, perceived objectivity is an important factor in the credibility of the study for potential investors and lending institutions. The purpose of the economic feasibility is to determine the positive economic benefits to the organization that the proposed system will provide. It includes quantification and identification of all the benefits expected. This assessment typically involves a cost benefits analysis.

In order to get a complete design for solar system the economic study is essential to identify the costs of installation of project in detail to study if the project is profitable or not.

The prices of all components are got from the local market of Hebron to get the most accurate.

Table 4.5: Price list of each component in the system from ULTRA SUN company(4)

Component	specification	quantity	Price ($)	Total Price ($)
Photovoltaic panel	550 watt	46	260	11960
Inverter	40 kW	1	17000	7120
String Fuse	20 A , 500 V	4	8.5	34
DC circuit breaker (for string)	20 A, 500 V	4	63.5	254
DC circuit breaker (for Array)	160 A, 500 V	2	200	134
DC surge arrester	15KA, 1000 V	1	122	122
AC circuit breaker (after each inverter)	40 A, 1000V	1	17	17
Min circuit breaker (for the system)	40 A, 1000 V	1	17	34
DC cable	25 mm^2	(R&M) (depends on connection & shape of the building)		2000
AC cable	21 mm^2	200	750	750
Grounding grid establishing	–	-		135
System Installation & operation Grid connection	–	-		4285
Electrical company fee	–	-		150

batteries	Batteries 24V	60	300	18000
maintenance	–	-		300
Total				55224

4.3 Economic feasibility study

Total cost = 49327+ 25795 + 55224 = 130.346$

By assume that every 3.5 NIS is equal 1$, so that total cost is 456000 NIS.

The annual generated energy from the system that is 195.58MWh/year

Saving money = annual energy * (price of kW) = 195.85*0.45=88.132 NIS

The payback period is:

payback period = $\frac{saving\ mony}{total\ cost} = \frac{456000}{88{,}132} = 5{,}12\ year,$

The payback period is 5 years, and after that period the project will generate a profit for the hospital.

Table 4.6: cumulative net cash flow calaculation.

Year	Cost	In come	Cumulative Net cash Flow
0	-456000	0	-456000
1	0	88132	-367868
2	0	88132	-279736
3	0	88132	-191604
4	0	88132	-103472
5	0	88132	-15340
6	0	88132	72792
7	0	88132	160924
8	0	88132	289056
9	0	88132	337188
10	0	88132	425320
11	0	88132	813452
12	0	88132	601584
13	0	88132	689716
14	0	88132	777848
15	0	88132	865980
16	0	88132	954112
17	0	88132	1042244
1	0	88132	1130376
18	0	88132	1218508
19	0	88132	1306640
20	0	88132	1394772
21	0	88132	1482904
22	0	88132	1571036
23	0	88132	1659168
24	0	88132	1747300
25	0	88132	1835432

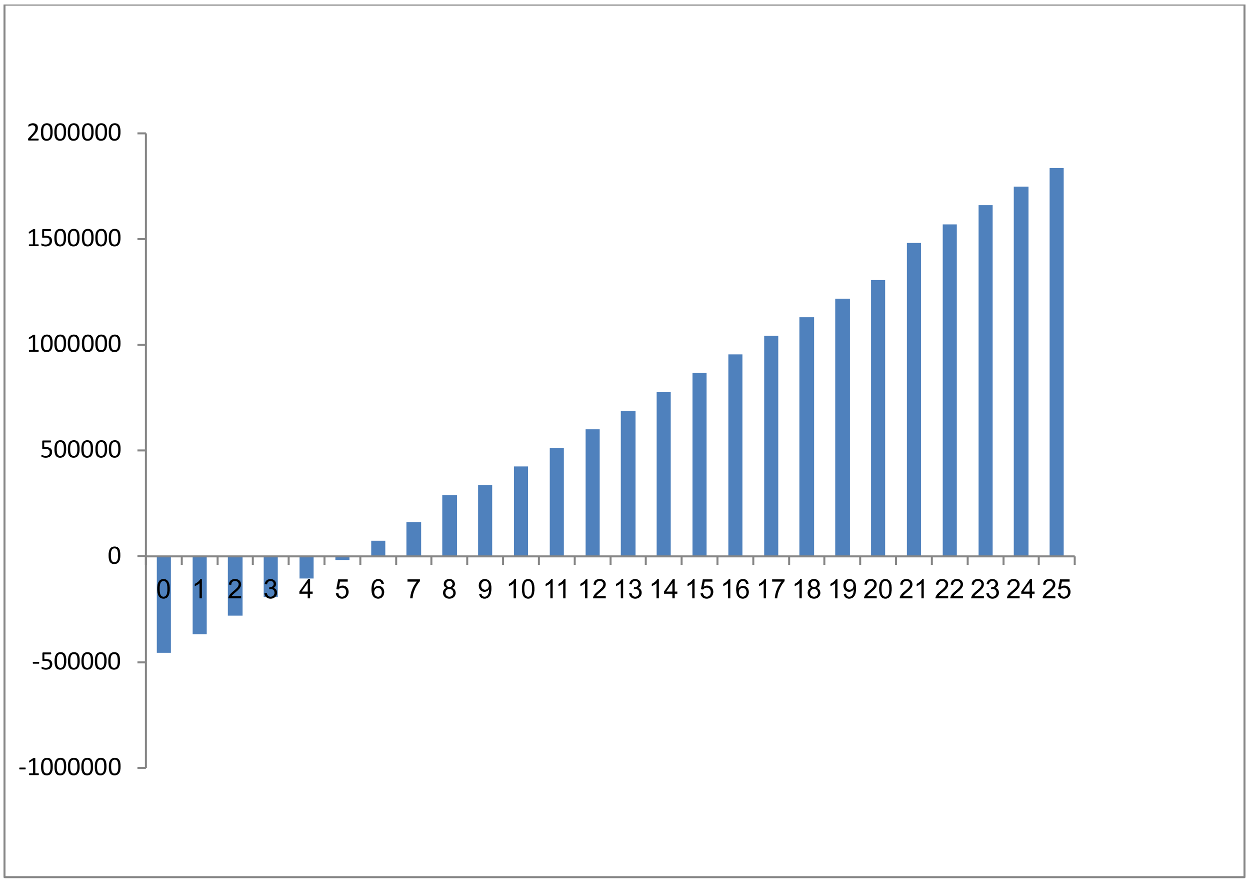


Fig.4.14: cumulative net cash flow.

5

Chapter 5: PV System Design using PV-syst

5.1 Overview

This chapter is mainly about designing a photovoltaic system for Hebron Governmental Hospital buildings using PVsyst software depending on the available space.

5.2 PV-syst introduction

Is a PC software package for the study, sizing, simulation and data analysis of complete PV systems, presents results in the form of a full report, specific graphs and tables, and data can be exported for use in other software [26].

This gives access to the four main part of the program fig. 5.1

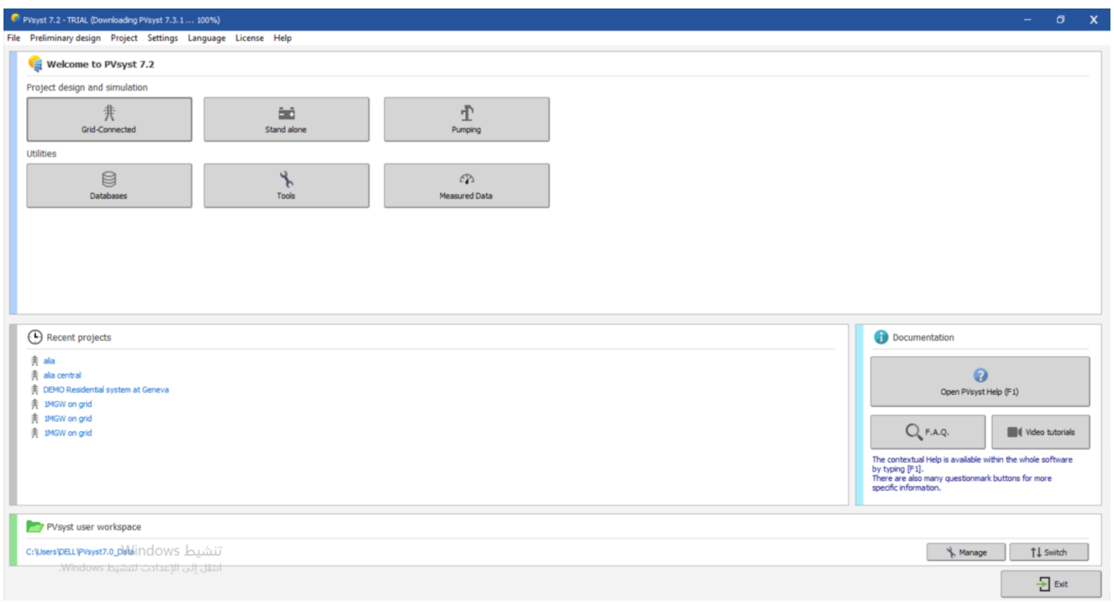


Fig. 5.1: four main parts of the PV syst program.

- **Preliminary design**: provides a quick evaluation of the potentials and possible constraints of a project in a given situation. This is very useful for the pre-sizing of

Stand-alone and Pumping systems. For grid connected systems. it is just an instrument for architects to get a quick evaluation of the PV potential of a building. The accuracy of this tool is limited and not intended to be used in reports for your customers.

- **Project design**: is the main part of the software and is used for the complete study of a project. It involves the choice of meteorological data, system design, shading studies, losses determination, and economic evaluation. The simulation is performed over a fill year in hourly steps and provides a complete report and many additional results.
- **Databases**: includes the climatic data management which consists of monthly and hourly data synthetic generation of hourly values and importing external data. The databases contain also the definitions of all the components involved in the PV installations like modules, inverters, batteries, etc.,
- **Tools**: provides some additional tools to quickly estimate and visualize the behavior of a solar installation. It also contains a dedicated set of tools that allows measured dits existing solar installations to be imported for a close comparison to the simulation.

