



Palestine Polytechnic University

College of Engineering

Bachelor degree of Power Engineering

**Design PV substation and study its impact on both
side (33k and 11k) of 10 MVA station**

Submitted by:

Ayman Ghaith

Amin Salah

Shams Addin Bitar

Supervisor: Dr. Nassim Iqteit

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الإهداء

نهدى هذا العمل المتواضع إلى والدينا الكرام اللذان لم يدخرأ جهداً
في توفير كل الظروف المناسبة لإنجاح هذا العمل ونهديه أيضاً إلى
أعضاء هيئة التدريس وموظفي جامعة بوليتيكنيك فلسطين ونخص بالذكر
الدكتور نسيم قطيط

كما نهدى هذا العمل المتواضع لوطننا الغالي وعاصمة بلادنا القدس
الشريف وإلى أرواح الوطن وإلى الأسرى وإلى كل من أحب
العلم والتعلم.

وصلت رحلتنا الجامعية إلى نهايتها بعد تعب ومشقة

وها نحن ذا نختم بحث تخرُّجنا بكل همّة ونشاط،

ونتمنّى لكل من كان له فضل ومسيرتنا،

وساعدنا ولو باليسير،

إلى من نفضّلها على أنفسنا، ولمَ لا فلقد ضحّت من أجلنا

ولم تدّخر جهداً في سبيل إيسعادنا على الدوام

(أمّي الحبيبة)

نسير في درب الحياة، ويقف من يُسيطر على أذهاننا في كل مسلك نسلكه

صاحب الوجه الطيب، والأفعال الحسنة،

فلم يخل علينا طيلة حياته

(والدي العزيز)

إلى جميع أساتذتنا الكرام، ممن لم يتوانوا في مد يد العون لنا في جامعة البوليتيكنك

يا بستان العلوم يا زهرا وأريج وريحان يا شعلة تثير درب الإنسان على مدى الأزمان يا من شققتم بسواعدكم

طريقنا ورصقتموه لنا لتعبر ونحن قد اطمأننا من غدر الزمان إليكم يا مدرسي الكرام نهدي لكم مشروعنا مع

فائق الاحترام.

كما نتقدم بجزيل الشكر لعضوي لجنة المناقشة: الدكتور سمير حنا والدكتور ماهر مغالسة.

الملخص

إن تقييم وتحسين أداء المحطات الكهربائية وشبكات التوزيع في الأنظمة الكهربائية يساعد على زيادة الموثوقية في الخدمة؛ كما أنه يخلق عائداً مادياً على الاستثمار في هذا المجال، بحيث تظهر العديد من الدراسات أن 30% - 40% من الاستثمار في قطاع الكهرباء ينفق على نظام المحطات وشبكات التوزيع الكهربائية.

يعمل هذا المشروع على تحليل وتقييم محطة بيت حنينا (10 ميغاواط، 11/33 كيلو فولت) من جهات مختلفة؛ سعة المحطة، وتوزيع الأحمال. من ناحية أخرى، وحتى يتم بناء محطة طاقة شمسية وربطها بمستوى 33 كيلو فولت أو 11 كيلو فولت، فإنه تم استخدام برنامج "الهومر برو" وذلك لتجميع المعلومات لإجمالي عدد الألواح وطريقة توصيلهم وقدرة كل لوح، والقدرة الاجمالية، وأيضا معلومات عن "الإنفيرتر" من حيث جهد الداخل وجهد الخارج، والكفاءة، والكابلات الواصلة بين الألواح و"الإنفيرتر"، وبين "الإنفيرتر" وخط الشبكة الرئيسي. كما تم استخدام البرنامج للحصول على معدل الاشعاع الشمسي ومعدل درجة الحرارة ضمن النطاق المكاني لبيت حنينا.

بناءً على جميع المعلومات التي تم الحصول عليها من خلال البرنامج، تم إنشاء محطة طاقة شمسية جديدة بسعة 2 ميغاواط تم فصلها إلى محطتين رئيسيتين بسعة 1 ميغاواط للمحطة الواحدة. تتكون كل محطة من 1668 لوح شمسي بقدرة 660 وات لكل لوح شمسي. تم استخدام "إنفيرتر" بسعة 1.25 ميغاواط لتوصيل الألواح بالشبكة الرئيسية. تم استخدام برنامج "الايتاب" لمعالجة جميع بيانات النظام وإجراء محاكاة مسبقة للنظام.

تم إجراء مقارنة كاملة عندما تم تدفق 2 ميغاواط من محطة الطاقة الشمسية إلى الشبكة الرئيسية على طرفي المحول (جهة 11 كيلو فولت وجهة 33 كيلو فولت) وتم تحديد الفروقات بين جهتي الربط على المحول .

Abstract

The Evaluation and improvement of electric substations, feeders and distribution network performance in the electrical systems leads to increased reliability in the service; it also leads to high financial return that encourages investment in this field. Studies show that 30% to 40% of the investment in the electricity sector is spent on substation distribution system.

This project will work on analyzing and evaluate the Beit Hanina substation (10 MW, 33/11 kV) from different sides; Station capacity, old cables, power factor, load distribution. On the other hand, in order to build a solar power plant and connect it to a level of 33 kV or 11 kV, the Homer Pro program was used to collect information about the total number of panels, the method of their connection, the capacity of each panel, the total capacity, as well as information about the inverter in terms of the internal voltage and the external effort, efficiency, as well as the cables connecting between the panels and the inverter and between the inverter and the main bus line. Homer program was also used to obtain the rate of solar radiation and the rate of heat in the spatial scale of Beit Hanina.

Based on all the information obtained through the programs, a new 2 MW solar power plant was built which is separated to two main stations with

1 MW capacity for a single station. Each station consists of 1668 solar panels with 660 watt capacity for each solar panel. A 1.25 MW inverter was used to connect the panels with the main network. ETAP program was used to process all system data and perform a preset system simulation.

A full comparison was done when a 2 MW flowed from the solar station to the main network on 11 kV and 33 kV transformers.

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List of Abbreviations

kWh	Kilowatt-hour
LOSSES	The power system losses
ETAP	Electrical Transient Analysis Program
MW	Mega Watt
kV	Kilovolt
MPC	Main power center
kVA	Kilovolt-ampere
MVA	Megavolt- Ampere
PF	Power Factor
AC	Alternating Current
DC	Direct Current
Tr.	Transformer
IEC	Israel Electrical Company
FF	Fill Factor

Chapter 1

Introduction

Beit Hanina is situated along Ramallah Road in northern East Jerusalem. It primarily consists of residential areas, located on either side of the Ramallah Road. It borders Shuafat to the south, the municipal border and the Jerusalem-Modi'in Road to the west, the Atarot Industrial Zone and the defunct Qalandiya Airport to the north. The Separation Barrier is also an important factor delineating all but the southern boundary of Beit Hanina.

Beit Hanina has been connected to a public electricity network since 1960. It is served by the Jerusalem Electricity Company, which is the main source of electricity in the town. Approximately 95% of the housing units in the town are connected to this network. The location of Beit Hanina station is indicated in Fig. (1.1).



Figure 1.1: Beit Hanina station.

The capacity of Beit Hanina station is 10MVA which provides the electricity to the village of Beit Hanina, Shoman, and Wad Al-Dam. The voltage of the station is 33 / 11 kV. Fig (1.2) denotes the single line diagram of Beit Hanina substation.

1.1. PROBLEM DEFINITION

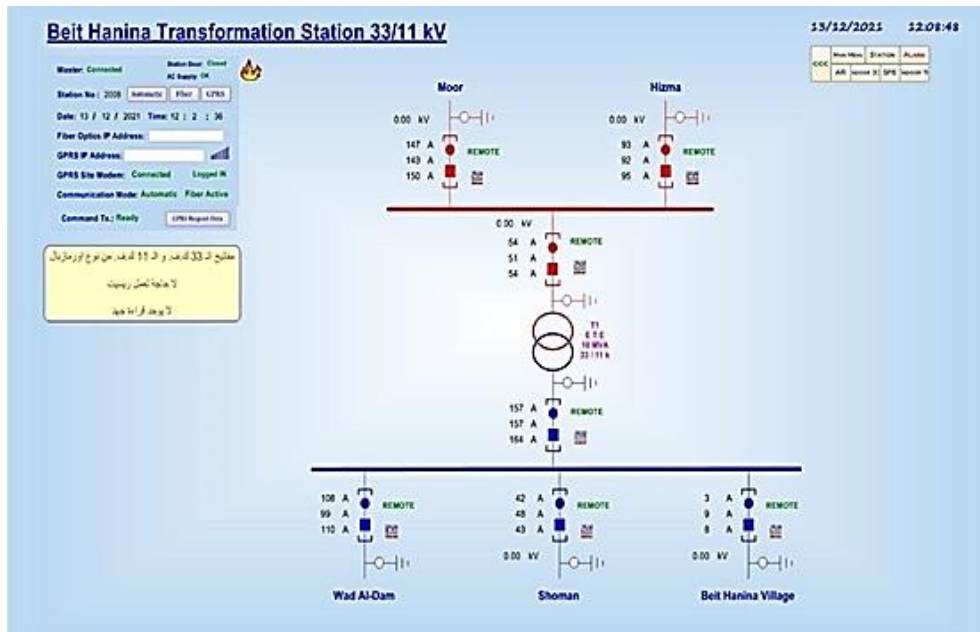


Figure 1.2: Beit Hanina Single Line Diagram.

1.1 Problem Definition

This project will analyze the Beit Hanina substation (10 MW, 33/11 kV) from different angles: Station capacity, old cables, power factor, and load distribution. On the other hand, the project will discuss the possibility of supporting the plant with a solar power plant and examine the best method to connect it to a level of 33 kV or 11 kV.

1.2 Project Motivation

The motivation behind this study is to evaluate and discuss the situation of the Beit Hanina station from different angles, by studying the possibility of supporting the plant with a solar power plant and examining the best to connect it to a level of 33 kV or 11 kV.

1.3 Project Objectives

1. Assessment of the Beit Hanina transformation station in the fields of capacity, cables, and load distribution.
2. Design an on-grid solar system station to support the Beit Hanina transformation station.
3. Study the impact of injection of the proposed PV station on the 33 kV or the 11 kV sides of the station.

The indirect objectives of the project are to maintain and develop the existing network and propose solutions to some existing problems. Moreover, finding an alternative source to supply the station with electrical energy instead of the connection point. Studying the effectiveness of the project and the possibility of applying this plan to the rest of the electrical stations. Applying all theoretical information to practice through our study of electrical power engineering.

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

1.4 Project Importance

It will be provided with clean and environmentally-friendly energy in addition to not increasing the load on the public network in the city, which leads to poor quality.

1.5 Time Schedule

Table 1.1: Time Schedule

-	Item	No. week
1	Ideation of the project and literature review	3 Weeks
2	Collection of information about the loads of low-voltage transformers on the electric network.	2 Weeks
3	Analyze the existing network and identify existing issues	4 Weeks
4	Analyze the network and load distributions	4 Weeks
5	Assess the land and its area for designing the PV station.	2 Weeks
–	For the project	-
6	Analyze the capacity of the station, cables, power factor, and load distributions.	4 Weeks
7	Design PV station and determine the appropriate size.	4 Weeks
8	Study the impact of injection the PV station on 33 kV or 11 kV	3 Weeks
9	Drafting the project	3 Weeks

Chapter 2

System Components

2.1 Overview of the distribution load of Beit Hanina station

The average load of Beit Hanina station increases with the passage of time, where the maximum average load is during winter. Table (2.1) displays the average load of Beit Hanina station, the table depicts the load station in 2020 by ampere unit, while Table (2.2) displays the average load in MW. The monthly load of the station at 11 kV is indicated in Fig. (2.3), and the feeder 11 kV, 33 kV load percentage is shown in Fig. (2.4) and Fig. (2.5).

2.1. OVERVIEW OF THE DISTRIBUTION LOAD OF BEIT HANINA

Table 2.1: Average load power of Beit Hanina station/ A

Average Load on Bait Hanina Transformation Station 2020 / A							
	Wad Al-Dam	Shoman	Beit Hanina Village	T1 - 11 kV	T1 - 33 kV	Moor IEC	Hizma
1	134.27	114.15	8.52	259.23	86.44	155.64	69.09
2	97.86	82.29	7.45	190.14	63.46	146.92	83.39
3	91.23	64.96	6.12	165.22	55.03	140.64	85.45
4	82.04	46.47	4.08	135.01	45.20	112.19	67.07
5	67.97	39.29	2.85	113.05	38.14	96.35	58.18
6	71.34	40.57	3.05	117.52	39.48	81.38	42.28
7	89.83	47.19	4.13	144.40	48.44	133.88	85.49
8	96.36	50.96	4.12	154.65	51.84	139.22	87.55
9	90.12	46.98	3.55	143.58	48.12	137.86	89.44
10	86.36	41.56	3.24	134.26	45.02	135.03	90.68
11	99.13	53.68	3.98	159.37	53.32	125.44	71.78
12	146.93	122.18	6.76	278.39	93.07	156.65	63.57
2020	96.12	62.52	4.82	166.23	55.63	130.10	74.50

Table 2.2: Average load power of Beit Hanine station/ MW

Average Load on Bait Hanina Transformation Station 2020 / MW							
	Wad Al-Dam	Shoman	Beit Hanina Village	T1 - 11 kV	T1 - 33 kV	Moor IEC	Hizma
1	2.52	2.15	0.16	4.87	4.87	8.78	3.90
2	1.84	1.55	0.14	3.57	3.58	8.28	4.70
3	1.71	1.22	0.12	3.11	3.10	7.93	4.82
4	1.54	0.87	0.08	2.54	2.55	6.33	3.78
5	1.28	0.74	0.05	2.12	2.15	5.43	3.28
6	1.34	0.76	0.06	2.21	2.23	4.59	2.38
7	1.69	0.89	0.08	2.71	2.73	7.55	4.82
8	1.81	0.96	0.08	2.91	2.92	7.85	4.94
9	1.69	0.88	0.07	2.70	2.71	7.77	5.04
10	1.62	0.78	0.06	2.52	2.54	7.61	5.11
11	1.86	1.01	0.07	3.00	3.01	7.07	4.05
12	2.76	2.30	0.13	5.23	5.25	8.83	3.58
2020	1.81	1.18	0.09	3.12	3.14	7.34	4.20

From Table (2.2), it seems that the less load value is 2MW, so according to that, a new solar power plant was selected to be 2MW, and if the injection from the solar power plant is more than the load, it will lead to inject to the network inversely, effecting the network. As a result of that, all the power that is generated by the solar power plant will flow toward the loads.

2.1. OVERVIEW OF THE DISTRIBUTION LOAD OF BEIT HANINA

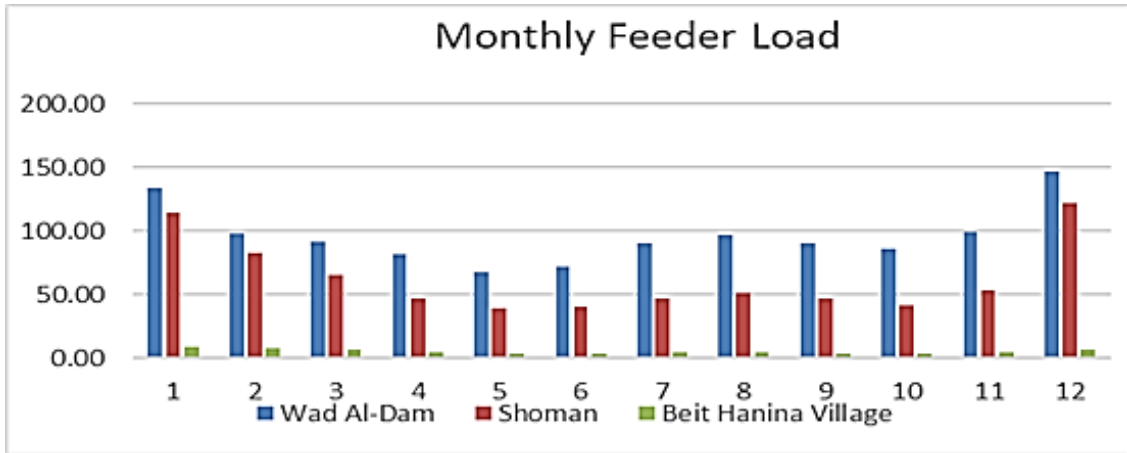


Figure 2.1: The monthly load of on the 11kV feeders of station.

