Palestine Polytechnic University

College of Engineering

Title

Feasibility Study of Solar Photovoltaic Integration on AL –KUM village Network.

By

Doaa abu khalaf **Hadeel halisi**

Supervisor

Dr. Nassim Iqtait

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

Hebron, December 2018

List of Continent

List of Figure

List of Table

الاهداء

إلى سندنا وقوتنا وملاذنا بعد الله إلى من أرضعتنا الحب والحنا امهاتنا

إلى من جرع الكأس فارغاً ليسقينا قطرة إلى من كلّت أناملة ليقدم لنا لحظة سعادة

آبائنا إلى من تذوقنا معهم أجمل اللحظات إلى من سنفتقدهم ...... وأتمنى أن يفتقدوننا

إلى من جعلهم الله أخوتنا بالله ...... ومن أحببناهم بالله اصدقائنا في الجامعة الى من ساهم في

وصولنا لطريق النهاية الى كل من علمنا شيئا جديداً الى اساتذتنا في الجامعة

شكر وتقدير

الحمد لله ذي المن والفضل والإحسان، حمداً يليق بجلاله وعظمته

والصلاة والسلام على معلم البشرية وهادي الانسانية وعلى آله وصحبه ومن تبعهم بإحسان إلى يوم الدين صلاةً تقضي لنا بها الحاجات، وترفعنا بها أعلى الدرجات، وتبلّغنا بها أقصى الغايات من جميع الخيرات في الحياة وبعد الممات

ولله الشكر أولاً وآخراً على حسن توفيقه، وكريم عونه، وعلى ما منّ وفتح به علينا من إنجاز بعد أن يسّر العسير وذلّل الصعب وفرج الهمّ

كما ندين بعظيم الفضل والشكر والعرفان بعد الله سبحانه وتعالى في إنجاز مقدمة مشروع التخرج بالصورة المرجوّة إلى المشرف الدكتور نسيم قطيط الذي منحنا من وقته وخبراته وتوجيهاته الكثير ومدّ يد العون لنا دون ضجر للسير قدماً نحو الأفضل سائلين المولى القدير أن يجزيه خير الجزاء

ويسرنا أن نخص بالشكر والعرفان بالجميل إلى مجلس قرية الكوم الذي مد لنا يد المساعدة

ونتوجه لكل من مدّ لنا يد العون بالشكر الكثير وجزاهم الله خير الجزاء

وختاماً، نسأل الله العليّ القدير أن يكون هذا العمل خالصاً لوجهه الكريم، وأن يجعله علماً نافعاً يسهّل لنا به طريقاً إلى الجنة

الملخص

خلال السنوات الماضية ازداد ربط الشبكة الكهربائية بنظام الخلايا الشمسية .وذلك لما له من فوائد كثيرة فالطاقة الشمسية متوفرة مجانا ,ولا تلوث البيئة . ولكن هذه الزيادة السريعة تؤدي لتأثير على جودة الطاقة .يهدف هذا المشروع لدراسة جدوى اضافة نظام خلايا شمسية لشبكة الكوم التابعة لمدينة دورا .ودراسة الآثار السلبية الناتجة عن ربط الشبكة بنظام الخلايا الشمسية .وذلك عن طريق تحليل الشبكة وبيانات الخلايا الشمسية وانتاج نموذج للشبكة بناء على هذه المعلومات . حيث تم العمل على محول واحد من محولات القرية وقدرته KVA250. في هذا الجزء من المشروع تم تجميع جميع بيانات الشبكة وعمل نموذج بسيط يوضح توزيع الاحمال ,على ان يتم محاكاة عمل الشبكة باستخدام برنامج E-TAB خلال الفصل القادم .

Abstract

Grid connected photovoltaic (PV) have rapidly increased over the past years. Because of its many benefits, solar energy is available free, and doesn't pollute the environment. This rapid increase will lead to the impact of power quality .This project aims to study the feasibility of adding solar photovoltaic system to the AL-KUM network of Dura city. And study the negative effects resulting from connecting the network with a solar photovoltaic system. This was done by analysis of network and PV data and producing models based on data. Where was working in one transformer of the village transformers its capacity 250 kVA rating . In this part of the project, all the network data were collected, and a simple model of load distribution was done. The work of the network will be simulated using the E-TAB program during the next semester.