5.3 **PV system design by PV-syst**

To the start design on the PV syst software first of all the location of the site should be determine by using this dashboard (project's location) fig. 5.2

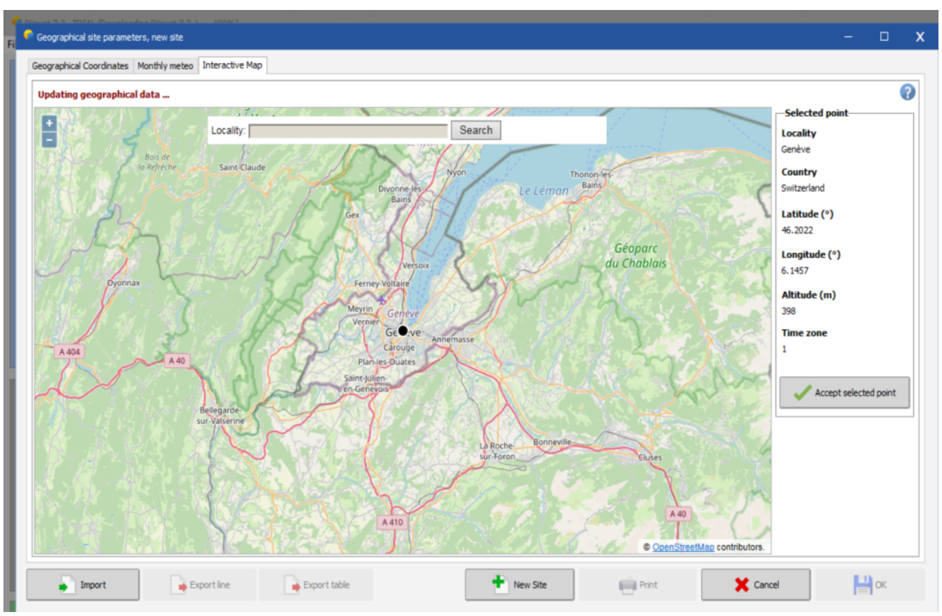


Fig. 5.2: project's location dashboard.

Then from the available choices in the software the active area will chosen and best tilt and azimuth angle of the panels will be determined system Specification dashboard Fig.5.3

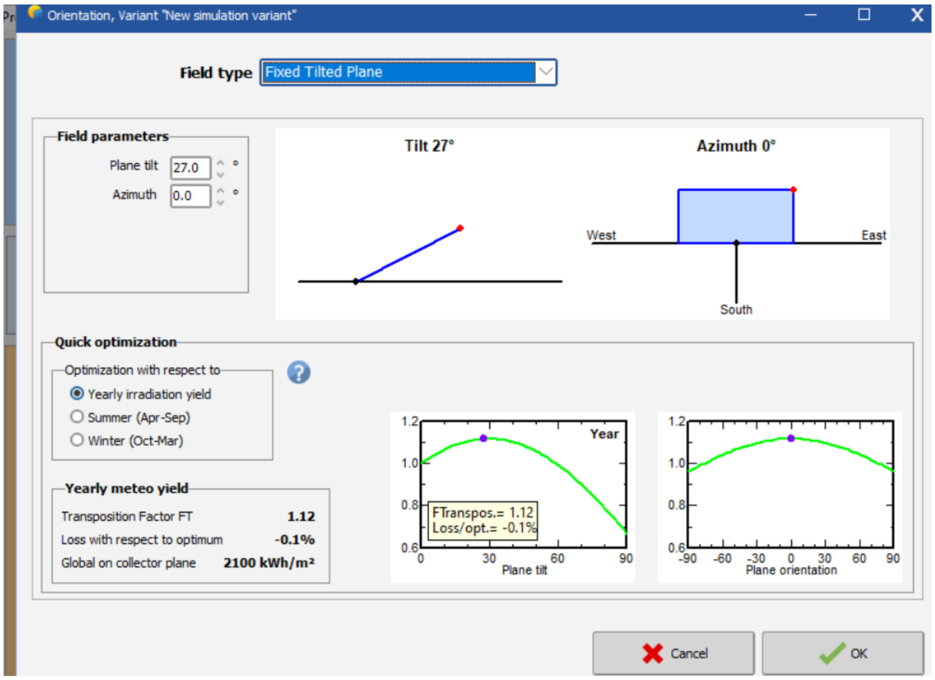


Fig. 5.3 system Specification dashboard

5.3.1 Emergency building

Then determining the Data sheet of the PV panel Fig. 5.4 and inverter Fig. 5.5 that decided to be used:

PVsyst V7.2.21

PV module - TSM-DE19-550Wp

Manufacturer	Generic	**Commercial data**	
Model	TSM-DE19-550Wp	Availability :	Prod. Since 2022
		Data source :	Datasheets 2022
Pnom STC power (manufacturer)	550 Wp	Technology	Si-mono
Module size (W x L)	1.096 x 2.384 m²	Rough module area (Amodule)	2.61 m²
Number of cells	2 x 55		

Specifications for the model (manufacturer or measurement data)

Reference temperature (TRef)	25 °C	Reference irradiance (GRef)	1000 W/m²
Open circuit voltage (Voc)	37.9 V	Short-circuit current (Isc)	18.52 A
Max. power point voltage (Vmpp)	31.6 V	Max. power point current (Impp)	17.40 A
=> maximum power (Pmpp)	549.8 W	Isc temperature coefficient (muIsc)	7.4 mA/°C

One-diode model parameters

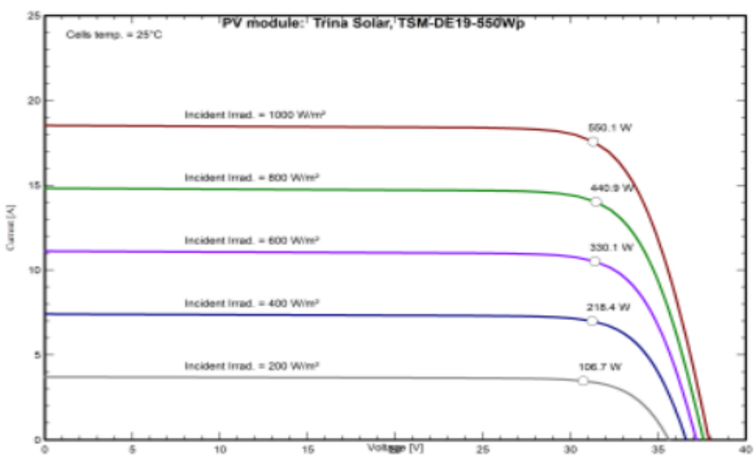
Shunt resistance (Rshunt)	200 Ω	Diode saturation current (IoRef)	0.040 nA
Serie resistance (Rserie)	0.12 Ω	Voc temp. coefficient (MuVoc)	-105 mV/°C
Specified Pmax temper. coeff. (muPMaxR)	-0.34 %/°C	Diode quality factor (Gamma)	1.00
		Diode factor temper. coeff. (muGamma)	0.000 1/°C

Reverse Bias Parameters, for use in behaviour of PV arrays under partial shadings or mismatch

Reverse characteristics (dark) (BRev)	3.20 mA/V²	(quadratic factor (per cell))	
Number of by-pass diodes per module	3	Direct voltage of by-pass diodes	-0.7 V

Model results for standard conditions (STC: T=25 °C, G=1000 W/m², AM=1.5)

Max. power point voltage (Vmpp)	31.3 V	Max. power point current (Impp)	17.58 A
Maximum power (Pmpp)	550.1 Wp	Power temper. coefficient (muPmpp)	-0.34 %/°C
Efficiency(/ Module area) (Eff_mod)	21.1 %	Fill factor (FF)	0.784



26/12/22 PVsyst Evaluation mode Page 1/1

Fig. 5.6 Data sheet of PV panel

PVsyst V7.2.21

Inverter - Sunny Tripower 25000TL-JP-30

Manufacturer Generic
Model Sunny Tripower 25000TL-JP-30

Commercial data

Availability : Prod. Since 2015

Data source : Manufacturer 2015

Remarks

Technology: TL, 16 kHz, SG, IGBT
Protection: -25 - +60°C, IP 65: outdoor installation possible
Control: Graphic
for japanese market

Sizes

Width	661 mm
Height	682 mm
Depth	264 mm
Weight	61.00 kg

Input characteristics (PV array side)

Operating mode	MPPT
Minimum MPP Voltage (Vmin)	390 V
Maximum MPP Voltage (Vmax)	800 V
Absolute max. PV Voltage (Vmax array)	1000 V
Min. Voltage for PNom (Vmin@Pnom)	390 V
Multi MPPT capability	
Number of MPPT inputs	2

Nominal PV Power (Pnom DC)	26 kW
Maximum PV Power (Pmax DC)	26 kW
Power Threshold (Pthresh.)	84 W
Behaviour at Vmin/Vmax	Limitation
Behaviour at Pnom	Limitation

Output characteristics (AC grid side)

Grid voltage (Imax)	Triphased 420 V
Grid frequency	50/60 Hz

Nominal AC Power (Pnom AC)	25 kWac
Maximum AC Power (Pmax AC)	25 kWac
Nominal AC current (Inom AC)	34 A
Maximum AC current (Imax AC)	38 A

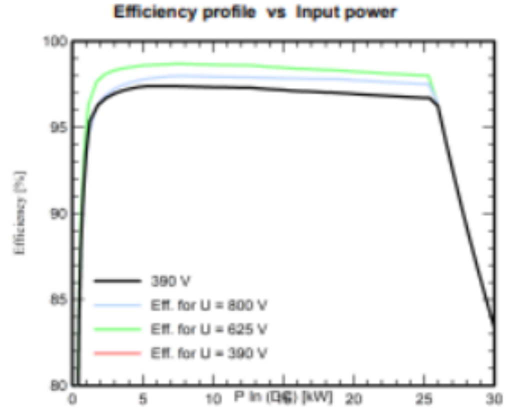
Efficiency defined for 3 voltages

		Maximum efficiency	European average efficiency
	V	%	%
Low voltage	390	97.4	97.1
Medium voltage	625	98.7	98.4
High voltage	800	98.0	97.7