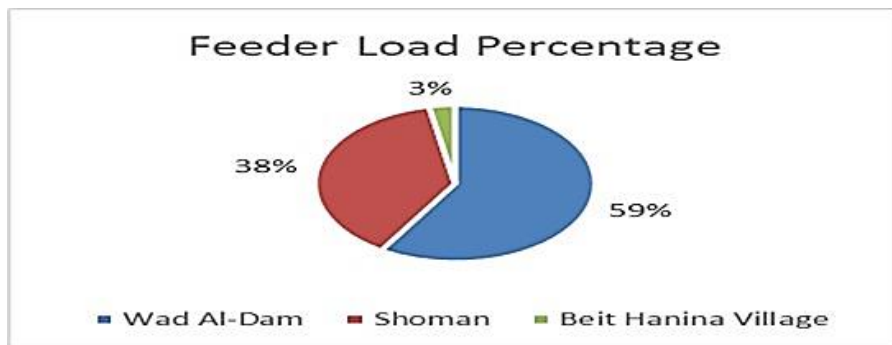


Figure 2.2: loading ratio of each feeder is 11 kV from the station

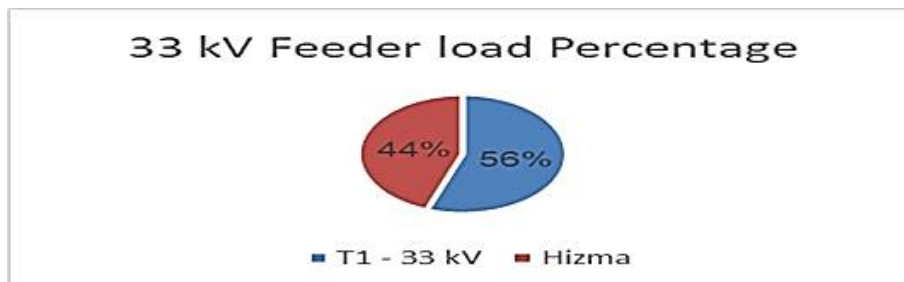


Figure 2.3: Loading ratio of each feeder is 33 kV from the station

The station transformer loading in ampere unit is given in Fig. (2.6), where the total load of the transformer is 180A. The injected yearly load is given in Fig. (2.7), where the point capacity is 360A.

2.1. OVERVIEW OF THE DISTRIBUTION LOAD OF BEIT HANINA

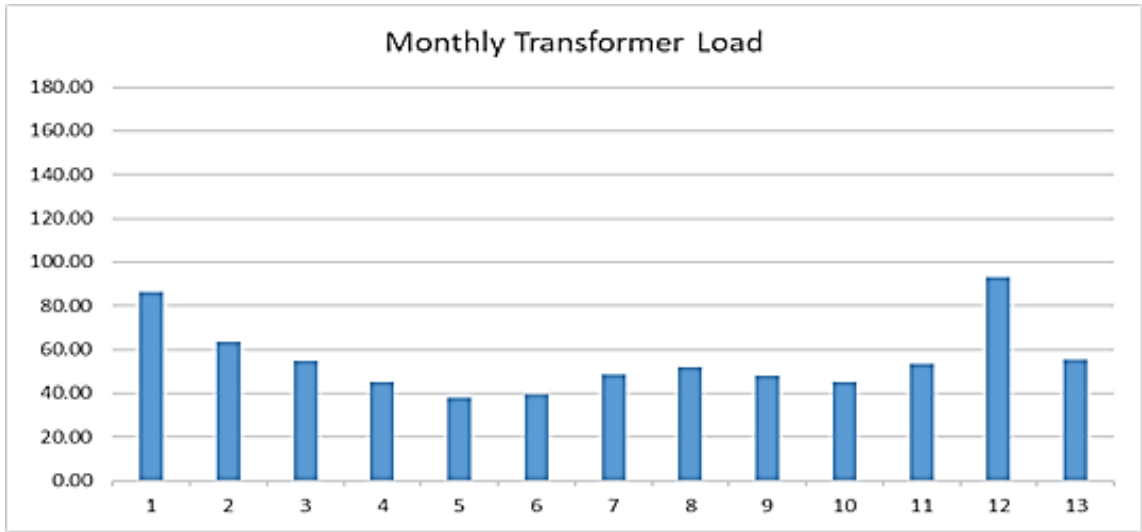


Figure 2.4: The yearly load of the transformer

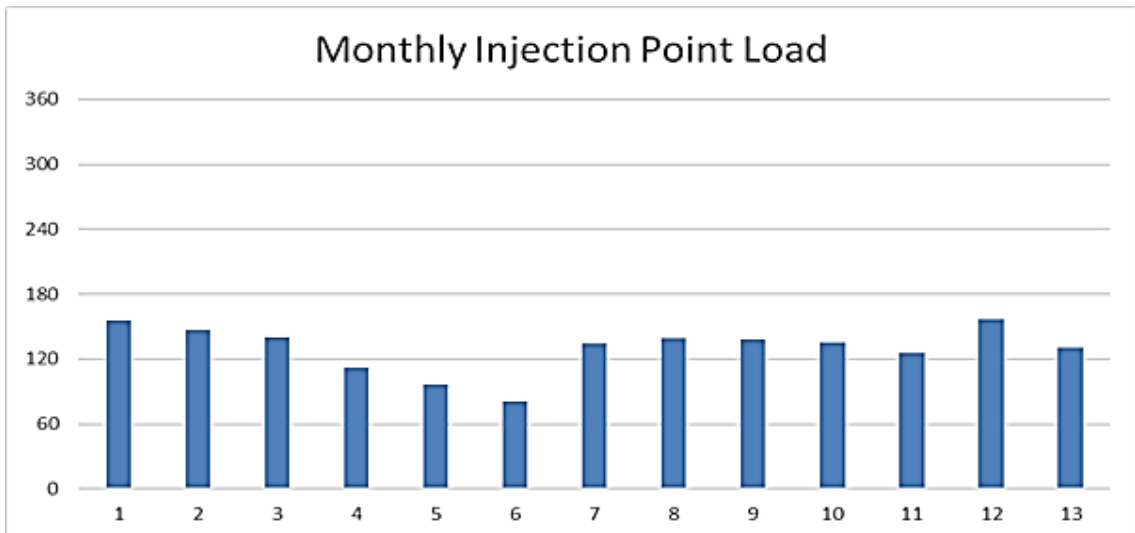


Figure 2.5: The yearly injection Point load of the transformer

The average recorded values of voltage in 2020 are shown in Table (2.3). The details of Beit Hanina Station feeders and the number and the size of distribution transformers are given in Table (2.4). The load percentage of distribution transformers are given in Table (2.4). The load percentage of distribution transformer is given in Fig. (2.10) and the percent of distribution transformers in each feeder is given in Fig. (2.11).

2.1. OVERVIEW OF THE DISTRIBUTION LOAD OF BEIT HANINA

Table 2.3: Average voltage kV in 2020

Average Voltage on Bait Hanina Transformation Station 2020 / kV							
	Wad Al-Dam	Shoman	Beit Hanina Village	T1 - 11 kV	T1 - 33 kV	MoorIEC	Hizma
1	11.1	11.1	11.1	11.1	34.0	34.0	34.0
2	11.2	11.2	11.2	11.2	34.1	34.1	34.1
3	11.2	11.2	11.2	11.2	34.1	34.1	34.1
4	11.3	11.3	11.3	11.3	34.4	34.4	34.4
5	11.5	11.5	11.5	11.5	34.5	34.5	34.5
6	11.5	11.5	11.5	11.5	34.5	34.5	34.5
7	11.3	11.3	11.3	11.3	34.4	34.4	34.4
8	11.2	11.2	11.2	11.2	34.2	34.2	34.2
9	11.2	11.2	11.2	11.2	34.2	34.2	34.2
10	11.3	11.3	11.3	11.3	34.3	34.3	34.3
11	11.2	11.2	11.2	11.2	34.1	34.1	34.1
12	11.1	11.1	11.1	11.1	34.0	34.0	34.0
2020	11.3	11.3	11.3	11.3	34.2	34.2	34.2

Table 2.4: Number of transformers on each feeder and its type.

Transformers of Bait hanina Transformation Station Feeders / kVA							
TRANSFORMERS	100	160	250	400	630	1000	Total
Bait Hanina village	1	1	2	0	0	0	4
Wad Al-Dam	0	0	3	1	9	3	16
Shoman	0	0	0	5	5	0	10
Total Number	1	1	5	6	14	3	30
Total (kVA)	100	160	1250	2400	8820	3000	15730

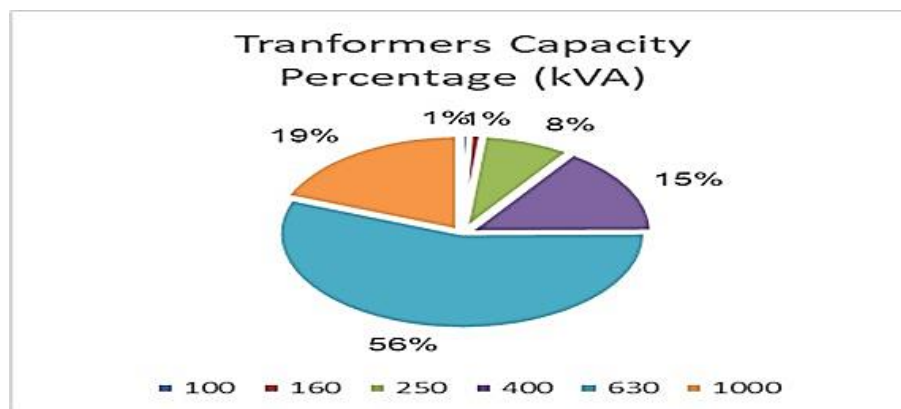


Figure 2.6: Transformer capacity percentage

2.1. OVERVIEW OF THE DISTRIBUTION LOAD OF BEIT HANINA

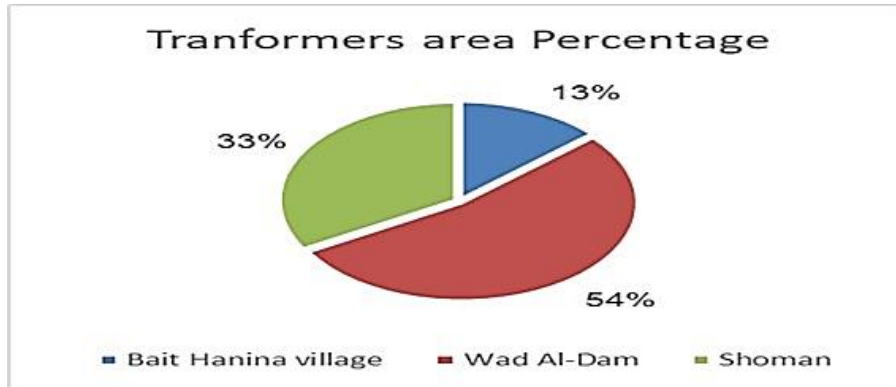


Figure 2.7: The percentage of transformers on each feeder from all transformers.

2.1.1 Beit Hanina station cables

Table (2.5) shows the type, size and length of cables used in the Beit Hanina station, while the size and number of each cable section is given in Table (2.6). The overhead and underground cables percentage is given in Fig. (2.14), while Fig. (2.15) displays the cable area percentage.

Table 2.5: Cable Type and length on Beit Hanina Transformation Station.

Cables of Beit Hanina Transformation Station feeders / km								
Cable	O.H (50) AL	O.H (95) AL	O.H Total	M.Core (120) Cu	S.Core (150) Cu	S.Core (240) AL	U.G Total	Total
Bait Hanina village	0.66	0.02	0.68	0.33	0.00	0.45	0.78	1.47
Wad Al-Dam	0.14	0.40	0.54	2.77	0.28	1.87	4.91	5.45
Shoman	0.44	0.90	1.34	1.65	0.60	0.00	2.25	3.59
Total	1.24	1.32	2.56	4.74	0.88	2.32	7.94	10.51

Table 2.6: Number of sections in Beit Hanina transformation station.

Cables Sections on Beit Hanina transformation station Feeders						
Section	O.H (50) AL	O.H (95) AL	M.Core (120) Cu	S.Core (150) Cu	S.Core (240) AL	Total
Bait Hanina village	1	1	1	0	1	4
Wad Al-Dam	1	1	9	1	8	20
Shoman	2	1	7	2	0	12
Total	4	3	17	3	9	36

2.1. OVERVIEW OF THE DISTRIBUTION LOAD OF BEIT HANINA

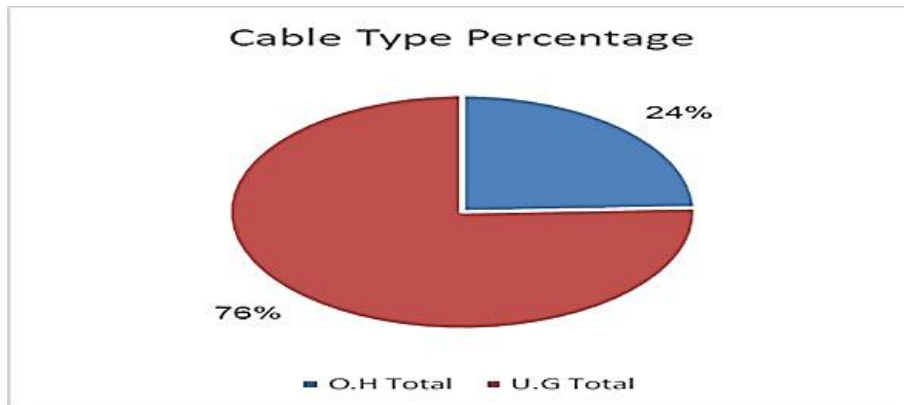


Figure 2.8: The percentage of overhead and grounded cables used in the transformer station.

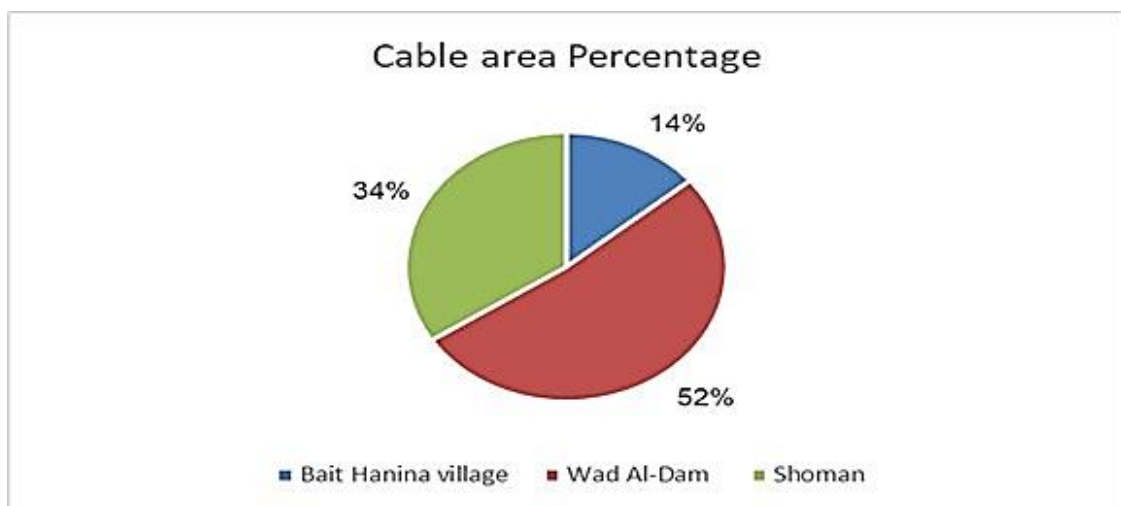


Figure 2.9: The ratio of cables for each feeder of the total cables.

2.2 System Block Diagram

Fig. (2.10) illustrates the main idea of the project, where the solar panel was used to collect the radiation, then the inverter used to convert and connect the panels with the main network. The step-up and step-down transformer proposed convert to 11 kV or 33 kV.



Figure 2.10: System Block Diagram.

Chapter 3

HOMER pro program simulation and results

3.1 HOMER Program Overview

HOMER simulates the operation of a system by doing energy balance calculations at each step during the year. AT each step, HOMER compares the electric and thermal demand momentarily to the energy that the system can supply at that time, and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, HOMER also decides at each step how to operate the generators and whether to charge or discharge the batteries. HOMER performs these energy balance calculations for each desired system configuration. It then determines whether a configuration is feasible, (i.e. Whether it can meet the electric demand under the conditions specified), and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and

3.2. PHOTOVOLTAIC POWER GENERATION

interest. The HOMER support site has various resources for assistance.

HOMER can assist in designing the best micro-power system to fulfill specific needs, which allows to:

- a. Evaluate off-grid or grid-connected power system designs.
- b. Choose the best system based on cost, technical requirements, or environmental considerations.
- c. Simulate a plethora of design configurations under market-price uncertainty and evaluate risks.
- d. Choose the best addition or retrofit for an existing system.
- e. Create a system with a load, generator, wind turbine, batteries, and a system converter.
- f. Perform an economic optimization to find the best combination of battery bank, converter, generator, and wind turbine quantities and capacities.
- g. Perform a sensitivity analysis to investigate how results are affected by fuel price, wind speed, and load size.
- h. Explore the effect of interest rate on the optimal system type.