Chapter1: Introduction

Grid connected photovoltaic (PV) have rapidly increased in the world over the past year, due to its free availability, to its ease of use to other electricity resources, and its green operation on the entire earth plant. So, it is necessary to connect the electrical grid to the photovoltaic system.

On this project we will study addition of solar photovoltaic on AL-KUM village network. AL-KUM is a village of Dura. It is under the rule of an independent local council, so it is not associated with any distribution company. The entire network consist of eight transformers distributed over the village with a population of 5000 people. Four of the transformers it distributed throughout the village to supply electricity to the villagers, and four of it on the village boundary it used to supply the village's factories with electricity. The work in this project will be only on one transformer .it is the closest transformer of the land owned by the village council .There are 137 load of this transformer all of it are residential. In the recent years in Palestine, electricity crises and the limitation coming from Israeli Energy authority becomes the main problem. From here we are looking for other sources of energy.

1.1 : Background

Solar power is the production of electric power by utilization thermal energy [1] sunlight rays from the sun .It consists of solar power source and a converter of the energy from sunlight to electric energy .this power can be independent of a conventional power grid or can be integrated to an existing conventional electricity grid at transmission or distribution level.

A solar photovoltaic (PV) power system can operate in isolation or connected to a power grid. The system normally consists of a micro power source (solar) and some local load. Additionally, it can be a solar without any loads connected but connected to a power grid. When connected to a grid, the operating condition of the grid are altered in either a positive or negative way [2].

There has been rapid increase of grid connected solar PV power in the world. This integration of solar PV power can result in improvement of the grids or can have negative impact on the steady state system operation parameters like load flow, short circuit and harmonics [3].

1.2: Overview

The idea of this project is to supply AL-KUM village network by solar energy. This project suggests to supply apart of network including transformer 250KVA by photovoltaic substation, where it can be located in the piece of land owned by village council.

1.3 :Project Objectives

The main objectives of this project can be summarized as follow:

1. Feasibility study of adding PV integration of AL-KUM village network.
2. Supply the village with electricity by connecting it with solar cell system.
3. Collect the data about the village network and analysis it.
4. Study the effects of the following aspects :
    - Load flow study.
    - Short-circuit study.

1.4: Project Motivations

The energy is a basic human need, there is no development without energy. Increasing demand for energy and limited sources especially in Palestine because of the blockade and the lack of access to resources. Traditional energy only through the state of occupation (Israel), so the energy needs to be channeled. Renewable energy sources such as solar cells as solution to the electricity problem in Palestine.

1.5: Importance of the project

Explain the importance of connecting the photovoltaic cell with the network, and make study about the village network and search about the negative and positive effects about connecting PV with the network.

1.6: Methodology

1. We visited the council of the village, and collected the data about network.
2. Analyze and simplify data.

3. We will use E-TAP program to study the network (in the next semester).

1.7: Project problems

We faced many problems when collecting information related to network, because the village is not connected to south electricity company, and connected directly with the AL- QUTRIA Company, in addition to that it has no electrical engineers but only have technical workers.

1.8: Literature Review

- A study was carried out on the integration of solar systems with distribution networks in the Marechal Deodoro-AL area in the case of overload. The analysis and simulation was carried out by the TADDRO program. The results of the study showed that the solar cells injected a current equivalent to 320 A in one of the buses of the feeder segment and also show that there is an increase in the level of voltage by about 2%, and also contribute to increase the quality of energy for the consumer [3].
- Increasing the use of network integration with solar cells in Algeria during the past years, which led to study the effect of these cells on the quality of energy of the user. The negative effects and positive effects of the integration of cells with the network were studied, the results of the study showed that the short circuit current levels are very low to cause significant power quality issues, however problems were noted about load flow, and harmonics [4].
- Study was conducted in Egypt because of the power electricity demand is increasing and rampant power cuts are a norm, and the scheduled outages it can be reach to 8 hours a day in some parts of the country. During the outages, industries, and consumers tend to use diesel generators, which not only expensive, but also leads to pollution. Renewable energy sources were the solution for faced this problems. The results of the study shows that the positive effects is Huge savings in the Transmission and Distribution losses (TDL),While the negative effects resulting from the uncontrolled of solar PV which causes voltage fluctuation within the network. Also, phase unbalance, loading on the distribution transformer, power factor, reactive power compensation, and harmonics is expected to have greater impacts on distribution network [5].