Remarks and Technical features

Array isolation monitoring
Internal DC switch
Output Voltage disconnect adjustement
ENS protection

Efficiency profile vs Input power



26/12/22 PVsyst Evaluation mode Page 1/1

Fig. 5.7 Data sheet of inverter

The proposed system design from the PV syst program Fig.5.8

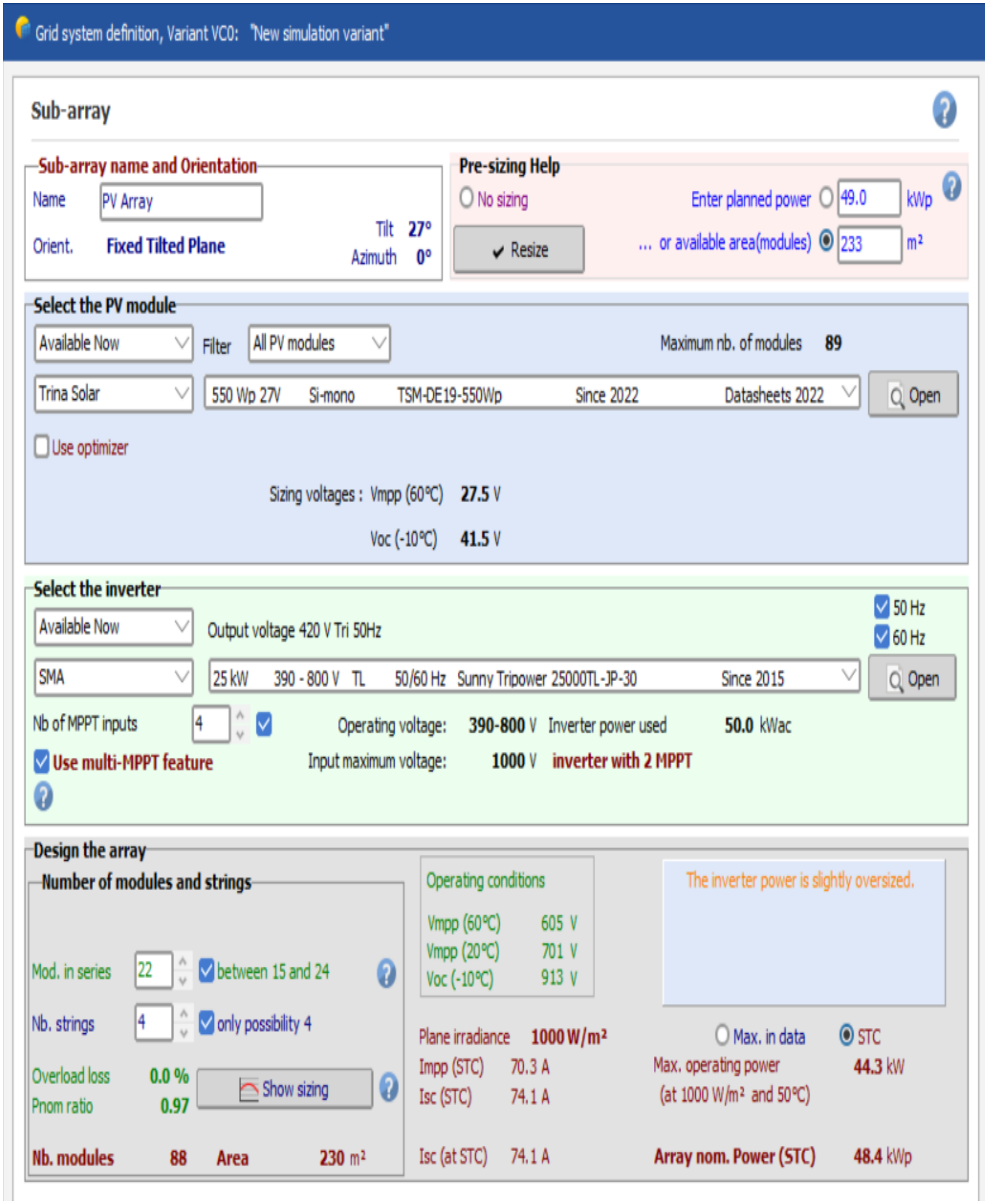


Fig. 5.8 system design of the PV syst

Summary of the software system design Fig. 5.9.

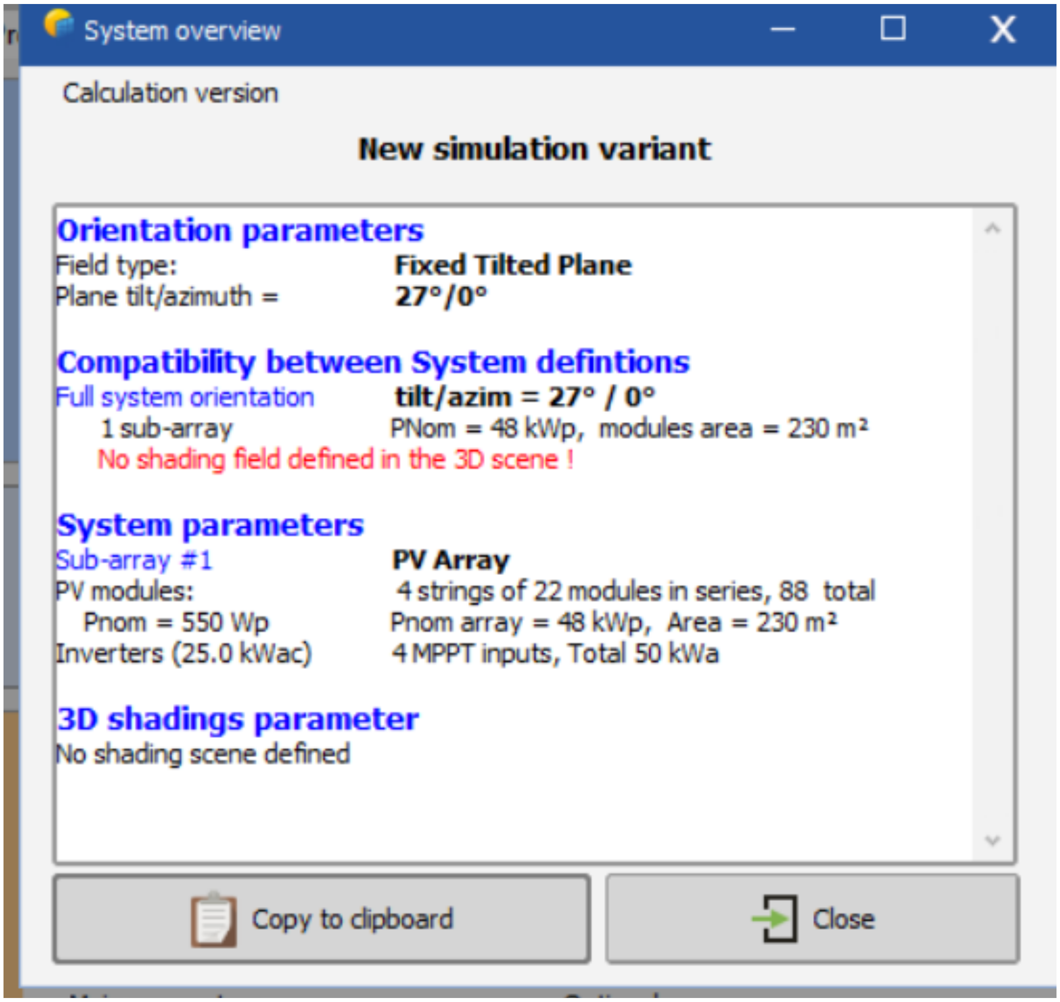


Fig. 5.9 summary of the calculation version.

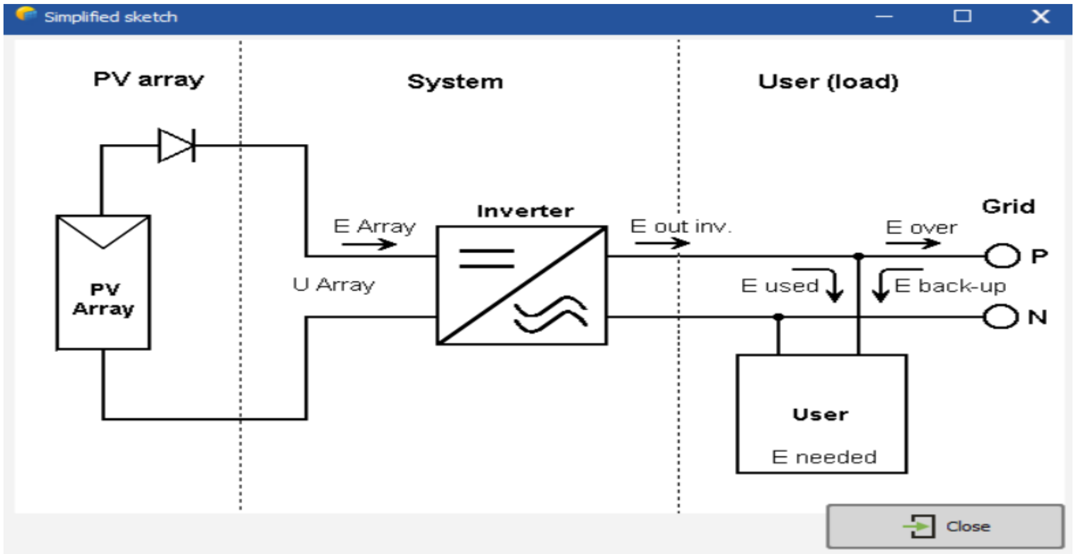


Fig. 5.10 Proposed Schematic diagram of the system from PV syst.

The PV-syst software also provide the expected output result for the system in every month Fig. 5.11.