3.2 Photovoltaic Power Generation

Photovoltaic cells are made of semi-conducting materials with the most commonly used material is silicon. When sunlight is absorbed by these materials,

3.2. PHOTOVOLTAIC POWER GENERATION

the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. A single PV cell typically produces a small amount of power and in order to increase the operating voltage, the cells are connected in a series to form a PV module. A photovoltaic array consists of a number of electrically-connected PV modules, which can be connected together in a series to generate a higher voltage or in parallel to get a higher current

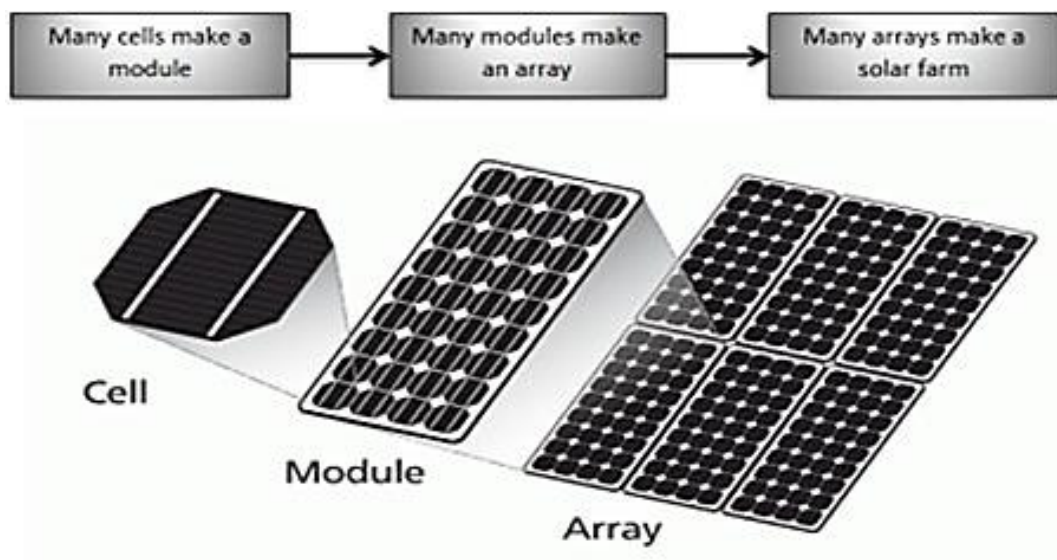


Figure 3.1: Solar cell to solar farm.

The Solar panel consists of main 6 components which are illustrated in Figure (3.2):

1. Extruded aluminum frame.
2. Tempered Glass - 3 to 4mm thick.
3. Silicon PV cells.
4. Encapsulation - EVA film layers.
5. Polymer rear back sheet.
6. Junction box - diodes and connectors.

3.2. PHOTOVOLTAIC POWER GENERATION

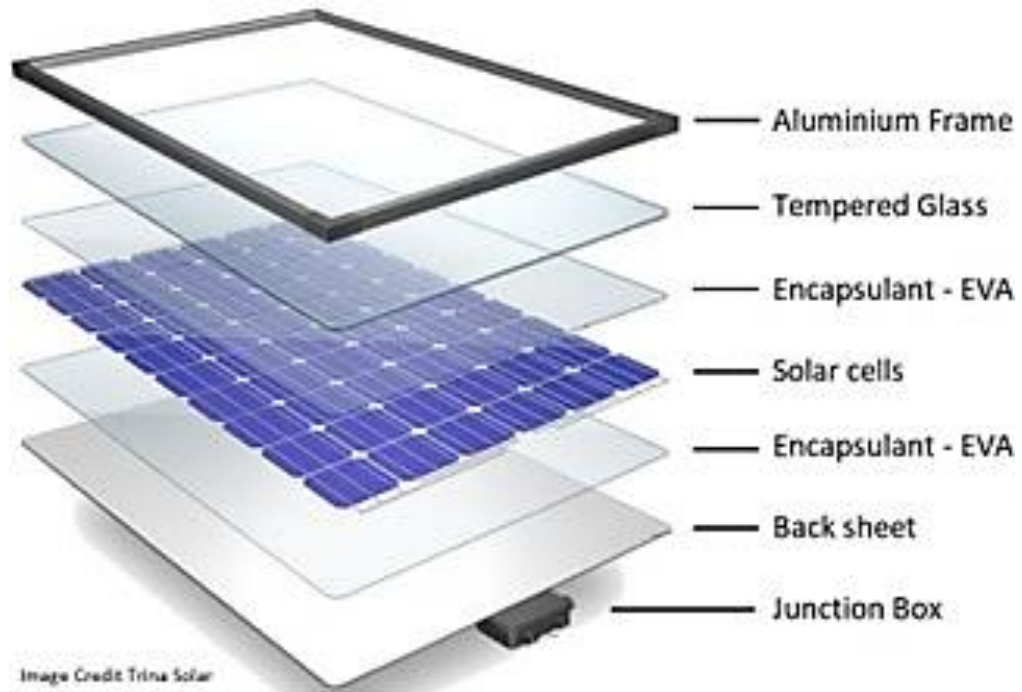


Figure 3.2: Solar panel components.

3.2.1 Characteristics of Photovoltaic Module

The performance of a photovoltaic module depends on the manufacturing technology and operating conditions (solar radiation and temperature). The curve of current – voltage (I-V), which determines the behavior of a photovoltaic cell, is illustrated in Fig. (3.3).

3.2. PHOTOVOLTAIC POWER GENERATION

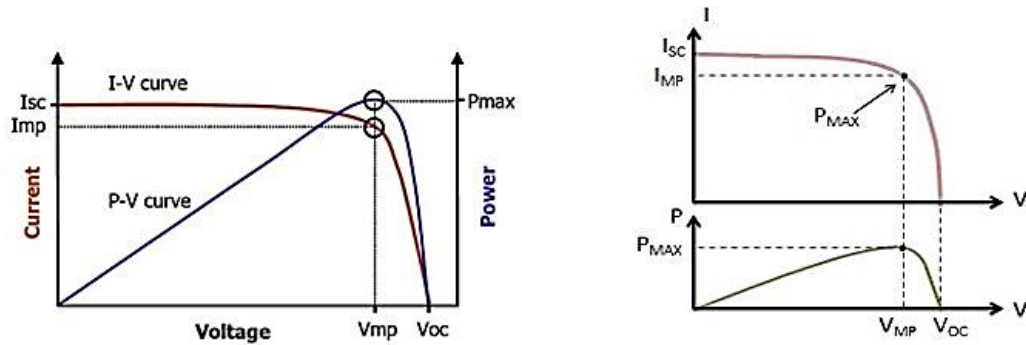


Figure 3.3: Voltage, current and power characteristics of PV panel.

The main electrical parameters that describe the performance of a Photovoltaic cell are:

1. Short circuit current I_{sc} : The value of (I_{sc}) can be obtained by connecting the terminals of a module via an ammeter and measuring the current value of (I_{sc}) changes in function of solar radiation and very little of temperature.
2. Open circuit voltage (V_{oc}): the voltage of a PV module measured at terminals at no load.
3. Maximum power point (MPP): the maximum power point of a photovoltaic is a unique point on the (I-V) or (P-V). Characteristics and the power supplied in this point is at its maximum, where they are measured in Watts (W). Its value can be calculated by the product V_{max} and I_{max}
4. Fill Factor (FF): the ratio of output power at maximum power point to the power computed by multiplying I_{sc} by V_{oc} . The FF is obtained according to the following equation:

$$FF = \frac{(V_{mpp} \times I_{mpp})}{V_{oc} \times I_{sc}} \quad (3.1)$$

3.3. INVERTER

Fig. (3.4) displays the configuration of connecting panels to each other.

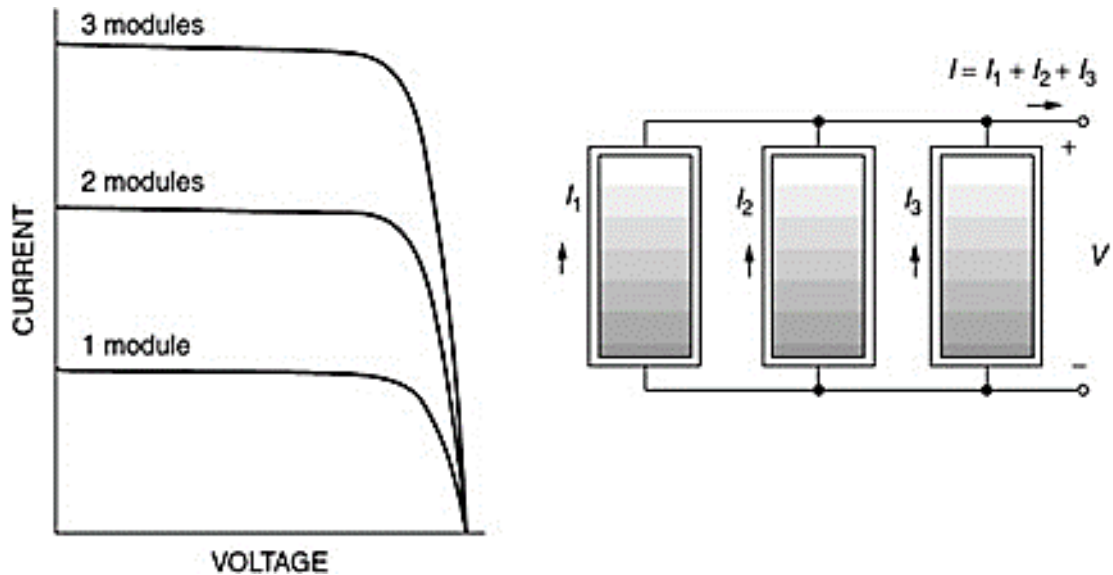


Figure 3.4: PV system Connection.

3.3 Inverter

The inverter is a unit for converting direct current (DC) to alternating current (AC), which acts as the interface between the PV arrays and the utility grid.

In general, inverters can be classified as:

- a. Central inverters.
- b. String inverters.
- c. Module-integrated inverters (AC modules).

- d. Multi-string inverters

Basic design concepts for PV installations are: central, string, multistring or AC module inverters as illustrated in Fig. (3.5).

3.4. SOLAR RADIATION AND TEMPERATURE.

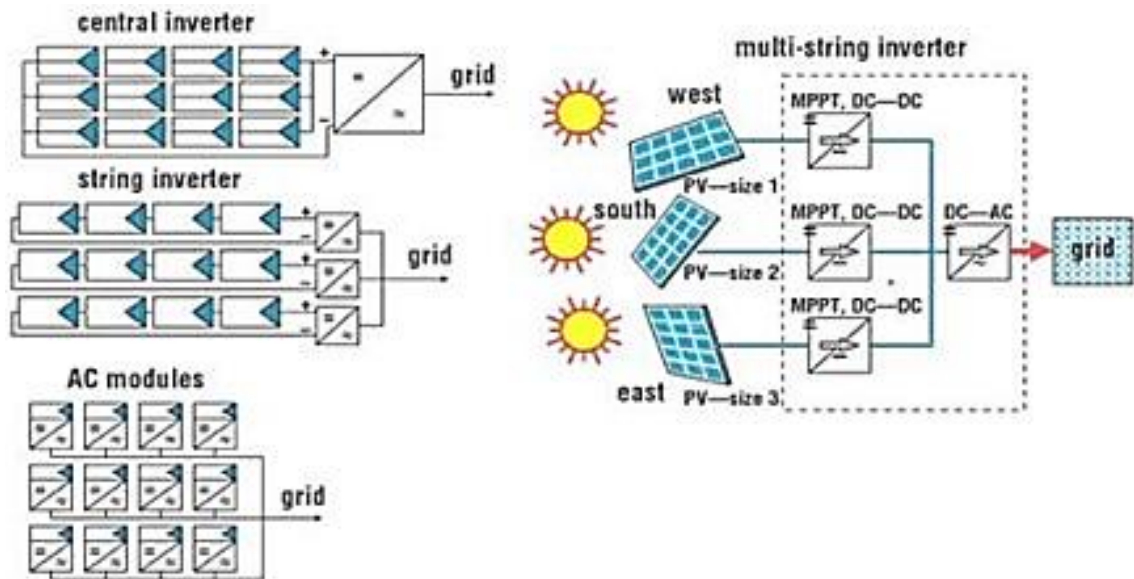


Figure 3.5: PV system.

3.4 Solar radiation and temperature.

The National Aeronautics and Space Administration (NASA) provides the solar radiation data for PPU as per the above data. The solar radiation in Palestine is explained in the Fig. (3.6).

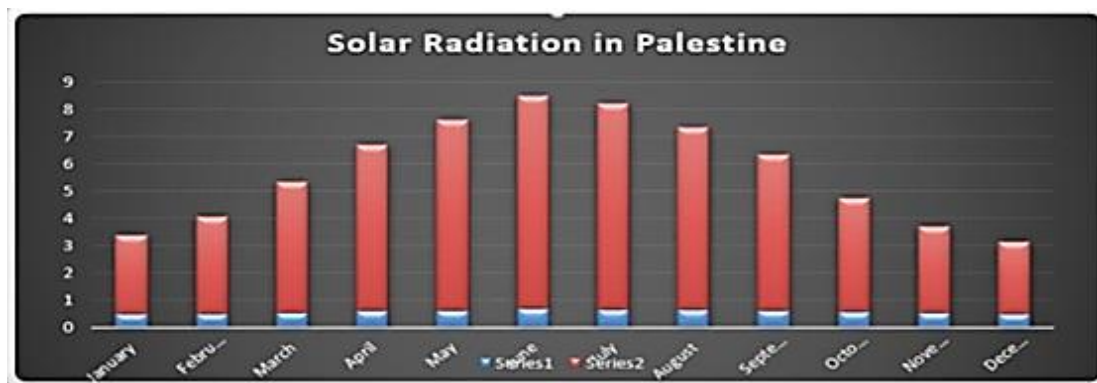


Figure 3.6: solar radiation in Palestine.

The annual average solar radiation is approximated to $5.15 \frac{kwh}{m^2 d}$

3.4. SOLAR RADIATION AND TEMPERATURE.

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

Fig. (3.7) illustrates the monthly average solar global horizontal irradiance (GHI).

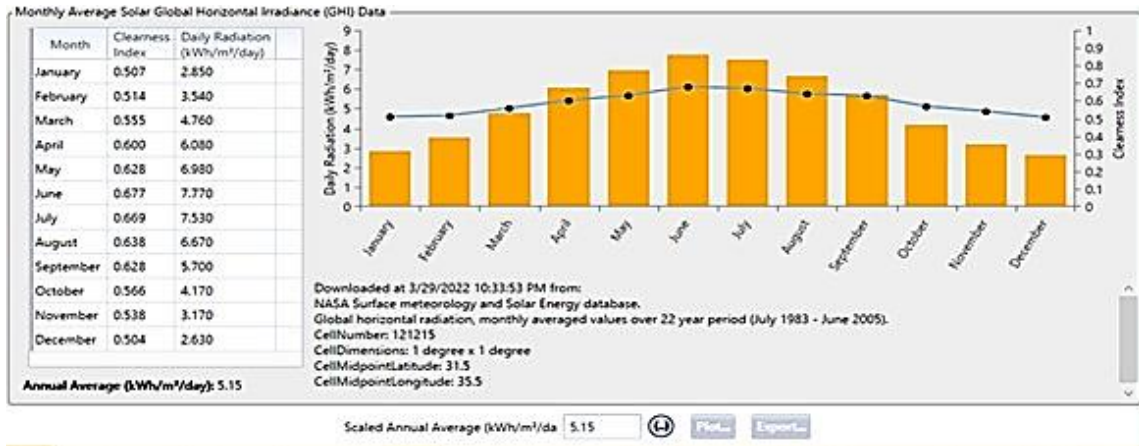


Figure 3.7: Monthly Average solar GHI.

The rate of temperature from the Homer program, whose data was included from the Internet, according to the project site on the map. Fig. (3.8) illustrate the monthly average temperature.



Figure 3.8: Monthly Average Temperature.

3.5. AC LOADS DATA

3.5 AC loads data

The AC loads hourly per day throughout the 12 months of the year and these values are packed based on the values of the worst month of the year, which is January as it is considered the most energy-consuming month in the region.

Fig. (3.9-3.11) below shows AC load data from the village of Beit Hanina containing a daily, seasonal and yearly profile hour by hour.