1.9 :Block diagram

This block diagram shows grid-connected PV power system, the solar PV system is used to convert the thermal energy from sunlight in to direct current (dc) power, the current and voltage from the single cell is very small. To increase the output voltage the cells are connected in series and in parallel to increase the output current. A combination of cells make up the PV module. since a direct current power is generated ,The invertor will transform generated DC current in to AC power this is because most of the electrical loads todays operates with alternating current ac power (see figure 1.1) [6] .

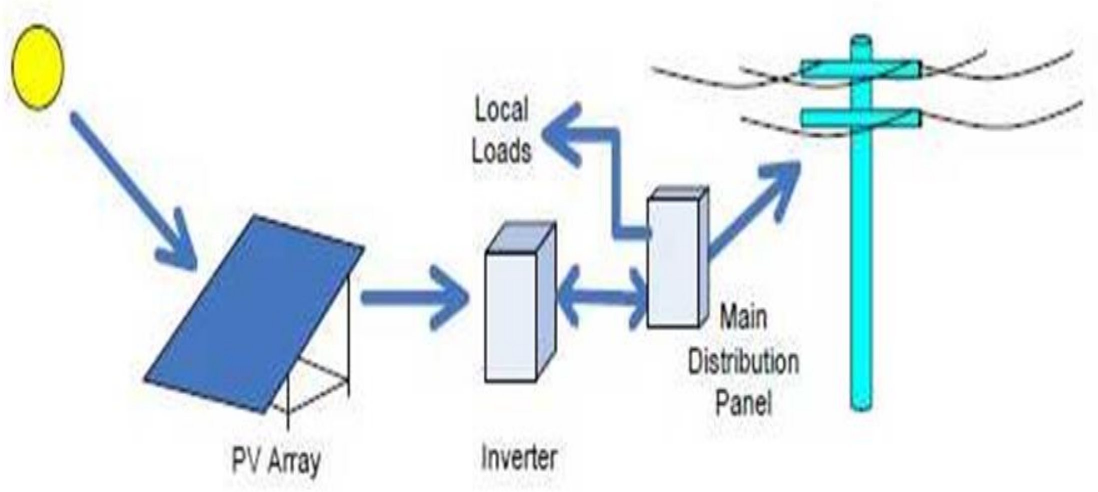

Figure 0-1 Grid Connected PV Power system.

1.10 :Time planning for the project

The project plan follows the following time schedule which includes the related tasks of study and system analysis. The following time plane are for the first semester.

Table 0-1 Timing Schedule of the First Semester.

week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Project selection															
collecting from different information															
Chapter 1															
Chapter 2															
Chapter 3															

Chapter 2: Effect of photovoltaic integration on distribution network

2.1 :Introduction

Grid connected photovoltaic (PV) have rapidly increase over the past year .this rapid increase will lead to the impact of these system on customer power quality. In first section of chapter we will explain in a simply way the negative effects resulting from photovoltaic integration in network.

This effect include short circuit, load flow, harmonic (study) and power factor. To minimize the negative impacts, this was done by analysis of network and PV data from selected case study areas as well as producing models based on data. This work (producing models) will be done in the next semester.

2.2: Short circuit study

Why do I have to have a short circuit study performed? Does it even have any real benefits? A simple way to answer those question is: Because it is very important and they are huge benefits to having a short circuit study done. Now let's go into the details.

A short circuit is an electrical circuit that allow a current to travel along an unintended path with no or very low electrical impedance This result is an excessive amount of current flowing in the circuit .And a short circuit is the voluntary or accidental connection of two (or more) points of an electrical circuit between which there exists a potential difference by a low resistance conductor. The following short circuit can be distinguished on a network:

- Single phase (80% of cases), where one phase and earth or neutral are connected together.
- Bi-phase (15% of cases), where the two phases are connected together.
- Three-phase (5%of cases), where the three phase are connected together.
- Bi-phase-ground, where two phase and the ground are connected together. [7,8]

Short circuit current contribution of photovoltaic power plant

The grid integration of renewable energies has greatly affected of the short circuit capacity (SCC) of power systems all over the world .symmetrical or unsymmetrical behavior of short circuit is different between renewable energy sources, e.g. solar energy, and conventional generators .the response of renewable energy generation to short circuit is controlled by the power electronics used in converter system. [9]

2.3:Load flow study

2.3.1 Load flow analysis

To start the voltage stability analysis of power system .The complex voltage must be calculated for all buses, calculate the power flow of the bus and calculate power flowing in all transmission line. For this purpose we use Load Flow Analysis .Load flow is used in planning studies, for designing a new network or expansion of an existing station. Then values of power flow and voltage are compared with the steady state device limits, to obtain the correct network values.