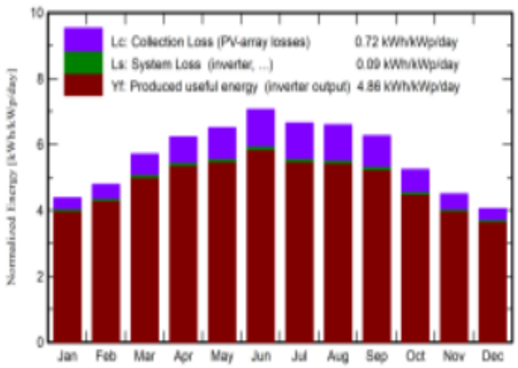
PVsyst V7.2.21
VC0, Simulation date:
26/12/22 11:17
with v7.2.21

Main results

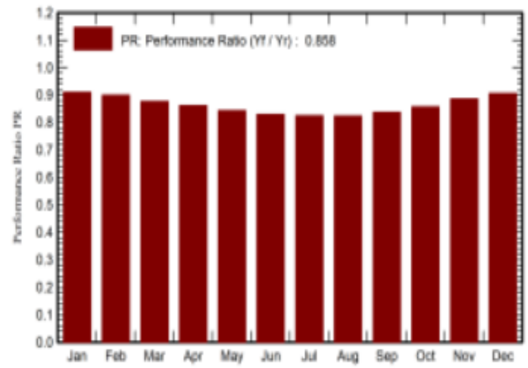
System Production

Produced Energy	85.90 MWh/year	Specific production	1775 kWh/kWp/year
		Performance Ratio PR	85.78 %

Normalized productions (per installed kWp)



Performance Ratio PR



Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	94.8	37.16	7.13	135.7	133.5	6.086	5.981	0.910
February	103.8	42.63	8.80	133.9	131.5	5.931	5.830	0.899
March	152.0	54.38	12.53	177.0	173.8	7.649	7.512	0.877
April	179.9	69.02	16.58	187.0	183.1	7.938	7.798	0.862
May	211.8	72.08	21.38	201.7	197.0	8.379	8.232	0.843
June	233.1	58.83	24.26	211.9	206.6	8.657	8.501	0.829
July	222.0	70.68	26.49	206.2	200.8	8.380	8.229	0.825
August	203.0	65.00	26.26	204.6	200.0	8.316	8.165	0.824
September	168.1	56.92	23.57	188.0	184.2	7.752	7.615	0.837
October	131.0	53.78	20.24	162.7	159.5	6.871	6.755	0.858
November	97.5	39.15	13.88	134.8	132.7	5.885	5.785	0.886
December	85.9	35.84	9.15	125.5	123.4	5.593	5.500	0.906
Year	1882.9	655.48	17.57	2069.0	2026.2	87.438	85.902	0.858

Legends

GlobHor	Global horizontal irradiation	EArray	Effective energy at the output of the array
DiffHor	Horizontal diffuse irradiation	E_Grid	Energy injected into grid
T_Amb	Ambient Temperature	PR	Performance Ratio
GlobInc	Global incident in coll. plane		
GlobEff	Effective Global, corr. for IAM and shadings		

Fig. 5.11 Expected output result for the system in every month.

5.3.2 Emergency building (central inverter)

Then determining the Data sheet of the PV panel Fig. 5.12 and inverter Fig. 5.13 that decided to be used:

PVsyst V7.2.21

PV module - TSM-DE19-550Wp

Manufacturer	Generic	**Commercial data**	
Model	TSM-DE19-550Wp	Availability :	Prod. Since 2022
		Data source :	Datasheets 2022
Pnom STC power (manufacturer)	550 Wp	Technology	Si-mono
Module size (W x L)	1.096 x 2.384 m²	Rough module area (Amodule)	2.61 m²
Number of cells	2 x 55		

Specifications for the model (manufacturer or measurement data)

Reference temperature (TRef)	25 °C	Reference irradiance (GRef)	1000 W/m²
Open circuit voltage (Voc)	37.9 V	Short-circuit current (Isc)	18.52 A
Max. power point voltage (Vmpp)	31.6 V	Max. power point current (Impp)	17.40 A
=> maximum power (Pmpp)	549.8 W	Isc temperature coefficient (muIsc)	7.4 mA/°C

One-diode model parameters

Shunt resistance (Rshunt)	200 Ω	Diode saturation current (IoRef)	0.040 nA
Serie resistance (Rserie)	0.12 Ω	Voc temp. coefficient (MuVoc)	-105 mV/°C
Specified Pmax temper. coeff. (muPMaxR)	-0.34 %/°C	Diode quality factor (Gamma)	1.00
		Diode factor temper. coeff. (muGamma)	0.000 1/°C

Reverse Bias Parameters, for use in behaviour of PV arrays under partial shadings or mismatch

Reverse characteristics (dark) (BRev)	3.20 mA/V²	(quadratic factor (per cell))	
Number of by-pass diodes per module	3	Direct voltage of by-pass diodes	-0.7 V

Model results for standard conditions (STC: T=25 °C, G=1000 W/m², AM=1.5)

Max. power point voltage (Vmpp)	31.3 V	Max. power point current (Impp)	17.58 A
Maximum power (Pmpp)	550.1 Wp	Power temper. coefficient (muPmpp)	-0.34 %/°C
Efficiency(/ Module area) (Eff_mod)	21.1 %	Fill factor (FF)	0.784

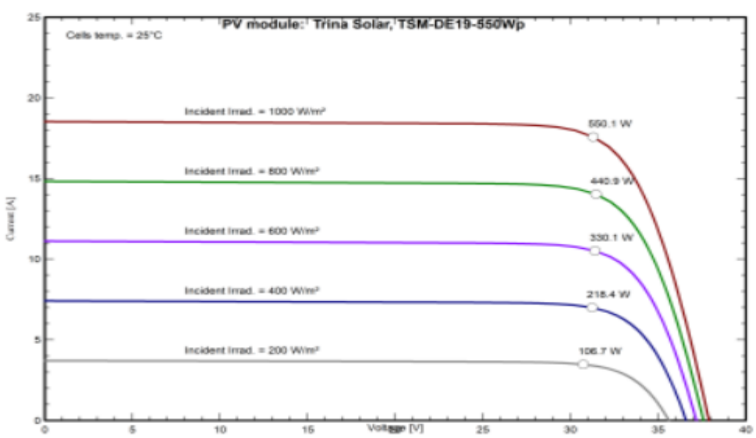


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Fig. 5.12 Data sheet of PV panel

PVsyst V7.2.21

Inverter - SG50-CX

Manufacturer	Generic
Model	SG50-CX

Commercial data

Availability : Prod. Since 2022

Data source : Datasheet 2022

Remarks		Sizes	
Technology: Transformerless		Width	645 mm
Protection: Protection: IP65 (outdoor)		Height	782 mm
Control: Control: LCD		Depth	310 mm
		Weight	62.00 kg

Input characteristics (PV array side)

Operating mode	MPPT		
Minimum MPP Voltage (Vmin)	200 V	Power Threshold (Pthresh.)	272 W
Maximum MPP Voltage (Vmax)	850 V		
Absolute max. PV Voltage (Vmax array)	1000 V		
Min. Voltage for PNom (Vmin@Pnom)	550 V		
"String" inverter with input protections		**Multi MPPT capability**	
Number of string inputs	10	Number of MPPT inputs	5
Behaviour at Vmin/Vmax	Limitation		
Behaviour at Pnom	Limitation		

Output characteristics (AC grid side)

Grid voltage (Imax)	Triphased 400 V	Nominal AC Power (Pnom AC)	55 kWac
Grid frequency	50/60 Hz	Maximum AC Power (Pmax AC)	55 kWac
		Nominal AC current (Inom AC)	79 A
		Maximum AC current (Imax AC)	84 A
Maximum efficiency	98.6 %		
European average efficiency	98.2 %		

Remarks and Technical features

Array isolation monitoring
Internal DC switch
Output Voltage disconnect adjustement
ENS protection