Hour	Weekends											
	January	February	March	April	May	June	July	August	September	October	November	December
0	0.131	0.128	0.120	0.109	0.098	0.090	0.087	0.090	0.098	0.109	0.120	0.128
1	0.114	0.111	0.105	0.095	0.085	0.079	0.076	0.079	0.085	0.095	0.105	0.111
2	0.114	0.111	0.105	0.095	0.085	0.079	0.076	0.079	0.085	0.095	0.105	0.111
3	0.114	0.111	0.105	0.095	0.085	0.079	0.076	0.079	0.085	0.095	0.105	0.111
4	0.392	0.383	0.360	0.327	0.294	0.271	0.262	0.271	0.294	0.327	0.360	0.383
5	0.600	0.585	0.550	0.500	0.450	0.415	0.400	0.415	0.450	0.500	0.550	0.585
6	0.660	0.644	0.605	0.550	0.495	0.457	0.440	0.457	0.495	0.550	0.605	0.644
7	0.600	0.585	0.550	0.500	0.450	0.415	0.400	0.415	0.450	0.500	0.550	0.585
8	0.504	0.491	0.462	0.420	0.378	0.349	0.336	0.349	0.378	0.420	0.462	0.491
9	0.516	0.503	0.473	0.430	0.387	0.357	0.344	0.357	0.387	0.430	0.473	0.503
10	0.594	0.579	0.545	0.495	0.446	0.411	0.396	0.411	0.446	0.495	0.545	0.579
11	0.640	0.624	0.586	0.533	0.480	0.442	0.426	0.442	0.480	0.533	0.586	0.624
12	0.829	0.808	0.760	0.691	0.622	0.574	0.553	0.574	0.622	0.691	0.760	0.808
13	0.623	0.607	0.571	0.519	0.467	0.431	0.415	0.431	0.467	0.519	0.571	0.607
14	0.502	0.489	0.460	0.418	0.376	0.347	0.334	0.347	0.376	0.418	0.460	0.489
15	0.476	0.464	0.437	0.397	0.357	0.330	0.318	0.330	0.357	0.397	0.437	0.464
16	0.491	0.479	0.450	0.409	0.368	0.339	0.327	0.339	0.368	0.409	0.450	0.479
17	0.790	0.770	0.724	0.658	0.592	0.546	0.526	0.546	0.592	0.658	0.724	0.770
18	1.477	1.440	1.354	1.231	1.108	1.022	0.985	1.022	1.108	1.231	1.354	1.440
19	1.204	1.174	1.103	1.003	0.903	0.832	0.802	0.832	0.903	1.003	1.103	1.174
20	0.811	0.791	0.744	0.676	0.608	0.561	0.541	0.561	0.608	0.676	0.744	0.791
21	0.576	0.562	0.528	0.480	0.432	0.398	0.384	0.398	0.432	0.480	0.528	0.562
22	0.360	0.351	0.330	0.300	0.270	0.249	0.240	0.249	0.270	0.300	0.330	0.351
23	0.245	0.239	0.224	0.204	0.184	0.169	0.163	0.169	0.184	0.204	0.224	0.239

Table 3.9: Beit Hanina yearly load data.

3.5. AC LOADS DATA

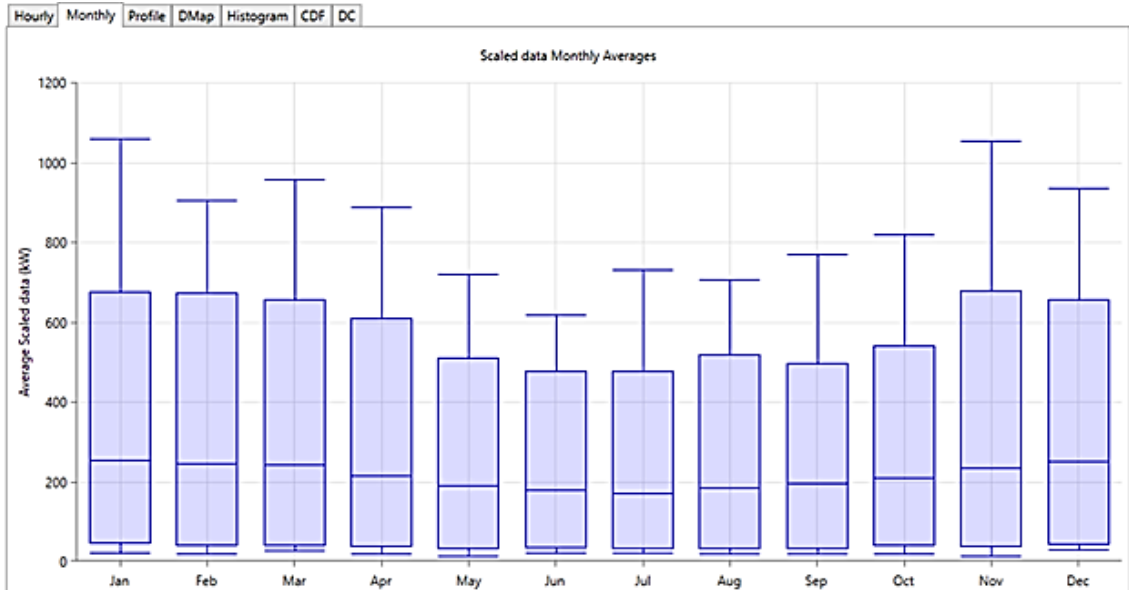


Figure 3.10: Beit Hanina average load monthly.

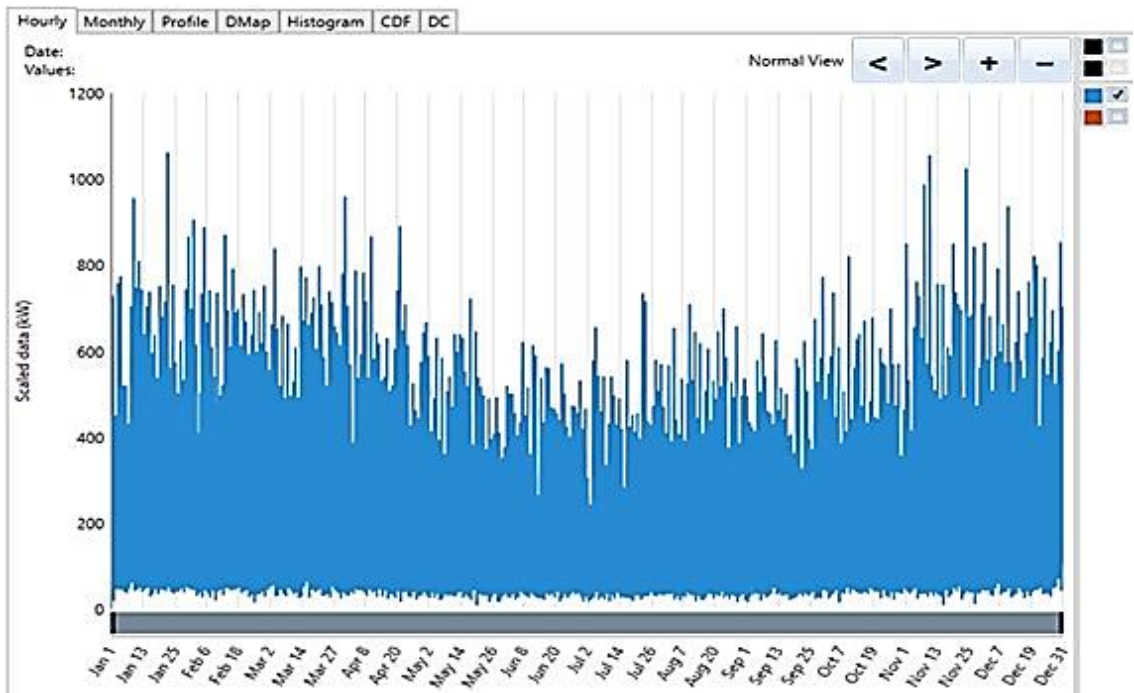


Figure 3.11: Beit Hanina hourly load data.

3.6. PV DATA

3.6 PV Data

The values and data of the solar panels were entered into the Homer pro program, the following Fig. (3.12-3.13) explains the data and result of the PV system.

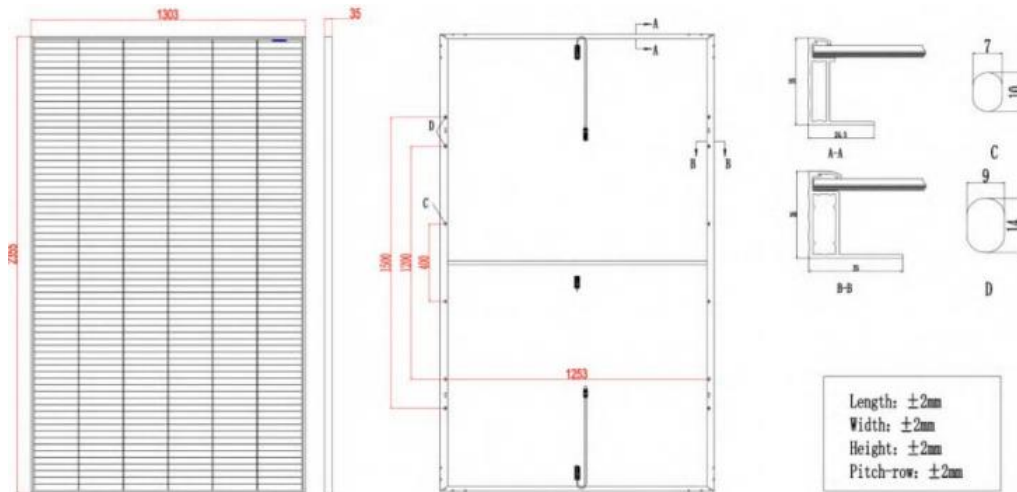


Figure 3.12: PV Data.

Therefore, this type of solar panels was used in the project due to the capacity it has, which is 660 watts, in the same size and generally accepted standards. Therefore, the existing space is exploited more, also for the availability of this type in the market and its appropriate price

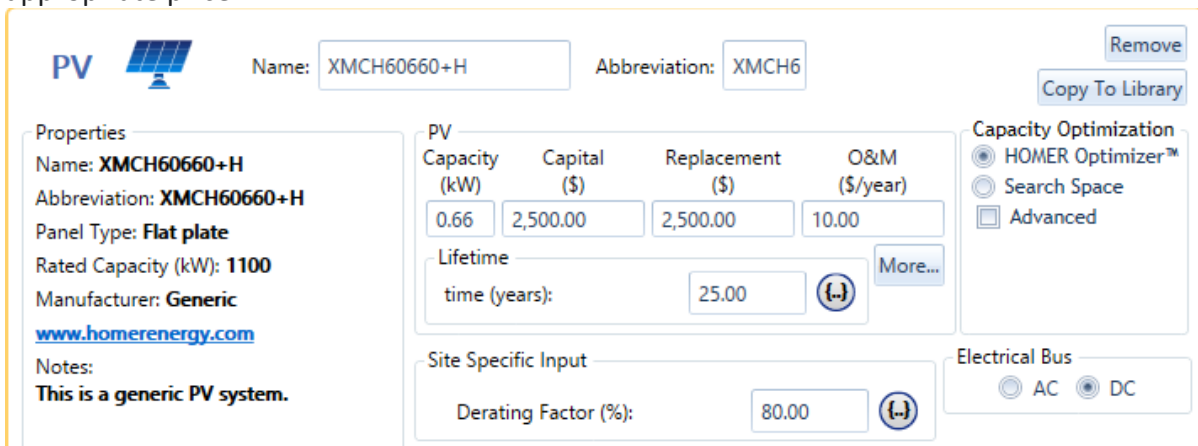


Figure 3.13: Value and Data of the solar panels.

The PV solar panel datasheet and characteristics are depicted in Fig. (3.14-3.15).

3.6. PV DATA

ELECTRICAL DATA (STC)		XMCH60635+H	XMCH60645+H	XMCH60650+H	XMCH60655+H	XMCH60660+H
Open circuit Voltage	(Voc)	45.90 V	46.00 V	46.10 V	46.20 V	46.30 V
Voltage a Pmax.	(Vmp)	37.4 V	37.5 V	37.6 V	37.7 V	37.8 V
Short-circuit current	(Isc)	17.85 A	17.94 A	18.03 A	18.12 A	18.21 A
Current at Pmax.	(Imp)	17.11 A	17.20 A	17.29 A	17.37 A	17.46 A
Peak Power (Pmax) Tollerance 0 ~ +5W		635 Wp	640 Wp	645 Wp	655 Wp	660 Wp
Module Efficiency		20.9 %	21.0 %	21.2 %	21.3 %	21.5 %
Maximum voltage		1500 DC	1500 DC	1500 DC	1500 DC	1500 DC
Maximum series fuse rating		25A	25A	25A	25A	25A
Operating Temperature		-40°C - +85°C	-40°C - +85°C	-40°C - +85°C	-40°C - +85°C	-40°C - +85°C

*STC (Standard test conditions)	MECHANICAL CHARACTERISTIC
---------------------------------	---------------------------

Figure 3.14: PV solar panel datasheet

*STC (Standard test conditions)	MECHANICAL CHARACTERISTIC
Irradiance 1000 w/m ² , module temperature 25°C, AM= 1.5	Max. surface load capacity (Pa) 5400
TEMPERATURE COEFFICIENT	Dimensions (mm) 2355X1303X35 mm
NMOT 42.3°C±2°C	Weight (Kg) 34
Pmax Temperature Coefficient -0.34%/ °C	Encapsulation EVA
Voc Temperature Coefficient -0.27%/ °C	Cells 210x210 mm PERC
Isc Temperature Coefficient 0.04% / °C	Backsheet High weatherability backsheet
PAKAGING CONFIGURATION	

Figure 3.15: Mechanical Characteristic.

On average, facing a collector toward the equator (Northern Hemisphere that means facing it south) and tilting it up at an angle equal to the local latitude is a good rule-of-thumb for annual performance. To emphasize winter collection, tilting at a higher angle. Vice versa for increased summer efficiency.

3.6. PV DATA

The proposed position of the PV panel is illustrated in Fig. (3.17), where the panels are fixed on altitude angel =31.77°.

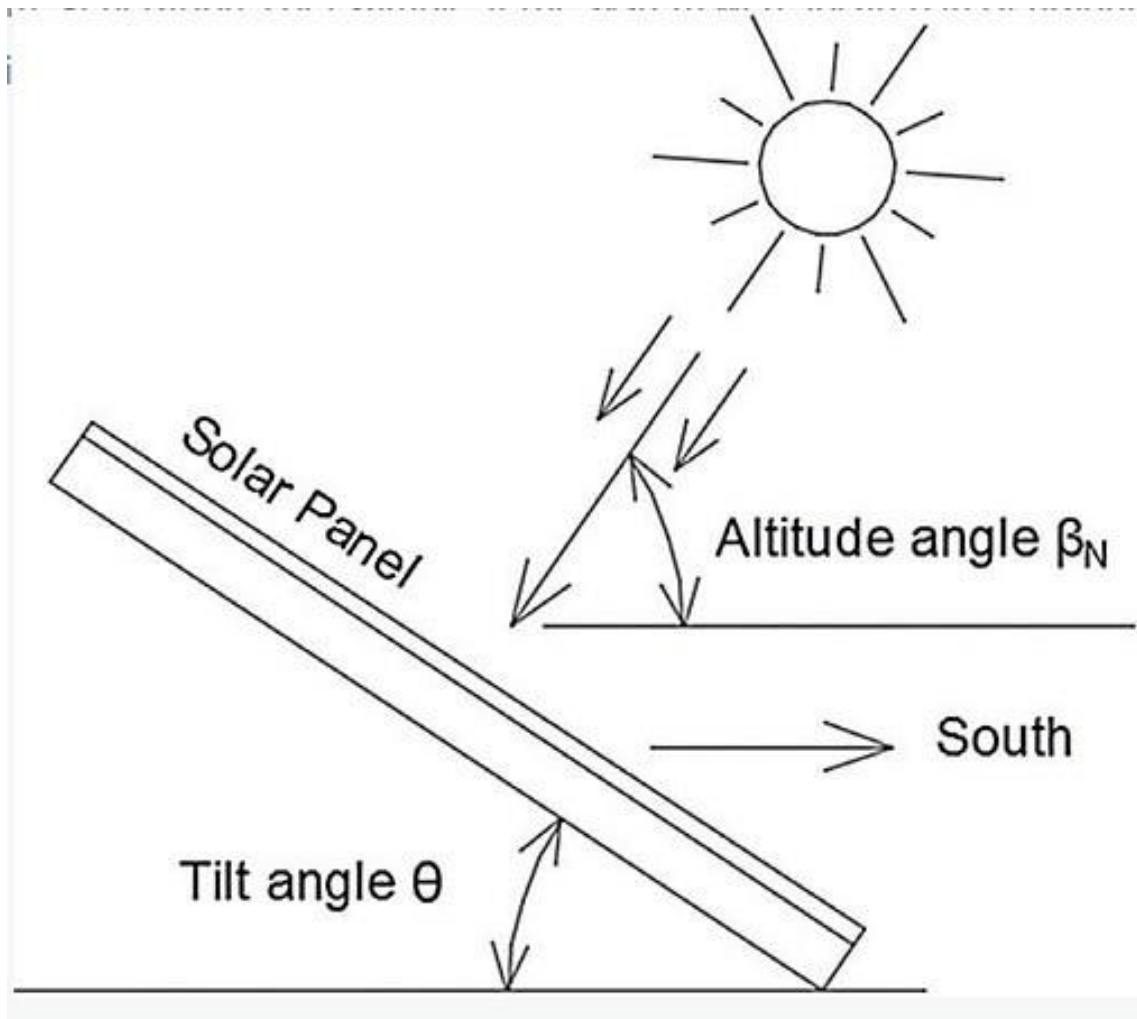


Figure 3.16: Solar panel tilt angel.

3.7. PANEL AND INVERTER DATA

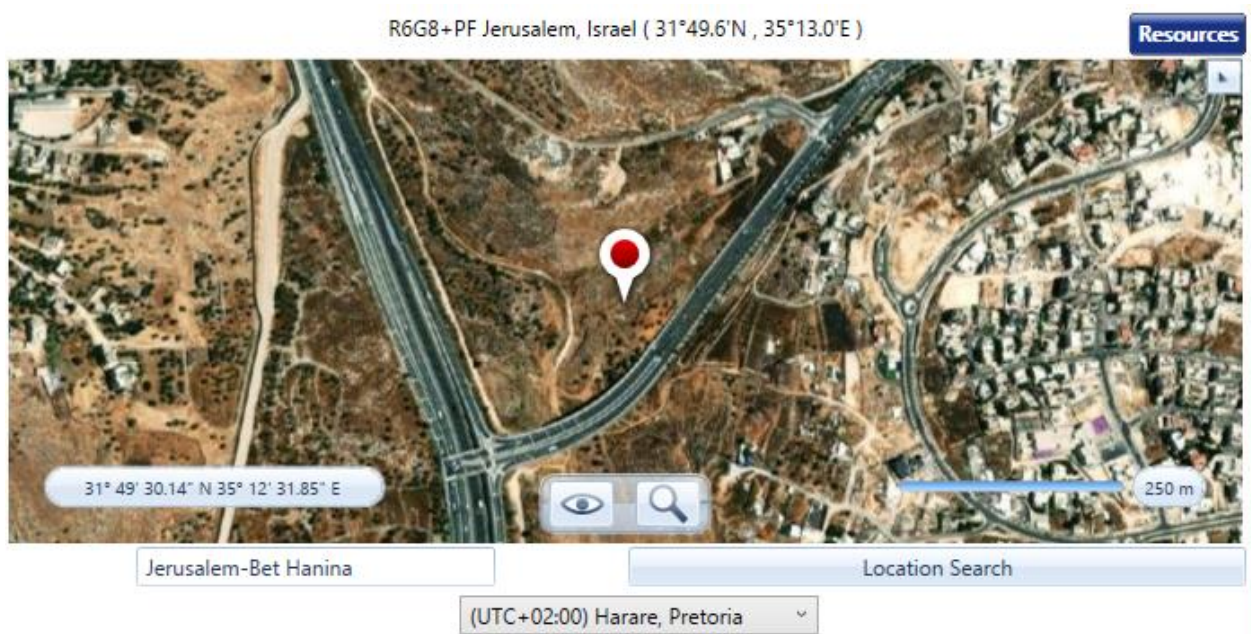


Figure 3.17: PV panel location.

3.7 Panel and inverter Data

The specifications of different type solar panel [5] are illustrated in Fig. (3.18). the newest solar panels in the market were chosen, reducing the most efficient power per panel. The panels have a peak power of (635-660) W. So, to reduce to 2 MW, around 3336 panels are required. An inverter of 1 MW capacity was chosen to connect 1668 solar panel. The full datasheet of the solar panel was attached in Appendix [A].

3.7. PANEL AND INVERTER DATA

ELECTRICAL DATA (STC)		XMCH60635+H	XMCH60645+H	XMCH60650+H	XMCH60655+H	XMCH60660+H
Open circuit Voltage	(Voc)	45.90 V	46.00 V	46.10 V	46.20 V	46.30 V
Voltage a Pmax.	(Vmp)	37.4 V	37.5 V	37.6 V	37.7 V	37.8 V
Short-circuit current	(Isc)	17.85 A	17.94 A	18.03 A	18.12 A	18.21 A
Current at Pmax.	(Imp)	17.11 A	17.20 A	17.29 A	17.37 A	17.46 A
Peak Power (Pmax) Tolerance 0 ~ +5W		635 Wp	640 Wp	645 Wp	655 Wp	660 Wp
Module Efficiency		20.9 %	21.0 %	21.2 %	21.3 %	21.5 %
Maximum voltage		1500 DC	1500 DC	1500 DC	1500 DC	1500 DC
Maximum series fuse rating		25A	25A	25A	25A	25A
Operating Temperature		-40°C - +85°C	-40°C - +85°C	-40°C - +85°C	-40°C - +85°C	-40°C - +85°C

*STC (Standard test conditions)	MECHANICAL CHARACTERISTIC
---------------------------------	---------------------------

Figure 3.18: Characteristics of the solar panel.

The inverters that are used in the design of this project has the same characteristics of the inverters depicted in Fig. (3.18-3.20). This particular inverter was used to deal with high voltage, which lead to low current and losses. The technical datasheet of the inverter is shown Appendix [B].

The screenshot displays a software interface for an inverter datasheet. At the top, the word "CONVERTER" is visible next to a logo. A dropdown menu shows "PVS800-MWS-1250KW-20*" with a "Complete Catalog" button below it. To the right, there are input fields for "Name:" (PVS800) and "Abbreviation:" (PVS800). Below this, there are two main sections: "Properties" and "Costs".

The "Properties" section contains the following information:

- Name: PVS800-MWS-1250KW-20*
- Abbreviation: PVS800-MWS-1250KW20*
- www.homerenergy.com
- Notes: This is a generic system converter.

The "Costs" section includes a table:

Capacity (kW)	Capital (\$)
1250	\$300.00

Below the table is a link: "Click here to add new item". There is also a "Multiplier:" field with a minus sign icon.

At the bottom, there is a "Generic" section with the URL "homerenergy.com" and the "HOMER Energy" logo. To the right, the "Inverter Input" section has input fields for "Lifetime (years):" (15.00) and "Efficiency (%):" (97.80).

Figure 3.19: Datasheet of Inverter 1.

3.8. PROJECT DESIGN

Technical data and types

Type code	PVS800-MWS-1000kW-20 ^{*)}	PVS800-MWS-1250kW-20 ^{*)}
	1 MW	1.25 MW
Input (DC)		
Maximum input power ($P_{PV, max}$)	2 x 600 kW	2 x 760 kW
DC voltage range, mpp ($U_{DC, mpp}$)	450 to 825 V	525 to 825 V
Maximum DC voltage ($U_{DC, max}$) ¹⁾	1000 V	1000 V
Maximum DC current ($I_{DC, max}$)	2 x 1145 A	
Voltage ripple, PV voltage (U_{PV})	< 3%	< 3%
Number of protected DC inputs (parallel)	2 x 8 (+/-)	2 x 8 (+/-)
Number of mppt trackers	2	2
Output (AC)		
Nominal AC output power ($P_{AC, N}$)	1000 kW	1250 kW
Nominal AC current ($I_{AC, N}$)	28.9 A	36.1 A
Nominal output voltage ($U_{AC, N}$) ²⁾	20 kV	20 kV
Output frequency	50/60 Hz	50/60 Hz
Harmonic distortion, current ³⁾	< 3%	< 3%
Power factor compensation (cosφ)	Yes	Yes
Inverter type (2 x ABB central inverters)	PVS800-57-0500kW-A	PVS800-57-0630kW-B
Transformer type ⁴⁾	ABB Vacuum cast coil dry-type	
Medium voltage switchgear type ⁵⁾	ABB SafeRing type DeV with REJ603 protection relay (self-powered)	
Efficiency		
Maximum ⁶⁾ (including transformer)	97.8%	97.8%
Euro-eta ⁶⁾ (including transformer)	97.1%	97.3%

Figure 3.20: Datasheet of Inverter 2.

3.8 Project design

As previously stated, a 2-megawatt solar panel plant station will be built to feed an existing electrical station. 2 MW solar power was decided to be less than the lowest load on the network. The proposed station will consist of a 2 solar power station, the capacity of each one is 1 megawatt. Each station contains 1668 solar panels, each one stands at 660 watts with a 1.25-megawatt inverter. Both power stations are identical. Fig. (3.21) illustrates the block diagram of the full project.

3.8. PROJECT DESIGN

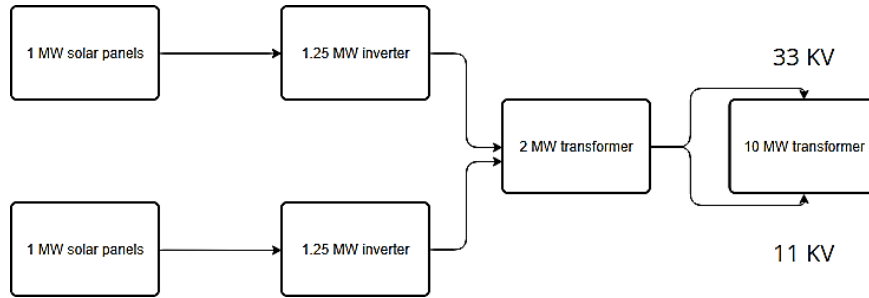


Figure 3.21: Project block diagram.

Fig. (3.22) shows how the solar panels were connected with the network, where an "XMCH60660" solar panel was selected. A "PVS800" inverter with 1.25 MW was selected to connect between an AC and DC line.

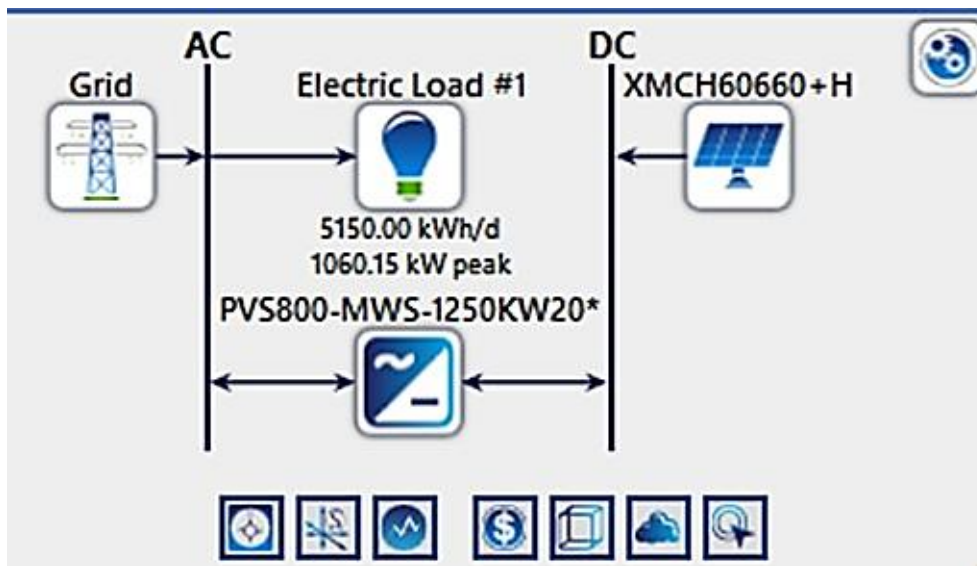


Figure 3.22: Project design.

3.8.1 Electrical Results

Fig. (3.23-3.24) contains some data and values about the inverters and solar panel.

3.8. PROJECT DESIGN

Value from inverter data sheet	
Capacity inverter	1.25 MW
Num . MPPT	2
Maximum DC voltage	825 V
Minimum DC voltage	525 V
Maximum DC current	1145 A

Figure 3.23: Value from inverter data sheet.

Value from PV data sheet	
Capacity panel	660 w
Current at pmax (Imp)	17.46 A
Short circuit current (Isc)	18.21 A
Voltage a pmax (Vmp)	37.8 V
Open circuit voltage (Voc)	46.30 V

Figure 3.24: Value from PV data sheet.

3.8.2 Calculation and result

$$\text{Total capacity per mppt} = \frac{p \text{ tot of station}}{N.\text{mppt}} = \frac{1,100,000}{2} = 550,000 \text{ w}/1\text{mppt} \quad (3.2)$$

Where number of panels per 1mppt can be calculated as:

$$\frac{p \text{ tot per 1mppt}}{p \text{ panel}} = \frac{550,000 \text{ w}}{660 \text{ w}} = 834 \text{ panel } /1\text{mppt} \quad (3.3)$$

3.8. PROJECT DESIGN

In this project, the value of 650v was determined, which is approximately in the middle of the specified range.

Number of panels in series at 1 string can be calculated as

$$\frac{V_{oc\ tot}}{V_{oc\ panel}} = \frac{650}{46.30} = 14 \text{ panels series /1string} \quad (3.4)$$

So, 14 panel will be in 1 string, and the number of strings can be calculated as:

$$\text{number of string} = \frac{\text{number of panels at 1mppt}}{\text{number of panel series}} = \frac{834}{14} = 60 \text{ string/1mppt} \quad (3.5)$$

$$P_{tot} = 14_{pan} \times 60_{str} \times 660_w = 554400 \approx 550000 \text{ watt} \quad (3.6)$$

$$V_{mpt-tot} = 14_{pan\ series} \times \text{voltage a pmax (vmp)} = 14 \times 37.8 = 539.2 \text{ volt} \quad (3.7)$$

I max of the inverter =

$$60_{str} \times (i_{mp})_{panel} = 60 * 17.46 = 1047.6A < 1145A \quad (3.8)$$

Isc max =

$$60_{str} \times (I_{sc})_{panel} = 60 * 18.21 = 1092.6A < 1145A \quad (3.9)$$

The increase or decrease in air temperature affects the solar panels, in order to ensure that these solar panels are not damaged, the calculations have been made so that the value remains within the range.

At T min = (-3C) COLD

3.8. PROJECT DESIGN

Voc tot =

$$14_{panel} \times V_{OC_{panel}} = 14 * 46.3 = 648.2V \quad (3.10)$$

Voc max =

$$V_{oc} * \left[1 - \frac{\Delta v}{c^{\circ}} (T - 25) \right] = 648.2 * \left[1 - \frac{0.27}{100} (-3 - 25) \right] = 697.2 V < 825 V$$

At Tmax = (40 C) HOT

(3.11)

Voc min t =

$$V_{oc} * \left[1 - \frac{\Delta v}{c^{\circ}} (T - 25) \right] = 648.2 * \left[1 - \frac{0.27}{100} (40 - 25) \right] = 621.26 V > 525 V$$

(3.12)

Therefore, and related to the previous results, the electrical production is illustrated in Fig. (3.25-3.26).

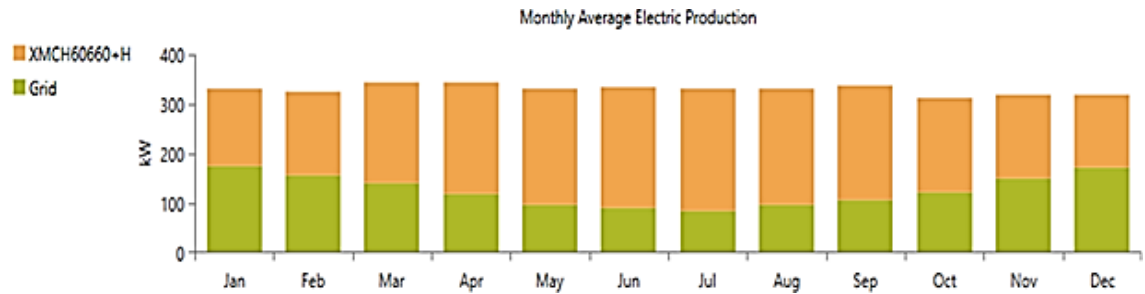


Figure 3.25: Results related to electrical production 1.

3.8. PROJECT DESIGN

Production	kWh/yr	%
XMCH60660+H	1,788,334	61.9
Grid Purchases	1,101,630	38.1
Total	2,889,964	100

Consumption	kWh/yr	%
AC Primary Load	1,879,750	65.9
DC Primary Load	0	0
Grid Sales	970,871	34.1
Total	2,850,621	100

Figure 3.26: Results related to electrical production 2.

As we note these tables show the electric result from the Homer program, where total production = 2889964 kwh/yr and total consumption = 2850621 kwh/yr as shown

Also, the Results related to the solar panel and inverter panel production are illustrated in Fig. (3.27-3.28) respectively.

Quantity	Value	Units
Rated Capacity	1,100	kW
Mean Output	204	kW
Mean Output	4,900	kWh/d
Capacity Factor	18.6	%
Total Production	1,788,334	kWh/yr

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	1,105	kW
PV Penetration	95.1	%
Hours of Operation	4,392	hrs/yr
Levelized Cost	0.190	\$/kWh

Figure 3.27: Results related to the solar panels.

Therefore, these results from the Homer program related to the solar panels used in the project were as follows rated capacity = 1100 kw, total production = 1788334 kwh/yr , mean output 4900kwh/d ,and hours of operation = 4392 hrs/yr

3.8. PROJECT DESIGN

Quantity	Inverter	Units
Capacity	1,081	kW
Mean Output	200	kW
Minimum Output	0	kW
Maximum Output	1,081	kW
Capacity Factor	18.5	%

Quantity	Inverter	Units
Hours of Operation	4,392	hrs/yr
Energy Out	1,748,991	kWh/yr
Energy In	1,788,334	kWh/yr
Losses	39,343	kWh/yr

Figure 3.28: Results related to the inverter.