Efficiency profile vs Input power

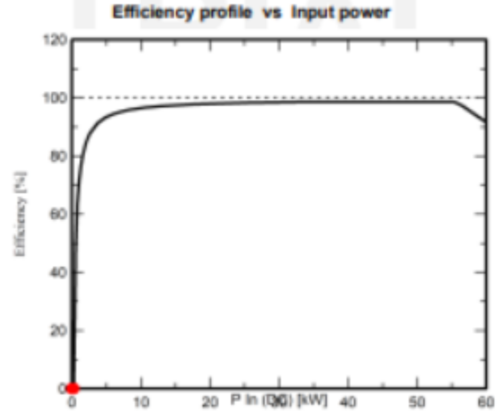


Fig. 5.13 Data sheet of inverter

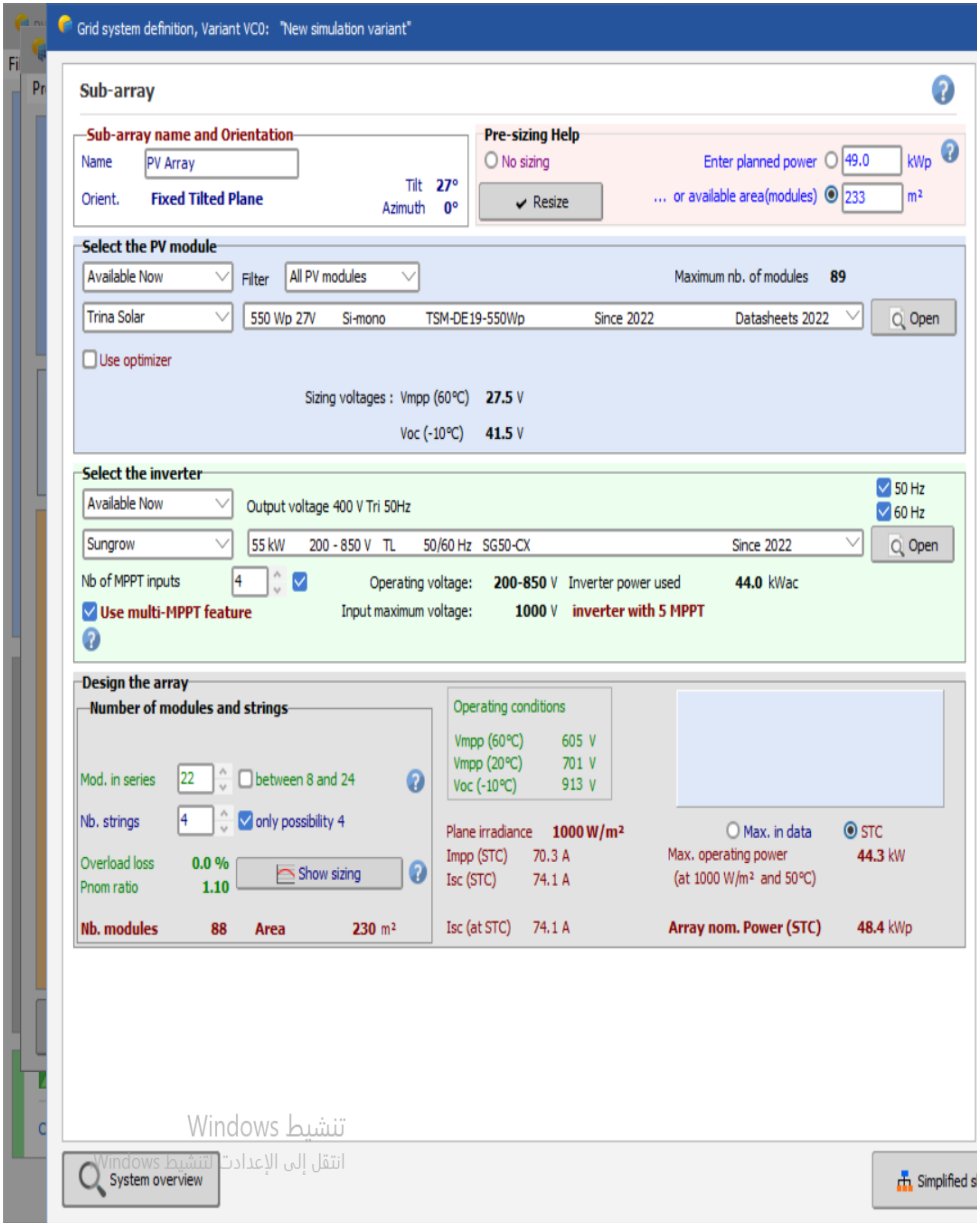


Fig. 5.14 system design of the PV syst.

Summary of the software system design Fig. 5.15.

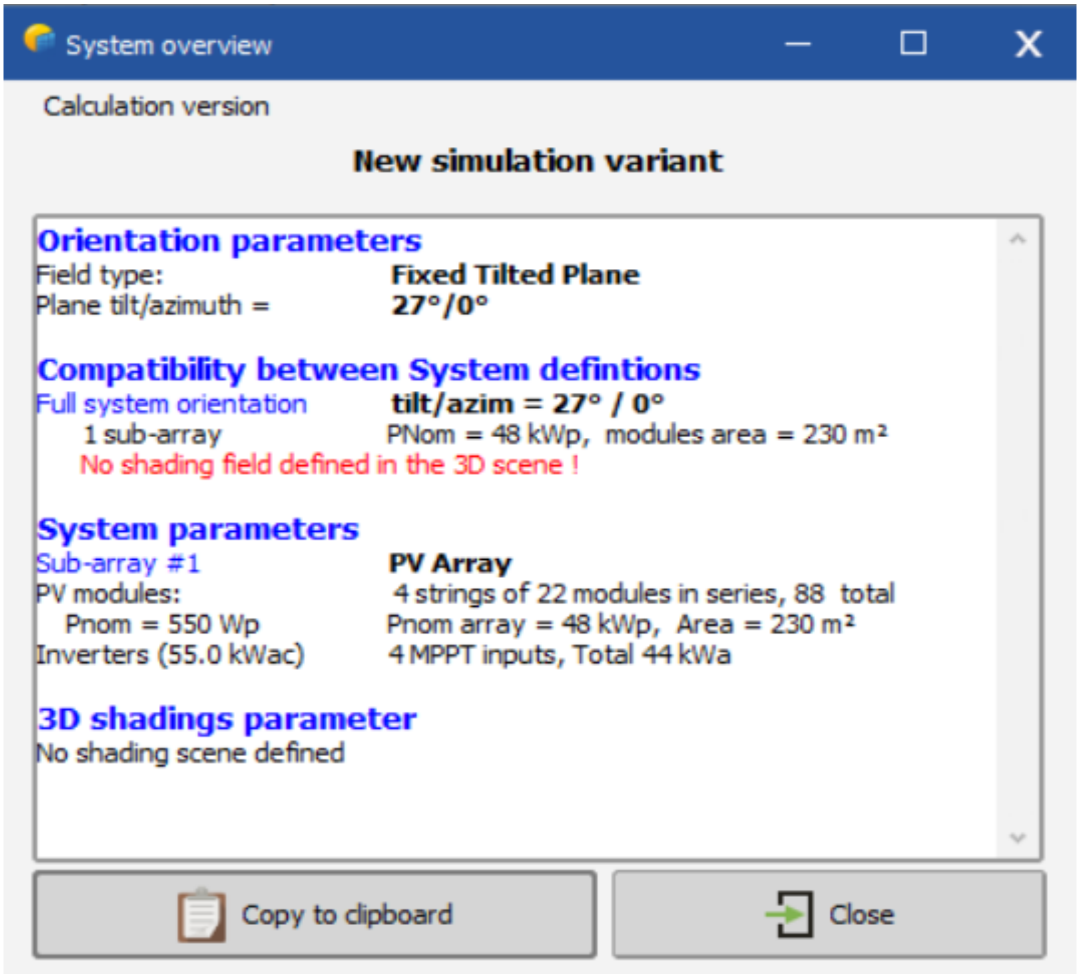


Fig. 5.15 summary of the calculation version.

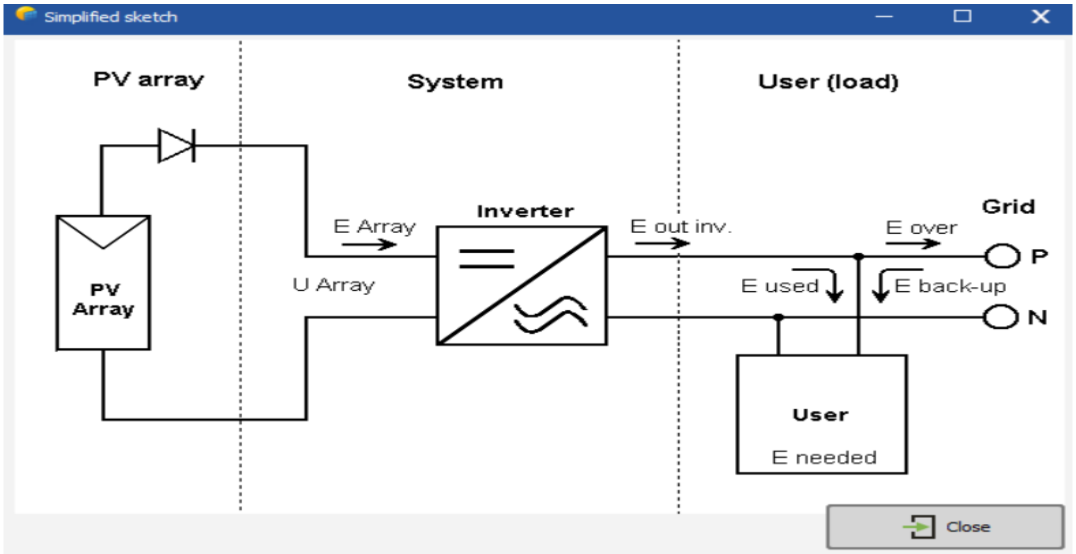


Fig. 5.16 Proposed Schematic diagram of the system from PV syst.

5.3.3 old building

Then determining the Data sheet of the PV panel Fig. 5.17 and inverter Fig. 5.18 that decided to be used:

PVsyst V7.2.21

PV module - TSM-DE19-550Wp

Manufacturer	Generic	**Commercial data**	
Model	TSM-DE19-550Wp	Availability :	Prod. Since 2022
		Data source :	Datasheets 2022
Pnom STC power (manufacturer)	550 Wp	Technology	Si-mono
Module size (W x L)	1.096 x 2.384 m²	Rough module area (Amodule)	2.61 m²
Number of cells	2 x 55		

Specifications for the model (manufacturer or measurement data)

Reference temperature (TRef)	25 °C	Reference irradiance (GRef)	1000 W/m²
Open circuit voltage (Voc)	37.9 V	Short-circuit current (Isc)	18.52 A
Max. power point voltage (Vmpp)	31.6 V	Max. power point current (Impp)	17.40 A
=> maximum power (Pmpp)	549.8 W	Isc temperature coefficient (muIsc)	7.4 mA/°C

One-diode model parameters

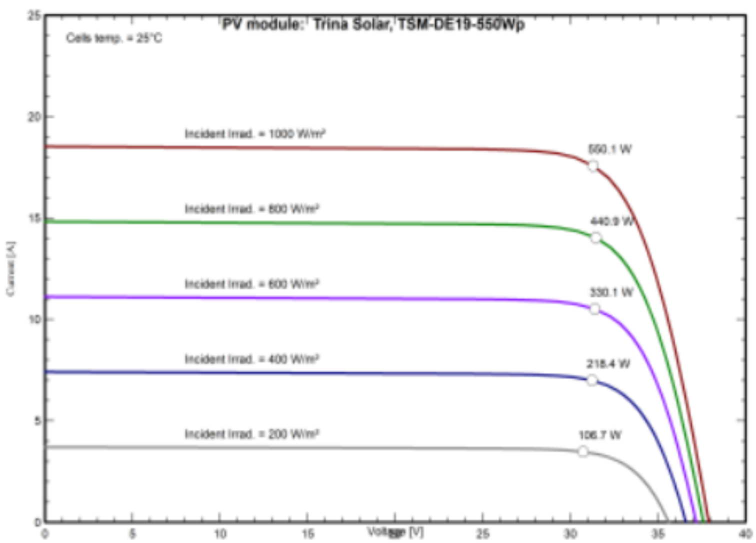
Shunt resistance (Rshunt)	200 Ω	Diode saturation current (IoRef)	0.040 nA
Serie resistance (Rserie)	0.12 Ω	Voc temp. coefficient (MuVoc)	-105 mV/°C
Specified Pmax temper. coeff. (muPMaxR)	-0.34 %/°C	Diode quality factor (Gamma)	1.00
		Diode factor temper. coeff. (muGamma)	0.000 1/°C