Therefore, these results from the Homer program related to the inverter used in the project were as follows, as shown maximum output = 1081 kw , energy output = 1748991 kwh/yr , loss = 39343 kwh/yr , and hours of operation = 4392 hrs/yr

3.8.3 Solar power plant design cost

components	Cost (₪)	Quantity	Total cost (₪)
Inverter (1.25)MW	120,000	1	120,000
Solar panel (660) W	1010/pan	1668	1,684,680
Cable DC	3.5/m	10,000 m	350,000
Caple AC	35/m	1700 m	59,500
Transformer (2)MVA	250,000	1	250,000
Iron structures	10,000	17	170,000
			2,634,180

Table 3.29: solar power plant design cost

We also note in this table that the total cost of designing a solar power plant with a capacity of 1 megawatt, which is about 2,634,180 shekels

Chapter 4

ETAP

4.1 ETAP overview

ETAP is the most comprehensive solution for the design, simulation, and analysis of generation, transmission, distribution, and industrial power systems. ETAP organizes the work on a project basis. Each project created provides all the necessary tools and support for modeling and analyzing an electrical power system. The proposed project consists of an electrical system that requires a unique set of electrical components and interconnections. In ETAP, each project provides a set of users, user access controls, and a separate database in which its elements and connectivity data are stored. The following Fig. (4.1) shows the numerous options and applications of ETAP.

4.1. ETAP

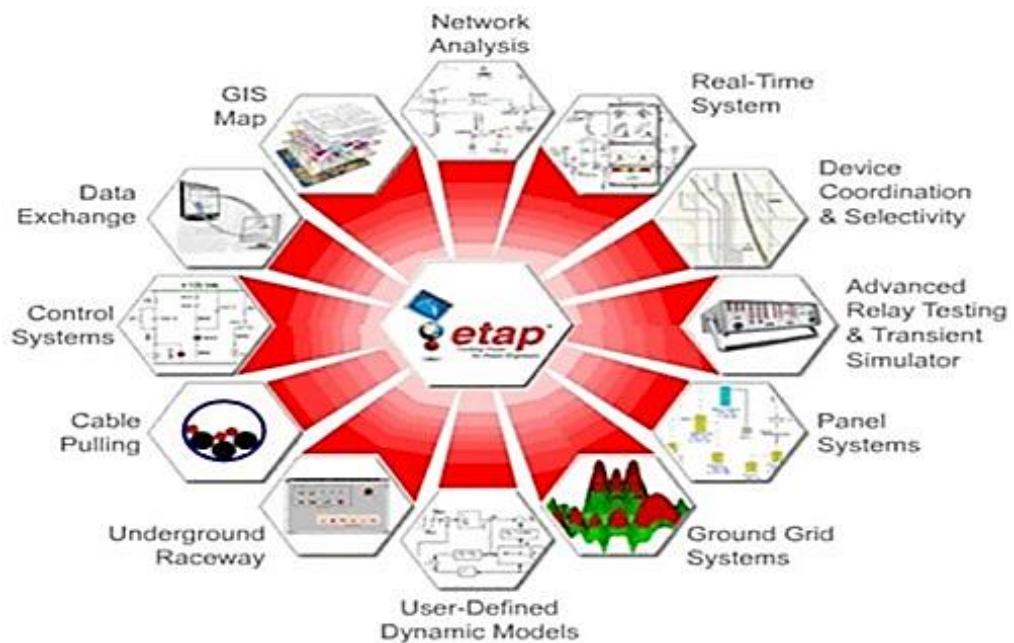


Figure 4.1: ETAP applications.

In this project, ETAP was utilized because it is suitable to study power flow losses and it has many options such as:

1. Virtual reality operation.
2. Total integration of data (electrical, logical, mechanical, and physical attributes).
3. Ring and radial systems.
4. Unlimited isolated subsystems.
5. No system connection limitations.
6. Multiple loading conditions.
7. User access control and data validation.
8. Asynchronous calculations, allow multiple modules to calculate simultaneously.

4.2 ETAP Power Load Flow

The ETAP Load Flow Analysis module calculates bus voltages, branch power factors, currents, and power flows throughout the electrical system. ETAP allows for swing, voltage regulated, and unregulated power sources with multiple power grids and generator connections. It is capable of performing analysis on both radial and loop systems. ETAP allows to select from several different methods in order to achieve the best calculation efficiency.

The Load Flow Toolbar section explains how to launch a load flow calculation, open and view an output report, or select display options. The Load Flow Study Case Editor section explains how to create a new study case, what parameters are required to specify a study case, and how to set them. The Display Options section explains what options are available for displaying some key system parameters and the output results on the one-line diagram, and how to set them. The Load Flow Calculation Methods section shows formulations of different load flow calculation methods. Comparisons on their rate of convergence, improving convergence based on different system parameters and configurations, and some tips on selecting an appropriate calculation method are also found in this section. The Required Data for calculations section describes what data is necessary to perform load flow calculations and where to enter them. The Load Flow Study Output Report section illustrates and explains output reports and their format. Finally, the Load Flow Result Analyzer allows you to view the results of various studies in one screen so you can analyze and compare the different results.

4.2. ETAP POWER LOAD

4.2.1 Mode toolbar

When the One-Line Diagram (Network Systems) button on the System toolbar is clicked, the Mode toolbar becomes available that contains all the study modules related to the one-line diagram. In general, ETAP has three modes of operation under Network Systems; Edit, AC Study, and DC Study. The AC Study mode consists of analyses such as Load Flow, Short-Circuit, Motor Acceleration, Transient Stability, and Protective Device Coordination.



Figure 4.2: Mode Toolbar.

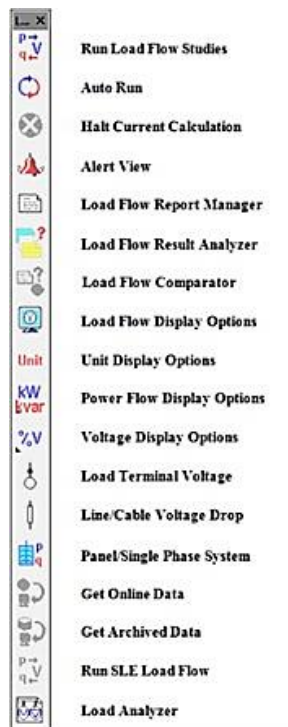


Figure 4.3: Load Flow Toolbar.

4.2.2 Load Flow Calculation Methods

ETAP provides four load flow calculation methods: Adaptive Newton-Raphson, Newton-Raphson, Fast-Decoupled, and Accelerated Gauss-Seidel. They possess different convergent characteristics, and sometimes one is more favorable in terms of achieving the best performance.

Any one of them could be selected depending on the desired system configuration, generation, loading condition, and the initial bus voltages.

4.3 Filling Data

In order to start the power flow and run the program, the data and specifications of the transformers, cables, overhead lines and loads are needed to be filled accurately in the filling areas.

4.3.1 Transformers Data

The information inserted in the transformer's editor were the voltage rating, power rating and the type of the transformer. All these data were important to power flow simulation and calculations. Those data and specifications were collected from JDECo.

4.3.2 Transmission Lines Data

In this part, the research team inserted the type of the transmission lines based on the data from JDECo, moreover, the length of each line and the type of connection were added, whether it was single phase or three phase.

4.4. ETAP

4.3.3 Load data

The value of the percentage of loading in the figure attached in Appendix A reflects on the power rating for the load, which is also related to the transformer loading connected to the load.

4.4 ETAP simulation

The sketches of the simulation project on ETAP as shown in Fig. (4.4). In the first scenario, the PV system is connected to the 11 kV bus to inject the power to the system and study its impact.

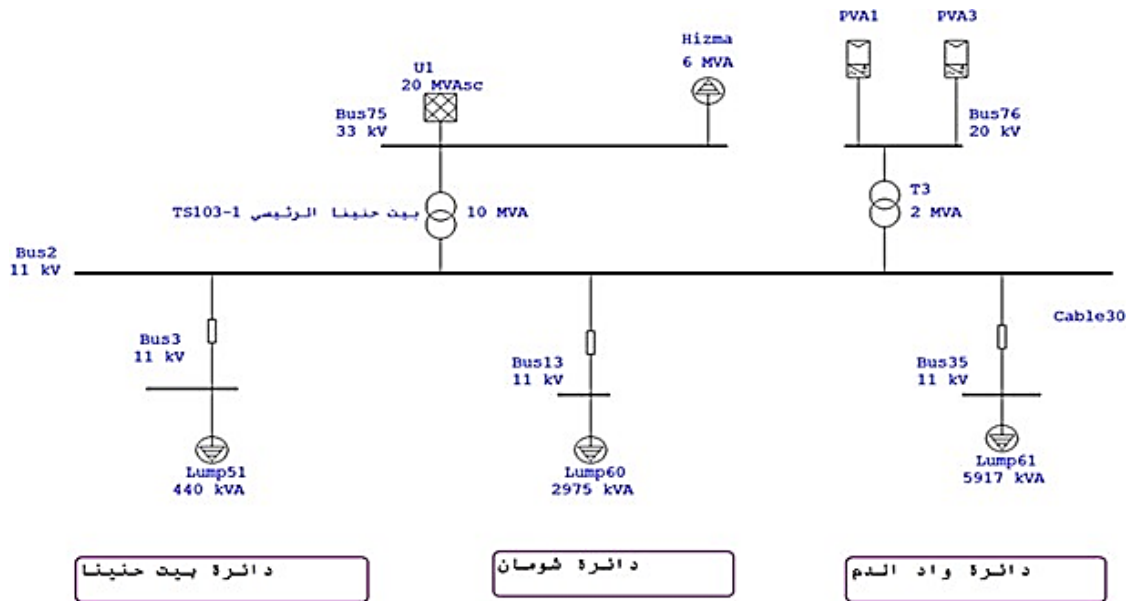


Figure 4.4: ETAP first scenario.

4.4. ETAP

The second scenario is depicted in Fig. (4.5), where the PV system is connected to the 33 kV.

Both scenarios were studied and provided the final results.

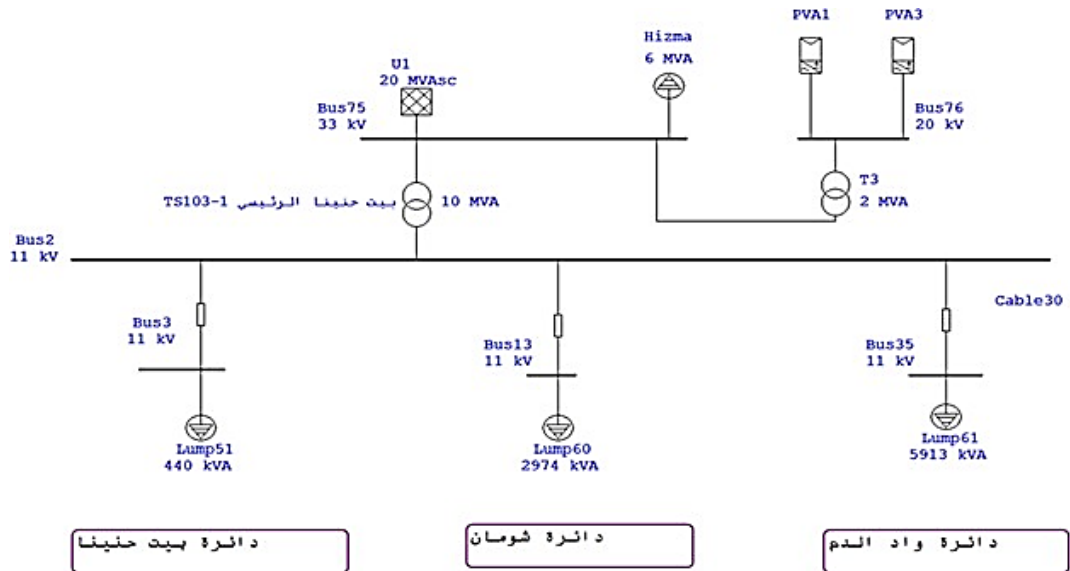


Figure 4.5: ETAP second scenario.

Chapter 5

Recommendations and final results

5.1 Final results

As a result of connecting the solar panel station (PV) system to the level of 11 kV and 33 kV, the team acquired some results as shown in the following figures. By comparing between an 11 kV and 33 kV, it is evident that there is a complete congruence between the results with regard to the current, voltage, power factor, KVAR and KW. Fig. (5.1) concludes that the result of the current was the same and it tragically increases as the amount of buses increases. While the voltage level has the same value, it increases dramatically as the amount of buses increases as shown in Fig. (5.2).

Fig. (5.3) compares between the two levels in regards to the power factor, the result displays a slight difference. Fig. (5.4-5.5) illustrates the comparison between the levels regards to KVAR and KW, as a result; the values have the same result and it increases when the number of buses increased.

5.1. FINAL RESULTS

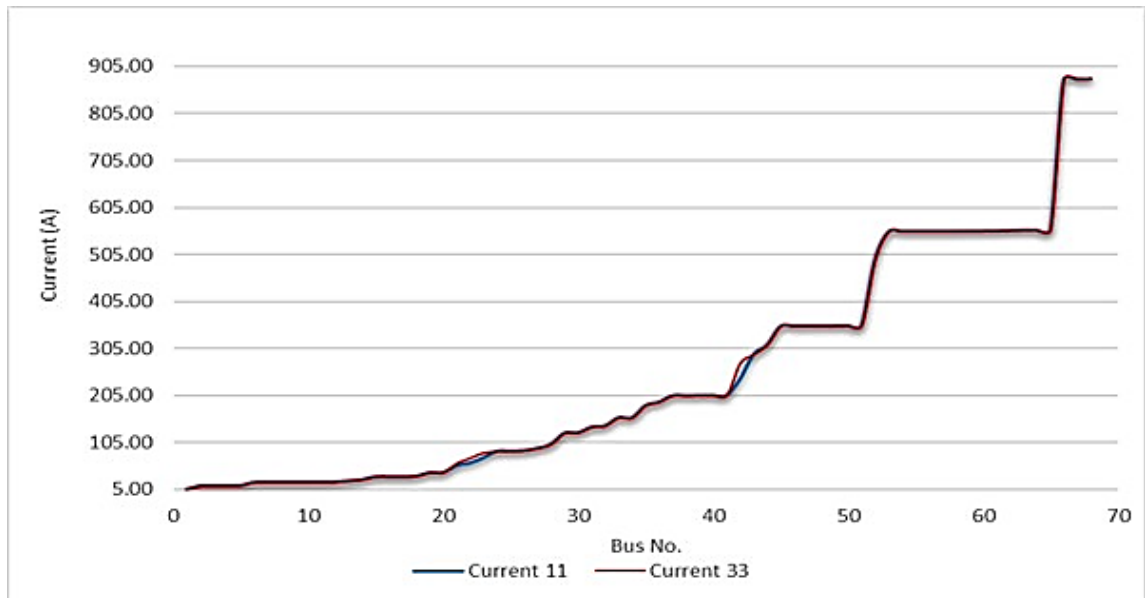


Figure 5.1: current comparison between 33 kV and 11 kV.

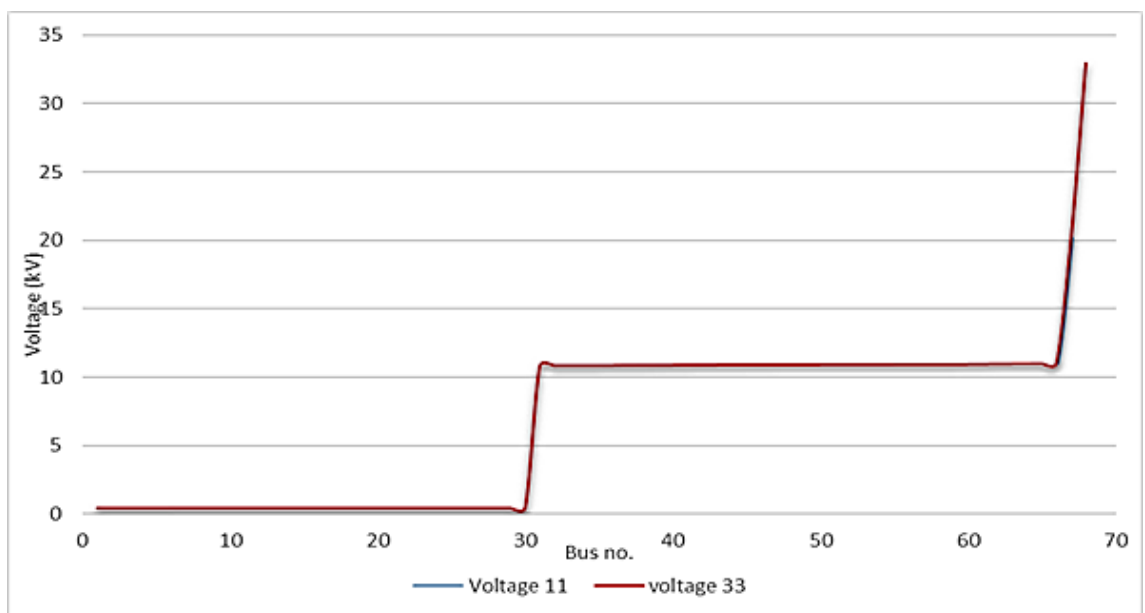


Figure 5.2: voltage comparison between 33 kV and 11 kV.

5.1. FINAL RESULTS

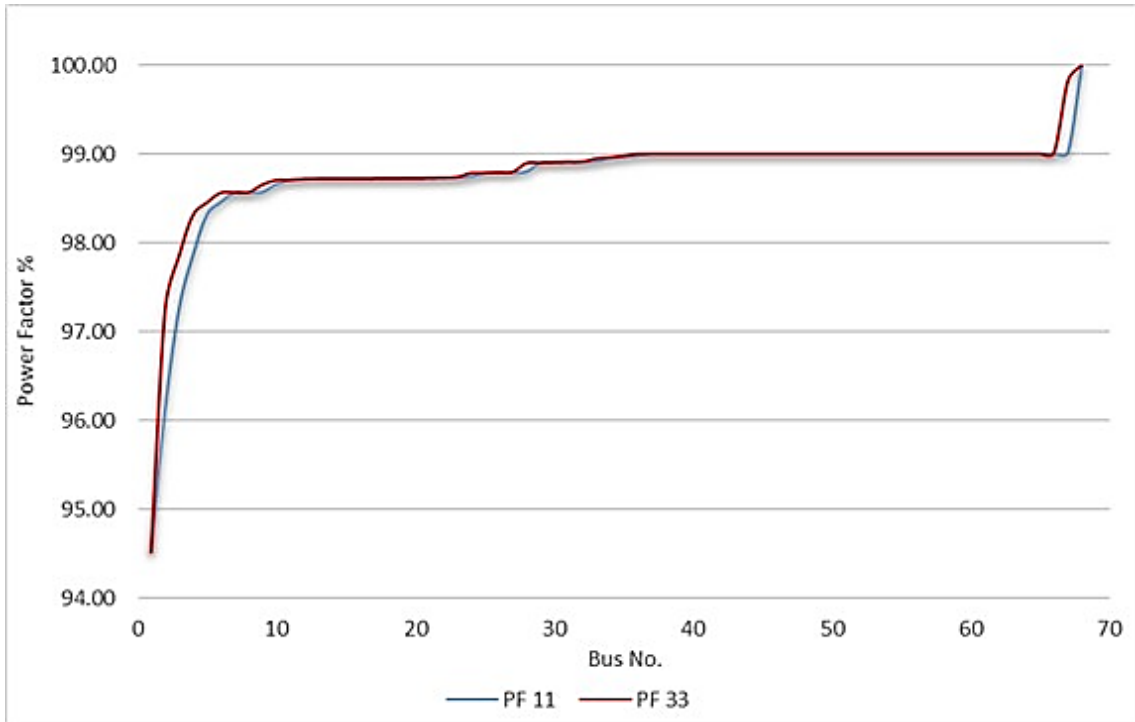


Figure 5.3: power factor comparison between 33 kV and 11 kV.

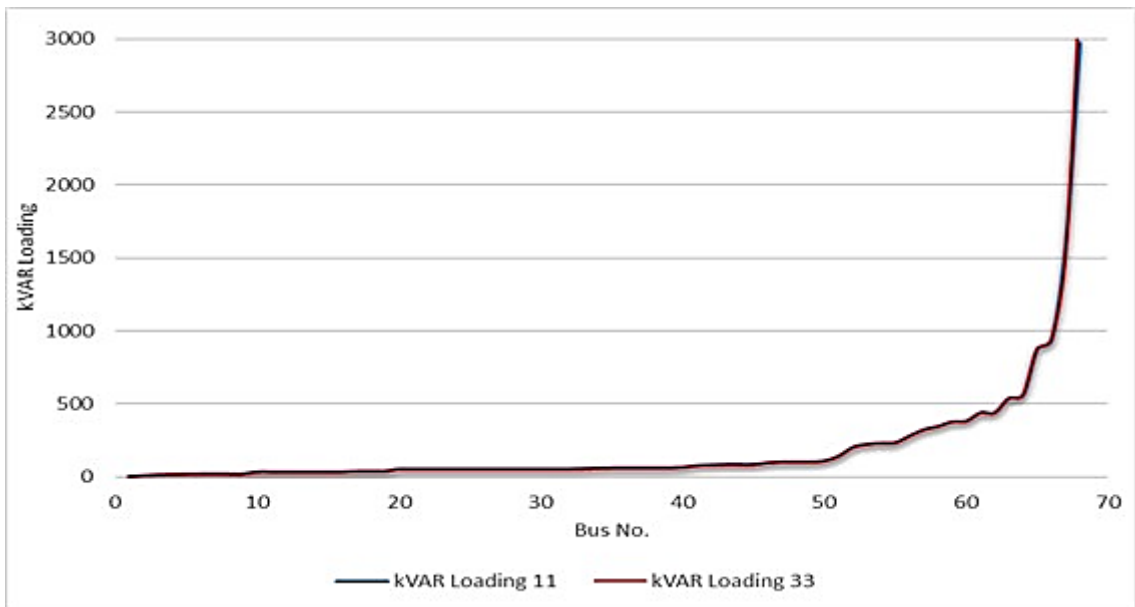


Figure 5.4: KVAR comparison between 33 kV and 11 kV.

5.1. FINAL RESULTS

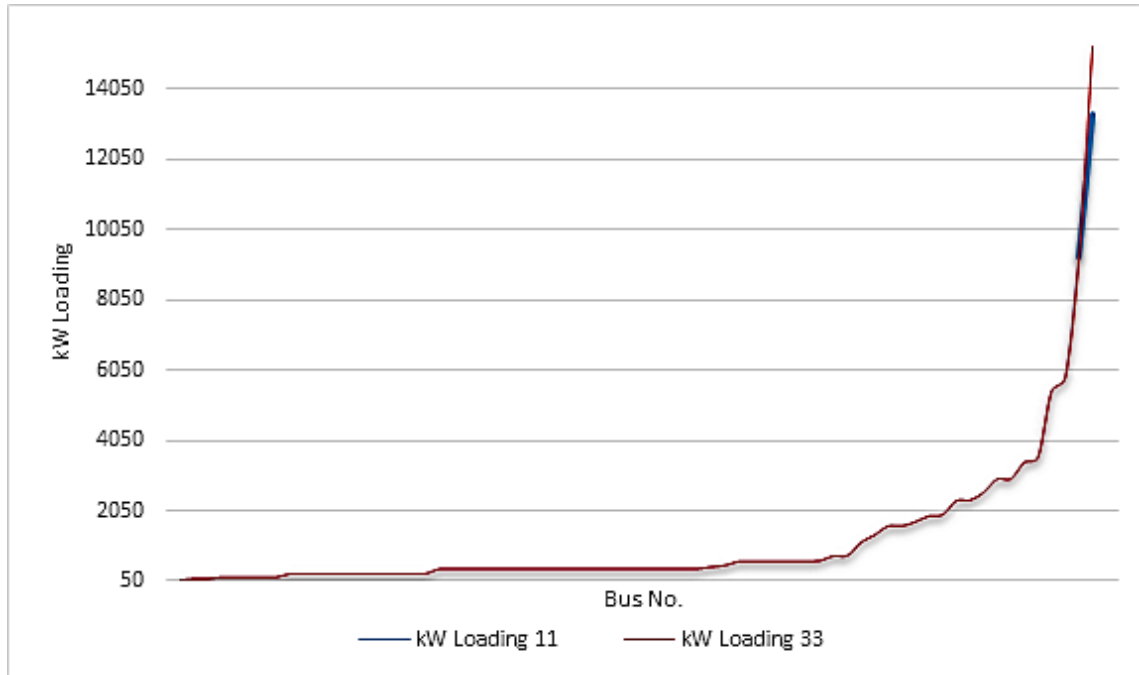


Figure 5.5: KW comparison between 33 kV and 11 kV.

When a comparison was performed between the two levels (11 kV and 33kV) in terms of the occurrence of losses and load on the transformer, it was found that there is a difference between the levels. Fig. (5.6) illustrates that the losses in a 33 kV is greater than losses in an 11 kV due to the existence of a power transformer. While the voltage drop percentage in the 2 levels (11 kV and 33 kV) have the same amount, it is approximately equal to 98% as shown in Fig. (5.7).

Fig. (5.8) compares between the transformers in terms of flowing loads, so that when a 2 MW flows through the main network, there is no effect on 11 kV and 33 kV, while when a 2 MW flows at the point beyond 11 kV transformer, this will lead to a reduction in the load of the 11 kV transformer.

5.1. FINAL RESULTS

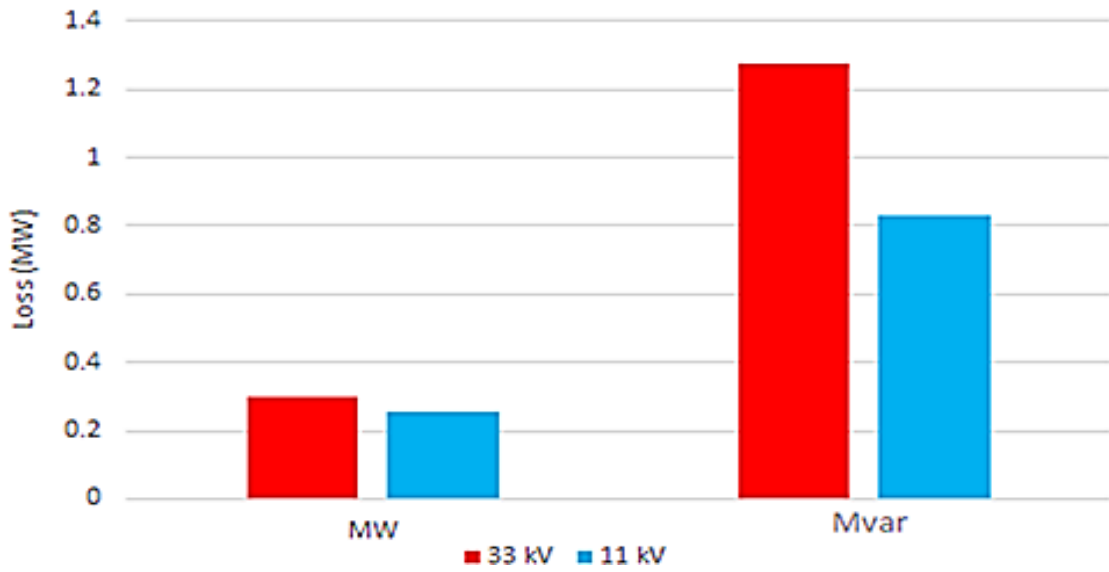


Figure 5.6: Loss comparison between 33 kV and 11 kV.

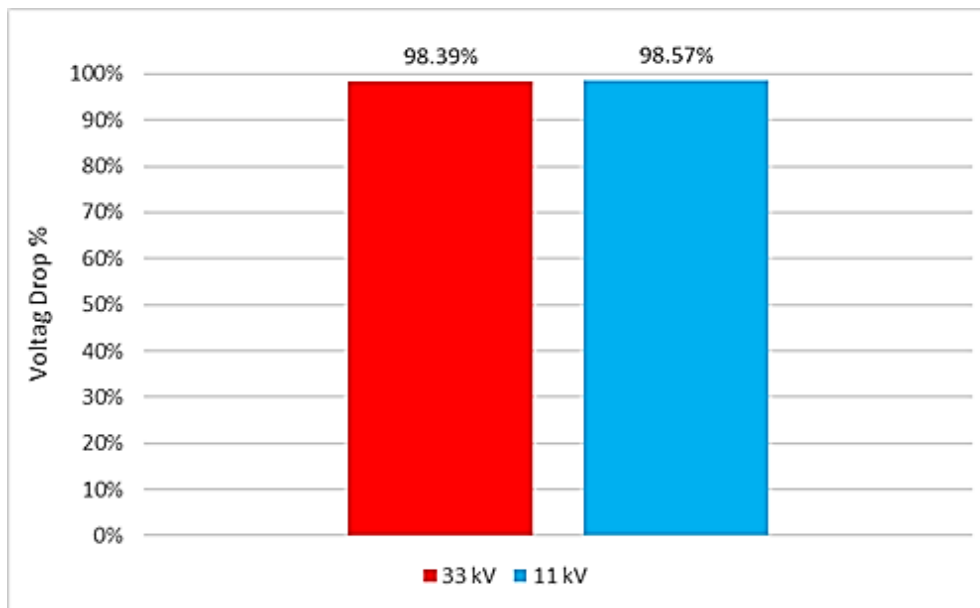


Figure 5.7: Voltage Drop comparison between 33 kV and 11 kV.

5.1. FINAL RESULTS

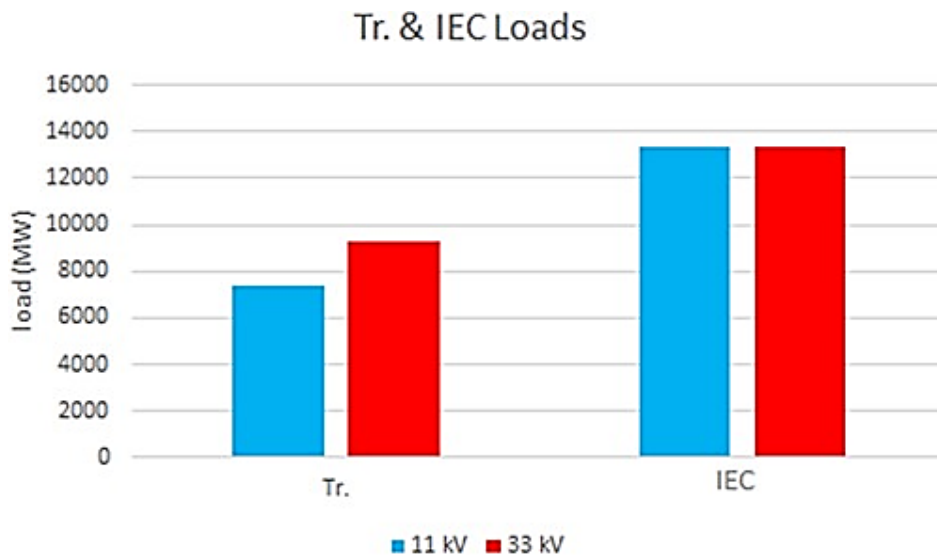


Figure 5.8: Tr. and IEC loads comparison between 33 kV and 11 kV.

According to the final result when comparing between the two levels of connection (11kV and 33kV), Fig. (5.9) illustrates the system block diagram that are used.

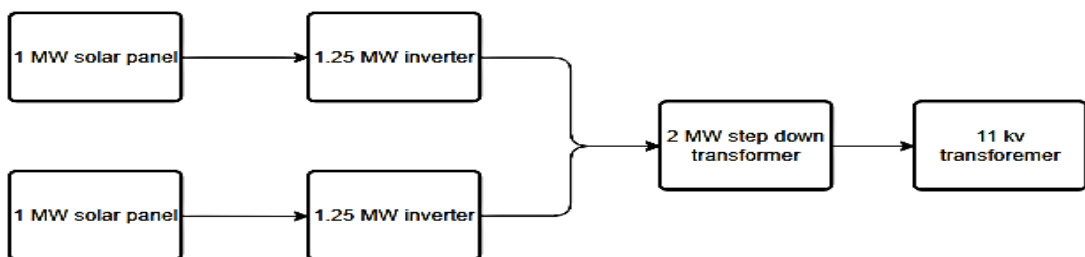


Figure 5.9: 11 kV system block diagram.

5.2 Conclusions and Recommendations

5.2.1 Conclusions

1. The electrical parameter value such as ,Current, voltage drop , PF, reactive and active powers maintained their value without changes and have not been affected when a 2MW power flow injected across the network operated by 11KV and 33KV power transformers.
2. It had been noticed that a greater power losses occurred when a power flow injected upon the 33KV side of the network compared with that upon the 11KV transformer side (power loss $\propto I^2 R$).
3. The 2MW power generation necessity stemmed its root from JDECO need to meet the minimal load required for 2MW load operation of its customers .

5.2.2 Recommendations

1. The installation of the photovoltaic modules must take into account some factors to take full advantage of solar radiation including: the orientation, the inclination, the latitude, the climatic conditions, and the effect of shadows between the PV panels.
2. Cleaning the solar panels and avoid building or placing high equipment in front of the panels to avoid the shadowing effects. Moreover, building a room for electrical equipment and cooling them as the need necessitates to obtain the highest efficiency.
3. Using closed loop control system tracker in order to operate the PV panel at the relevant azimuth angle.
4. Using a high efficiency power transformer to meet the maximum power

5.2. *CONCLUSIONS AND RECOMMENDATIONS*

load consumption.

5. Preparing a financial proposal for building a stand by power solar station in order to minimize air pollution and to meet the climate change standards in the country.