Reverse Bias Parameters, for use in behaviour of PV arrays under partial shadings or mismatch

Reverse characteristics (dark) (BRev)	3.20 mA/V²	(quadratic factor (per cell))	
Number of by-pass diodes per module	3	Direct voltage of by-pass diodes	-0.7 V

Model results for standard conditions (STC: T=25 °C, G=1000 W/m², AM=1.5)

Max. power point voltage (Vmpp)	31.3 V	Max. power point current (Impp)	17.58 A
Maximum power (Pmpp)	550.1 Wp	Power temper. coefficient (muPmpp)	-0.34 %/°C
Efficiency(/ Module area) (Eff_mod)	21.1 %	Fill factor (FF)	0.784



26/12/22 PVsyst Evaluation mode Page 1/1

Fig. 5.17 Data sheet of PV panel

PVsyst V7.2.21

Inverter - Sunny Tripower 25000TL-JP-30

Manufacturer	Generic
Model	Sunny Tripower 25000TL-JP-30

Commercial data

Availability : Prod. Since 2015

Data source : Manufacturer 2015

Remarks

Technology: TL, 16 kHz, SG, IGBT

Protection: -25 - +60°C, IP 65: outdoor installation possible

Control: Graphic

for japanese market

Sizes

Width	661 mm
Height	682 mm
Depth	264 mm
Weight	61.00 kg

Input characteristics (PV array side)

Operating mode	MPPT		
Minimum MPP Voltage (Vmin)	390 V	Nominal PV Power (Pnom DC)	26 kW
Maximum MPP Voltage (Vmax)	800 V	Maximum PV Power (Pmax DC)	26 kW
Absolute max. PV Voltage (Vmax array)	1000 V	Power Threshold (Pthresh.)	84 W
Min. Voltage for PNom (Vmin@Pnom)	390 V		
Multi MPPT capability		Behaviour at Vmin/Vmax	Limitation
Number of MPPT inputs	2	Behaviour at Pnom	Limitation

Output characteristics (AC grid side)

Grid voltage (lmax)	Triphased 420 V	Nominal AC Power (Pnom AC)	25 kWac
Grid frequency	50/60 Hz	Maximum AC Power (Pmax AC)	25 kWac
		Nominal AC current (Inom AC)	34 A
		Maximum AC current (Imax AC)	38 A

Efficiency defined for 3 voltages

		Maximum efficiency	European average efficiency
	V	%	%
Low voltage	390	97.4	97.1
Medium voltage	625	98.7	98.4
High voltage	800	98.0	97.7

Remarks and Technical features

Array isolation monitoring

Internal DC switch

Output Voltage disconnect adjustement

ENS protection

Efficiency profile vs Input power

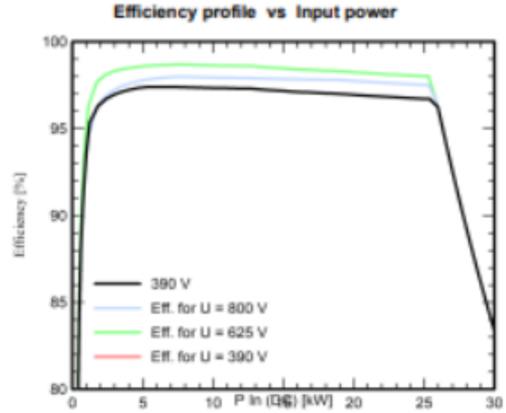


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Fig. 5.18 Data sheet of inverter

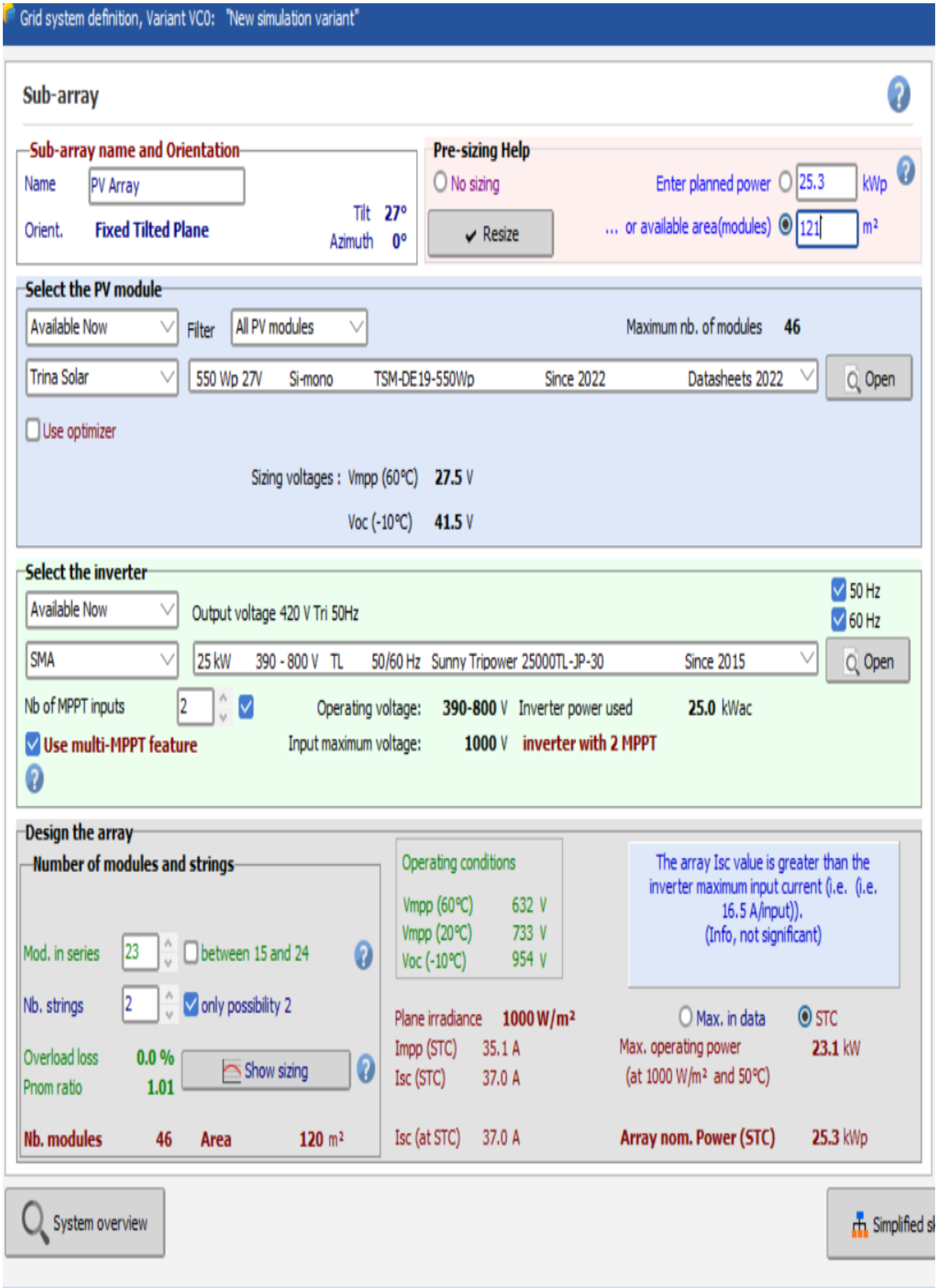

Fig. 5.19 system design of the PV syst

Summary of the software system design Fig. 5.20.

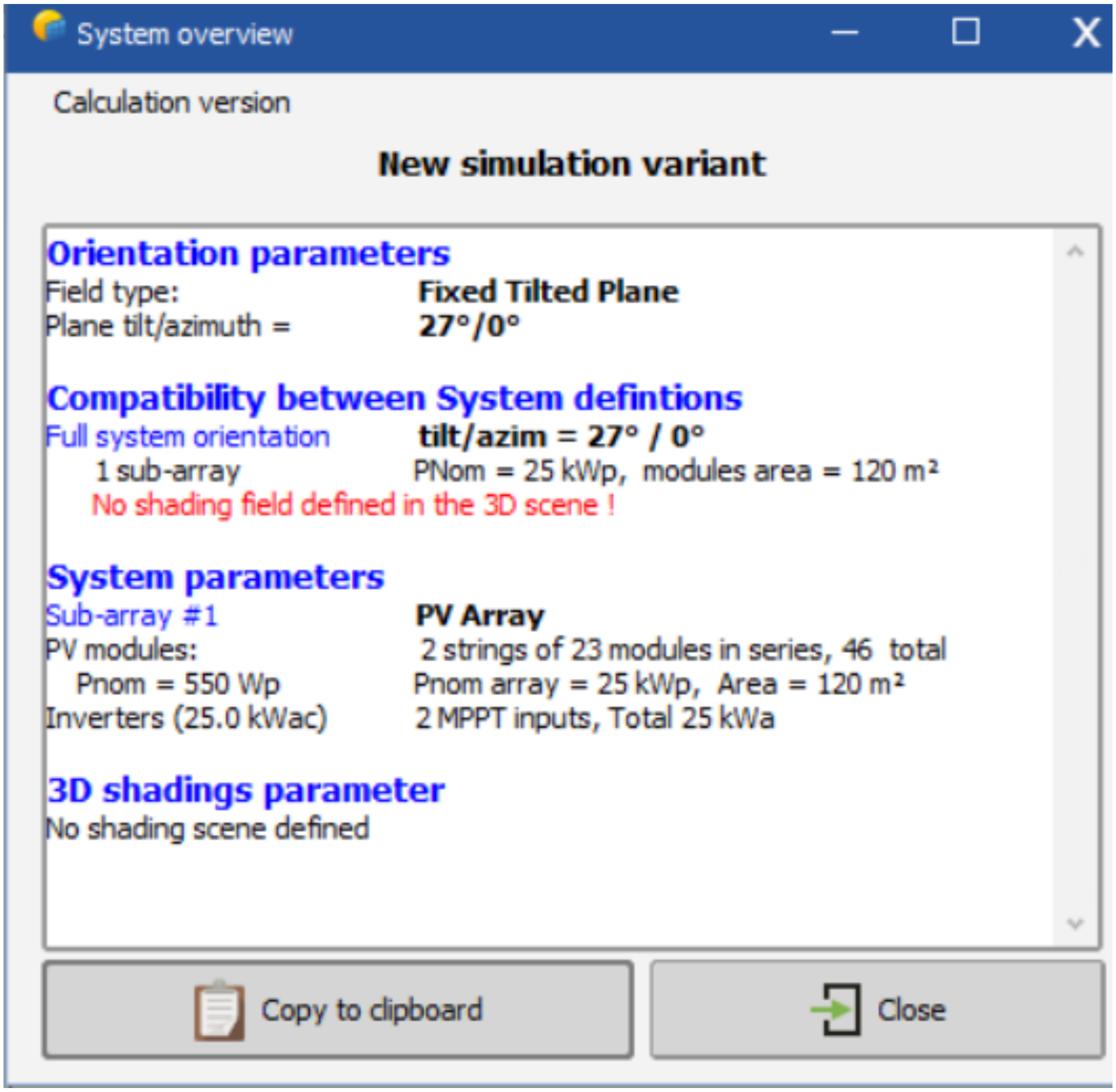

Fig. 5.20 summary of the calculation version.

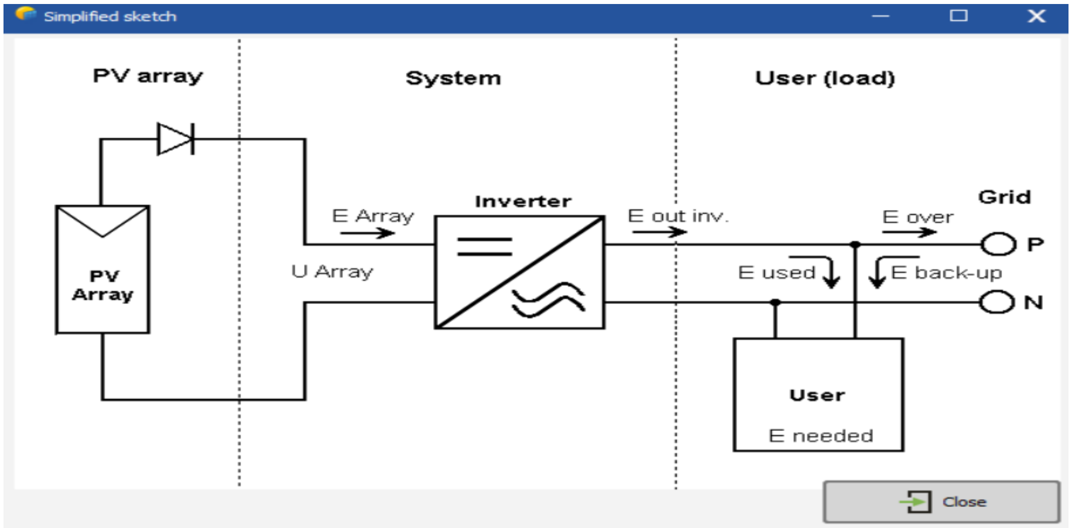

Fig. 5.21 Proposed Schematic diagram of the system from PV syst.

5.4 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:

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ConvertLIVE ,https://convertlive.com/ar/u/%D8%AA%D8%AD%D9%88%D9%8A%D9%84/%D8%B7%D9%86-%D9%85%D9%86-%D8%A7%D9%84%D8%AA%D8%A8%D8%B1%D9%8A%D8%AF/%D8%A5%D9%84%D9%89/%D9%83%D9%8A%D9%84%D9%88%D9%88%D8%A7%D8%AA [4]

Monitoring Equipment to Reduce Energy Consumption in Hospitals "2014" https://healthmanagement.org/c/hospital/issuearticle/monitoring-equipment-to-reduce-energy-consumption-in-hospitals [5]

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M.Rashid, "power electronics devices, circuit and applications" , pearson, 2014 [7]

S.Sharma,C.P.Kurian,andL.S.Paragond,"SolarPVSystemDesign Using PVsyst: A Case Study of an Academic Institute," in 2018 [8]

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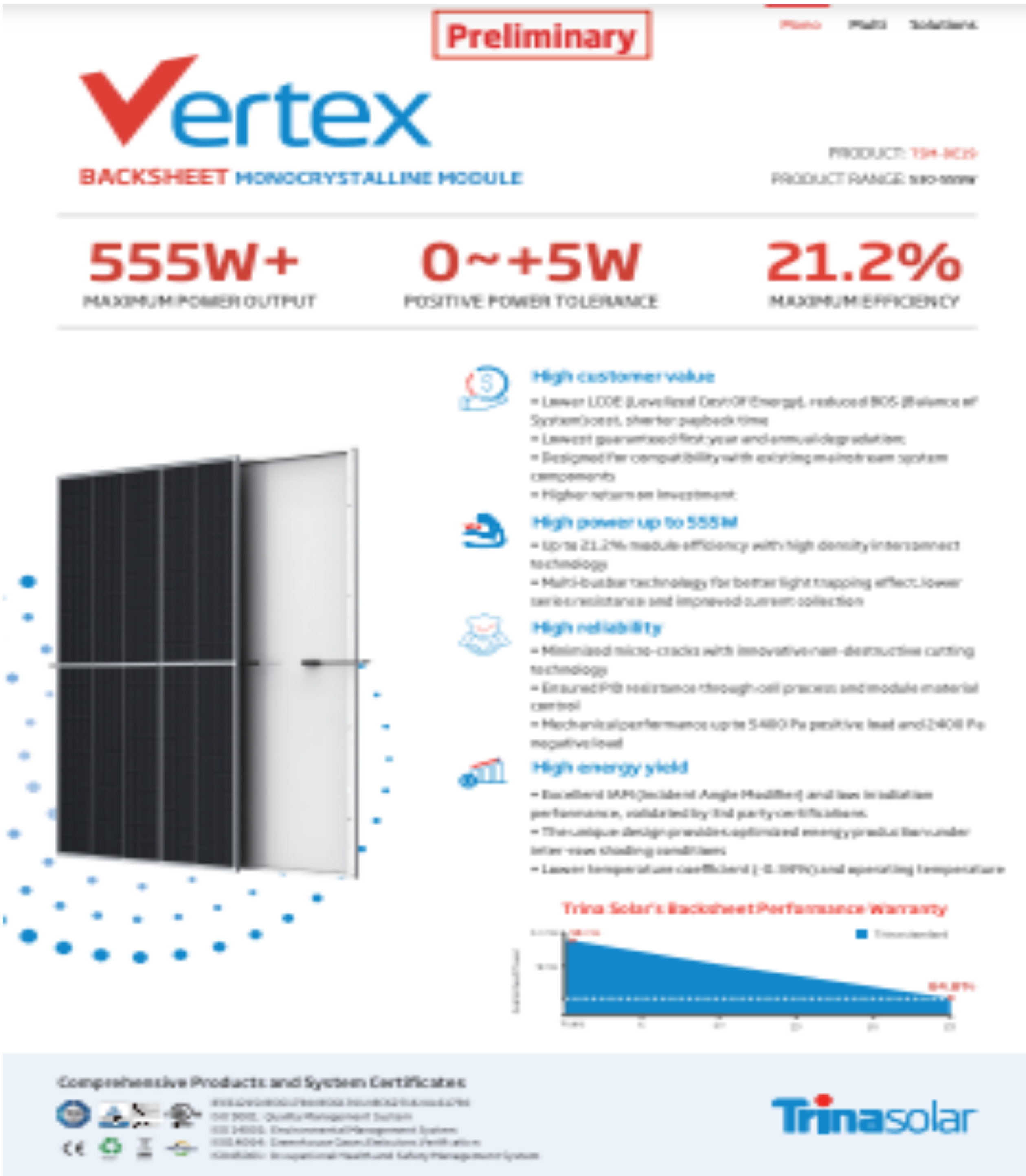
M. Maghalseh " PV SYSTEM DESIGN PRINCIPLES 2" in 2022 [10]

Appendix

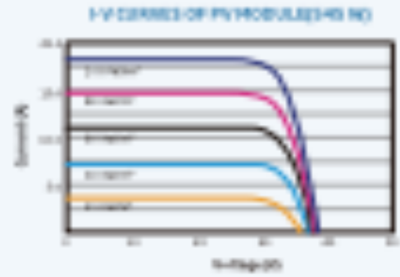
[A]

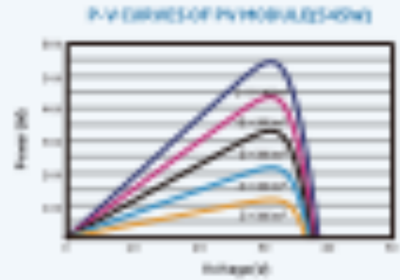

Preliminary
Vertex
BACKSHEET MONOCRYSTALLINE MODULE
555W+
MAXIMUM POWER OUTPUT
0~+5W
POSITIVE POWER TOLERANCE
21.2%
MAXIMUM EFFICIENCY
High customer value
High power up to 555W
High reliability
High energy yield
Trina Solar's Backsheet Performance Warranty
Comprehensive Products and System Certificates
Trinasolar

Vertex

Front View

Back View





Trinasolar

[B]

SUNNY TRIPOWER
15000TL / 20000TL / 25000TL

SMA

Efficient
- Maximum efficiency of 98.4%
- Yield increase without installation effort due to integrated shade management SMA ShadeFix

Safe
- DC surge arrester (SPD type II) can be integrated

Flexible
- DC input voltage of up to 1000 V
- Multistring capability for optimum system design
- Optional display

Innovative
- Cutting-edge grid management functions with Integrated Plant Control
- Reactive power available 24/7 (Q on Demand 24/7)

SUNNY TRIPOWER 15000TL / 20000TL / 25000TL

The versatile specialist for large-scale commercial plants and solar power plants

The Sunny Tripower is the ideal inverter for large-scale commercial and industrial plants. Not only does it deliver extraordinary high yields with an efficiency of 98.4%, but it also offers enormous design flexibility and compatibility with many PV modules thanks to its multistring capabilities and wide input voltage range.
The future is now: the Sunny Tripower comes with cutting-edge grid management functions such as Integrated Plant Control, which allows the inverter to regulate reactive power at the point of common coupling. Separate controllers are no longer needed, lowering system costs. Another new feature-reactive power provision on demand (Q on Demand 24/7).