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Appendix A



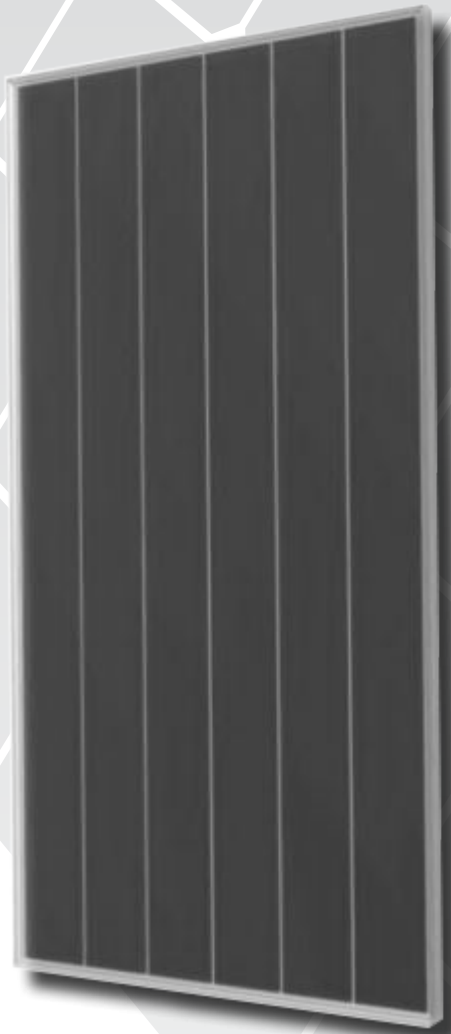
Product Warranty



Linear Output Warranty

X-CHROS Monocrystalline PERC High Efficiency SHINGLED

635 - 645 - 650 - 655 - 660 Wp



Shingled solar cells



Positive Tolerance



High Voltage 1500 DC



Anti-PID and low LID

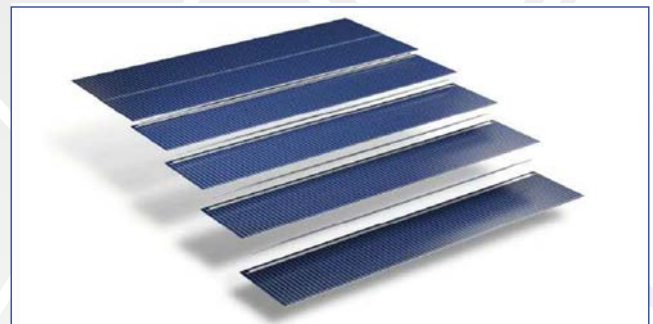


21.5 % max efficiency



Fire reaction Class 1

The new photovoltaic modules X-CHROS is one of a wide range of products made by Sunerg and It is manufactured according to IEC 61215, IEC 61730 standard and CE. PERC Shingled Technology provides ultra -high efficiency with better performance in low irradiation. Maximizes installation capacity in limited space



CORRESPOND TO
PV CYCLE | CE |

UNI EN ISO 9001:2008
UNI EN ISO 14001:2004
UNI EN BS OHSAS 18001:2007

| Quality management system
| Standards for environmental management system
| International standards for occupational health and safety

ELECTRICAL DATA (STC)		XMCH60635+H	XMCH60645+H	XMCH60650+H	XMCH60655+H	XMCH60660+H
Open circuit Voltage	(Voc)	45.90 V	46.00 V	46.10 V	46.20 V	46.30 V
Voltage a Pmax.	(Vmp)	37.4 V	37.5 V	37.6 V	37.7 V	37.8 V
Short-circuit current	(Isc)	17.85 A	17.94 A	18.03 A	18.12 A	18.21 A
Current at Pmax.	(Imp)	17.11 A	17.20 A	17.29 A	17.37 A	17.46 A
Peak Power (Pmax) Tolerance 0 ~ +5W		635 Wp	640 Wp	645 Wp	655 Wp	660 Wp
Module Efficiency		20.9 %	21.0 %	21.2 %	21.3 %	21.5 %
Maximum voltage		1500 DC	1500 DC	1500 DC	1500 DC	1500 DC
Maximum series fuse rating		25A	25A	25A	25A	25A
Operating Temperature		-40°C - +85°C	-40°C - +85°C	-40°C - +85°C	-40°C - +85°C	-40°C - +85°C

* STC (Standard test conditions)

Irradiance 1000 w/m², module temperature 25°C, AM= 1.5

TEMPERATURE COEFFICIENT

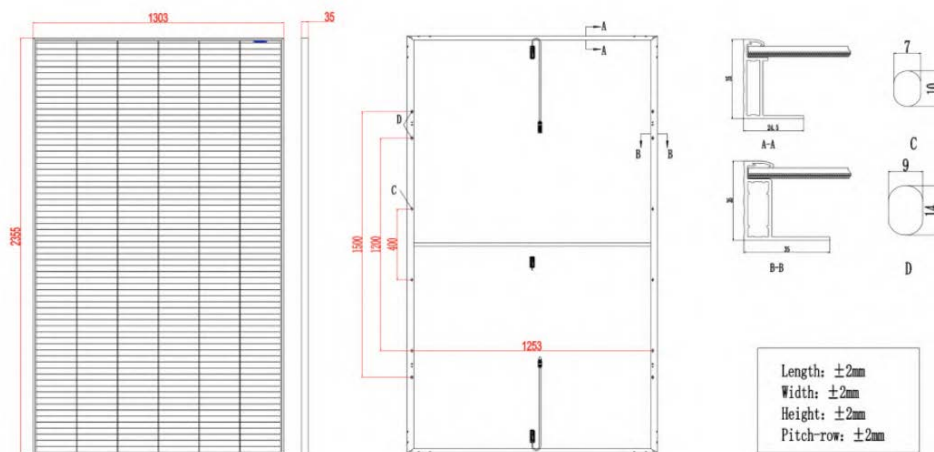
NMOT	42.3°C±2°C
Pmax Temperature Coefficient	-0.34%/ °C
Voc Temperature Coefficient	-0.27%/ °C
Isc Temperature Coefficient	0.04% / °C

MECHANICAL CHARACTERISTIC

Max. surface load capacity (Pa)	5400
Dimensions (mm)	2355X1303X35 mm
Weight (Kg)	34
Encapsulation	EVA
Cells	210x210 mm PERC
Backsheet	High weatherability backsheet

PAKAGING CONFIGURATION

Modules per pallet	31		
Pallets per container 40'GP	16	Modules per Container	496



GENERAL INFORMATION

Glass	AR coating tempered glass, 3.2mm
Farme	Anodized Aluminum alloy
Juntion Box	IP68, three diodes
Output Cable - connectors	4mm ² , lenght 800 mm (vertical) +250mm/-150mm (horizontal) MC4 Compatible

Sunerg Solar S.r.l. reserves the right to make changes to the technical data of the product without prior notice. The technical details of the form, although included with the utmost care, may contain errors or inaccuracies not attributable to Sunerg Solar S.r.l.

Appendix B

ABB megawatt station

PVS800-MWS

1 to 1.25 MW



The ABB megawatt station is a turnkey solution designed for large-scale solar power generation. It houses all the electrical equipment that is needed to rapidly connect a photovoltaic (PV) power plant to a medium voltage (MV) electricity grid. All the components within the megawatt station are from ABB's product portfolio.

Turnkey-solution for PV power plants

The ABB megawatt station design capitalizes on ABB's long experience in developing and manufacturing secondary substations for utilities and major end-users worldwide in conventional power transmission installations.

A station houses two ABB central inverters, an optimized transformer, MV switchgear, a monitoring system and DC connections from solar array. The station is used to connect a PV power plant to a MV electricity grid, easily and rapidly. To meet the PV power plant's demanded capacity, several ABB megawatt stations can be combined.

Compact design eases transportation

The steel-framed insulated container comes complete with a concrete foundation. A thermally insulated inverter compartment enables operation in harsh temperature and humidity environments and is designed for at least 25 years of operation.

The hollow concrete foundation has a double floor within the inverter compartment. This provides easy access for cabling. Additionally the small inverter footprint makes the container compact and easy to lift via a standard crane, thereby simplifying transportation.

The complete ABB megawatt station weighs only 20 tons. At 50 m³, the container's volume is some 15 percent smaller than equivalent solutions.

Micro inverters

String inverters

Central inverters

Turnkey stations

PV + Storage



Highlights

- Proven technology and reliable components
- Compact and robust design
- High total efficiency
- Modular and serviceable system
- Double-stage air pre-filtering for reduced maintenance
- Global life cycle services and support

Accessories

- Solar array junction boxes with string monitoring
- Remote monitoring solutions
- Warranty extensions
- Solar inverter care contracts

Options

- MV AC output voltages (6 to 24 kV)
- Different MV switchgear configurations
- Air-insulated MV switchgear
- Optional liquid-filled and dry-type transformers
- I/O extensions
- DC grounding (negative and positive)
- Fieldbus and Ethernet connections
- Auxiliary power supply from main power connections

ABB megawatt station

Solar inverters

ABB solar inverters are the result of decades of industry experience and the use of proven frequency converter technology. As such the solar inverters provide a highly efficient and cost-effective way to convert the direct current, generated by solar modules, into high-quality and CO₂-free alternating current. Two ABB central inverters are used in the ABB megawatt station. The inverters provide high efficiency conversion with low auxiliary power consumption.

Transformer

The ABB megawatt station features an ABB vacuum cast coil dry-type transformer. The transformer is designed to meet the reliability, durability, and efficiency required in PV applications. It is specifically designed and optimized for ABB solar inverters to provide the best performance throughout the lifetime of the plant.

The transformer is environmentally safe, having no volatile liquids that can leak, and it carries no fire or explosion risk. It provides excellent mechanical and short-circuit characteristics.

As a major global transformer manufacturer, ABB offers a wide range of liquid-filled and dry-type transformers. Alternate power transformers are available to meet customer requirements. All ABB's transformers are manufactured in accordance with the most demanding industry and international standards.

Switchgear

ABB offers a complete range of medium voltage switchgear for secondary distribution, including air-insulated and gas-insulated switchgear.

The ABB megawatt station is equipped, as standard, with the widely proven ABB SafeRing, SF6-insulated switchgear. A sealed steel tank with constant atmospheric conditions ensures a high level of reliability as well as personnel safety. The virtually maintenance-free system comes in a compact and flexible design that allows for a versatile switchgear configuration. As an option ABB's gas-insulated SafePlus and air-insulated Unisec switchgear are also available.

Technical data and types

Type code	PVS800-MWS-1000kW-20 ^{*)}	PVS800-MWS-1250kW-20 ^{*)}
	1 MW	1.25 MW
Input (DC)		
Maximum input power ($P_{PV, max}$)	2 × 600 kW	2 × 760 kW
DC voltage range, mpp ($U_{DC, mpp}$)	450 to 825 V	525 to 825 V
Maximum DC voltage ($U_{DC, max}$) ¹⁾	1000 V	1000 V
Maximum DC current ($I_{DC, max}$)	2 × 1145 A	
Voltage ripple, PV voltage (U_{PV})	< 3%	< 3%
Number of protected DC inputs (parallel)	2 × 8 (+/-)	2 × 8 (+/-)
Number of mppt trackers	2	2
Output (AC)		
Nominal AC output power ($P_{AC, N}$)	1000 kW	1250 kW
Nominal AC current ($I_{AC, N}$)	28.9 A	36.1 A
Nominal output voltage ($U_{AC, N}$) ²⁾	20 kV	20 kV
Output frequency	50/60 Hz	50/60 Hz
Harmonic distortion, current ³⁾	< 3%	< 3%
Power factor compensation (cosφ)	Yes	Yes
Inverter type (2 x ABB central inverters)	PVS800-57-0500kW-A	PVS800-57-0630kW-B
Transformer type ⁴⁾	ABB Vacuum cast coil dry-type	
Medium voltage switchgear type ⁵⁾	ABB SafeRing type DeV with REJ603 protection relay (self-powered)	
Efficiency		
Maximum ⁶⁾ (including transformer)	97.8%	97.8%
Euro-eta ⁶⁾ (including transformer)	97.1%	97.3%

¹⁾ If DC voltage is > 1000 V, the inverter will not be damaged, but will not start

²⁾ Voltages between 6 and 24 kV available as an option

³⁾ At nominal power

⁴⁾ Other ABB transformer types available as an option

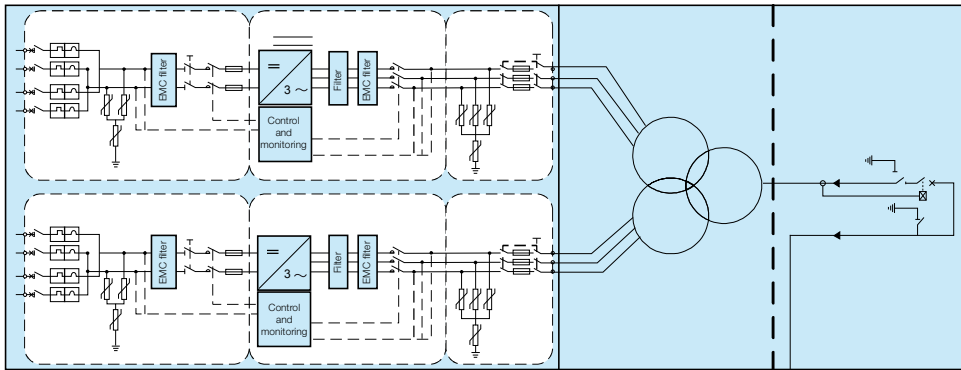
⁵⁾ Other ABB switchgear types available as an option

⁶⁾ Efficiency without auxiliary power consumption, at lowest DC voltage

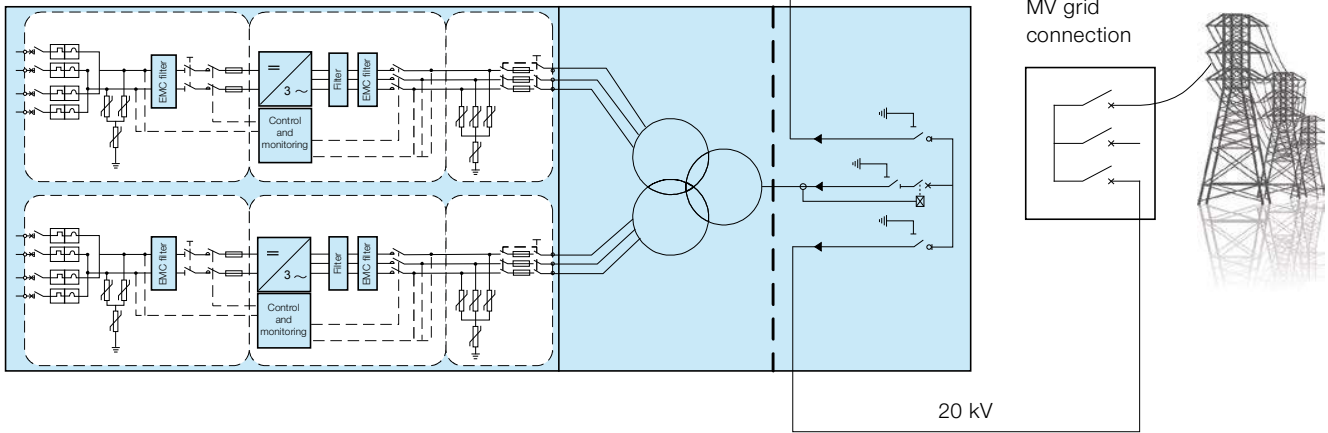
^{*)} Improved design, first shown at Intersolar 2014

ABB megawatt station design and grid connection

1: PVS800-MWS



2: PVS800-MWS



Type code	PVS800-MWS-1000kW-20	PVS800-MWS-1250kW-20
	1 MW	1.25 MW
Power consumption		
Own consumption in operation ⁷⁾	< 1200 W	< 1200 W
Standby operation consumption ⁷⁾	< 140 W	< 140 W
External auxiliary voltage	3 ~ 400 V/50 Hz	3 ~ 400 V/50 Hz
Dimensions and weight		
Width/Height/Depth, mm	W 6930/H 3070/D 2430	W 6930/H 3070/D 2430
Weight approx.	20 t	21 t
Environmental limits		
Degree of protection	IP54 (inverter section)/IP23d (transformer and switchgear section)	IP54 (inverter section)/IP23d (transformer and switchgear section)
Ambient temperature range (nominal ratings)	-20 to +40 °C	-20 to +40 °C
Maximum ambient temperature ⁸⁾	+50 °C	+50 °C
Relative humidity, non condensing	15 to 95%	15 to 95%
Maximum altitude (above sea level) ⁹⁾	2000 m	2000 m
Maximum cooling air flow	6720 m ³ /h	6720 m ³ /h
User interface and communications		
Local user interface	Inverter's control panel and PC interface through ABB Drive Window	
Fieldbus connectivity	Modbus, PROFIBUS, Ethernet	
Product compliance		
Conformity	IEC 62271-202 High-voltage/low-voltage prefabricated substation	
Certifications and approvals	BDEW	
Grid support	Reactive power compensation, Power reduction, Low voltage ride through	

⁷⁾ Without options and heating

⁸⁾ Power derating after 40 °C

⁹⁾ Power derating above 1000 m. Above 2000 m special requirements.