SMA SMART CONNECTED

The integrated service for ease and comfort

SMA Smart Connected* is the free monitoring of the inverter via the SMA Sunny Portal. If there is an inverter fault, SMA proactively informs the PV system operator and the installer. This saves valuable working time and costs.

With SMA Smart Connected, the installer benefits from rapid diagnoses by SMA. They can thus quickly rectify the fault and score points with the customer thanks to the attraction of additional services.

ACTIVATION OF SMA SMART CONNECTED

During registration of the system in the Sunny Portal, the installer activates SMA Smart Connected and benefits from the automatic inverter monitoring by SMA.

AUTOMATIC INVERTER MONITORING

SMA takes on the job of inverter monitoring with SMA Smart Connected. SMA automatically checks the individual inverters for anomalies around the clock during operation. Every customer thus benefits from SMA's long years of experience.

PROACTIVE COMMUNICATION IN THE EVENT OF FAULTS

After a fault has been diagnosed and analysed, SMA informs the installer and end customer immediately by e-mail. Everyone is thus optimally prepared for the troubleshooting. This minimises the downtime and saves time and money. The regular power reports also provide valuable information about the overall system.

REPLACEMENT SERVICE

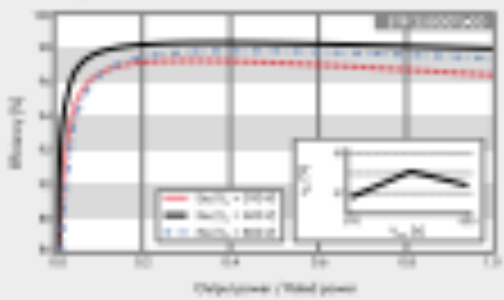
If a replacement device is necessary, SMA automatically supplies a new inverter within one to three days of the fault diagnosis. The installer can contact the PV system operator of their own accord and replace the inverter.

PERFORMANCE SERVICE

The PV system operator can claim compensation from SMA if the replacement inverter cannot be delivered within three days.

* Details see document "Description of Services – SMA SMART CONNECTED"

Efficiency Curve



Accessory

● Standard features ○ Optional features – Not available
Data at nominal conditions
Status: [illegible]

Technical data	Sunny Tripower 15000TL	Sunny Tripower 20000TL	Sunny Tripower 25000TL
Input (DC)			
Max. generator power	27000 Wp	36000 Wp	45000 Wp
DC rated power	15330 W	20440 W	25550 W
Max. input voltage	1000 V	1000 V	1000 V
MPP voltage range / rated input voltage	240 V to 800 V / 600 V	320 V to 800 V / 600 V	390 V to 800 V / 600 V
Min. input voltage / start input voltage	150 V / 188 V	150 V / 188 V	150 V / 188 V
Max. input current input A / input B	33 A / 33 A	33 A / 33 A	33 A / 33 A
Max. DC short-circuit current input A / input B	43 A / 43 A	43 A / 43 A	43 A / 43 A
Number of independent MPP inputs / strings per MPP input	2 / A:3; B:3	2 / A:3; B:3	2 / A:3; B:3
Output (AC)			
Rated power (at 230 V, 50 Hz)	15000 W	20000 W	25000 W
Max. AC apparent power	15000 VA	20000 VA	25000 VA
AC nominal voltage	3 / N / PE, 220 V / 380 V 3 / N / PE, 230 V / 400 V 3 / N / PE, 240 V / 415 V		
AC voltage range	180 V to 280 V		
AC grid frequency / range	50 Hz / 44 Hz to 55 Hz 60 Hz / 54 Hz to 65 Hz		
Rated power frequency / rated grid voltage	50 Hz / 230 V		
Max. output current / Rated output current	29 A / 21.7 A	29 A / 29 A	36.2 A / 36.2 A
Power factor at rated power / Adjustable displacement power factor	1 / 0 overexcited to 0 underexcited		
THD	≤3%		
Feed-in phases / connection phases	3 / 3		
Efficiency			
Max. efficiency / European Efficiency	98.4% / 98.0%	98.4% / 98.0%	98.3% / 98.1%
Protective devices			
DC-side disconnection device	●		
Ground fault monitoring / grid monitoring	● / ●		
DC surge arrester (Type II) can be integrated	○		
DC reverse polarity protection / AC short-circuit current capability / galvanically isolated	● / ● / –		
All-pole sensitive residual-current monitoring unit	●		
Protection class (according to IEC 62109-1) / overvoltage category (according to IEC 62109-1)	I / AC: III; DC: II		
General data			
Dimensions (W / H / D)	661 / 682 / 264 mm (26.0 / 26.9 / 10.4 inch)		
Weight	61 kg (134.48 lb)		
Operating temperature range	−25 °C to +60 °C (−13 °F to +140 °F)		
Noise emission (typical)	51 dB(A)		
Self-consumption (at night)	1 W		
Topology / cooling concept	Transformerless / OptiCool		
Degree of protection (as per IEC 60529)	IP65		
Climatic category (according to IEC 60721-3-4)	4K4H		
Maximum permissible value for relative humidity (non-condensing)	100%		
Features / Function / Accessories			
DC connection / AC connection	SUNCLIX / spring-cage terminal		
Display	○		
Interface: RS485, Speedwire/Webconnect	○ / ●		
Data interface: SMA Modbus / SunSpec Modbus	● / ●		
Multifunction relay / Power Control Module	○ / ○		
Shade management SMA ShadeFix / Integrated Plant Control / Q on Demand 24/7	● / ● / ●		
Off-Grid capable / SMA Fuel Save Controller compatible	● / ●		
Guarantee: 5 / 10 / 15 / 20 years	● / ○ / ○ / ○		
Certificates and permits (more available on request) * Does not apply to all national appendices of EN 50438	[illegible]		
Type designation	STP 15000TL-30	STP 20000TL-30	STP 25000TL-30

[C]

SUNNY TRIPOWER CORE1
STP 50-40

Cost Effective
- Floor mounted device easy to install
- No DC fuse required
- Integrated DC disconnector

Highly Integrated
- Integrated WiFi access with any mobile device
- 12 direct string inputs reduce labor and material costs
- AC/DC overvoltage protection (optional)

Fastest Installation
- Fast grid connection due to easy inverter configuration and commissioning
- Completely accessible connection areas

Maximum Yields
- Up to 150% DC/AC ratio
- Yield increase without installation effort due to integrated shade management SMA ShadeFix

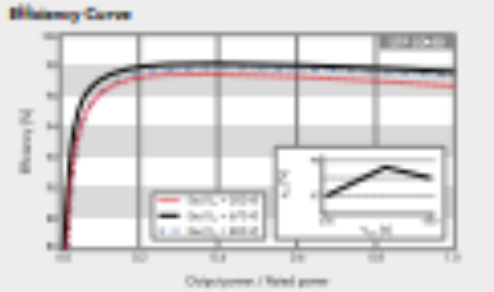
SUNNY TRIPOWER CORE1

Stands on its own

The Sunny Tripower CORE1 is the world's first free-standing string inverter for decentralized rooftop and ground-based PV systems as well as covered parking spaces. The CORE1 is the third generation in the successful Sunny Tripower product family and is revolutionizing the world of commercial inverters with its innovative design. SMA engineers developed an inverter that combines a unique design with an innovative installation method to significantly reduce installation time and provide all target groups with a maximum return on investment.
From delivery and installation to operation, the Sunny Tripower CORE1 generates widespread savings in logistics, labor, materials and services. Commercial PV installations are now quicker and easier to complete than ever before.

BLOCK DIAGRAM

Efficiency Curve



Accessories

www.SMA-Solar.com

SMA Solar Technology

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No.	Item	Specification
1	Charge cut-off voltage	DC 29.2V
2	Nominal voltage	24V
3	Nominal capacity	400Ah
4	Continuous discharger current	100A/200A /300A/(can be customize)
5	Charge current	Standard charge: 10 Approx 10 Hour Rapid charge: 20 Approx 5 Hour
6	Standard Charging method	0.2 CC(constant current) charge to 73V, then CV(constant voltage 58.4V) charge till charge current decline to less than 0.02C
7	Max. charge current	100A
8	Max. discharge current2	300A
9	Max.Pulse Current	200A/400A/600A(2S)
10	Discharge cut-off voltage	20V
11	Cell	3.2v lithium
12	Operating temperature	Charging: 0°C - 45°C Discharging: -10°C- 60°C
13	Storage temperature	-10°C to + 45°C
14	Battery Weight	Approx. 56 kg
15	Battery Dimension	250*320*420mm
16	Battery outgoing voltage	17.5V-29.2V
17	BMS built in	Yes