2.3.2 Load flow study

In a three phase ac power system, active power (P) and reactive power (Q) flows from the generating stations to load through different network buses and transmission lines. These powers are supplied by generators at generating buses. This flow of active and reactive power is called Load Flow or Power Flow.

.Power flow analysis is very important in planning an designing the future expansion of power system or addition to existing ones like adding new generator sites, meeting increase load demand and locating new transmission sites . Load flow study detect best place ,optimal capacity of generating station , substation and new line .load flow study works to reduce transmission losses and prevent line overloads . Different conventional techniques for solving the power flow problem are [10]:

- Gauss-seidel (GS) method.
- Newton Raphson method.
- Fast Decoupled Load Flow (FDLF).

The purpose of load flow study of the distribution network is to develop the network like cables and lines. When PV produces more power than the load need, a thermal and voltage fluctuation are studied. As long as the output of the PV is less than maximum limit for the load, PV production will only reduce line voltage drop .in case of the production of PV exceed the load it will be an increase in voltage or increase in thermal load of lines or cables.

2.3.3 Formulation of power-flow study

The bus is the node connected by one or more lines, and it also connected to one load or many loads and generators .It is not necessary to have a wire, load and generator on the bus. The bus is represented by a vertical line with many components [10].

There are three types of buses:

- **Generator Bus (P-V bus)** this bus is also called as P-V bus. In this type true or active power P are specified, and the voltage magnitude is maintained constant at a specified value by adjusting the field current of synchronous generator. The reactive power generation Q and phase angle δ of voltage is computed. V and δ are unknown.
- **Load Bus (P-Q)** - This bus is also called P-Q bus and the total injected power is specified. In this real and reactive power are specified, and for which bus voltage

has to be calculated. The magnitude and phase angle of the voltage has to be computed. All buses having no generators are load buses. Q and δ are unknown.

- **Slack bus** – It is also called as reference bus. At this bus magnitude and phase angle of the voltage are specified. The phase angle is mostly set to zero. The active and reactive powers at this bus are to be determined through the solution of equations. In here P and Q are unknown.

The power flow equations it need a numeric iterative algorithm to be solved, because it non-linear equation equations and can't be can't be solved analytically.

2.3.4 Importance of load flow studies

Load Flow studies provide a systematical mathematical approach for determination of various bus voltages, their phase angle, active and reactive power flow through different branches, generators and loads under steady state conditions .

Load flow studies help to determine the best size and best location for power capacitors, for these purposes, for power factor improvement and for raising network voltages. Load flow studies help to determine the best location and determine optimum capacity for generating station, substation and new line. Load Flow is an essential part in power system studies.it helps to calculate line losses for various conditions. It prepares software for online operation, control and monitoring of the power system. It also in analyzing the effect of temporary loss of generating station or transmission path on the power flow [10].

2.4 Harmonic study

2.4.1 Harmonic in general

In an electric power system, a harmonic is a voltage or current at a multiple of the fundamental frequency of the system, produced by the action of non-linear loads such as rectifiers, discharge lighting, or saturated magnetic devices. Harmonic frequencies in the power grid area are a frequent cause of power quality problems. Harmonic in power system result in increasing heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors.

The main effects of the voltage and current harmonics in a power system:

- The chance for elaboration of some harmonics as a result of serial and parallel resonance.

- Performance reduction in generation, transport and energy usage systems.
- The aging of the grid insulation peripherals and as issue, energy reduction.
- Malfunctioning of the system or some of its elements.

Non-linear power supplies consume electricity in high-amplitude short pulses, and its causes electrical and voltage wave shape harmonic distortion. The effect shifts from power source and affects the related equipment. As great frequency harmonic electricity flow through power system, would cause communication errors such as

- Overheating of electrical distribution equipment, cables, and transformers.
- High voltages and circulating currents caused by harmonic resonance.

- High voltages and circulating currents caused by harmonic resonance.
- High internal energy losses in connected equipment, causing component failure and shortened life span.
- False tripping of branch circuit breakers.
- Metering errors.
- Fires in wiring and distribution systems.
- Generator failures.
- Lower system element, resulting in fines on monthly utility bills [11].

Recently, photovoltaic (PV) technology has been one of the promising renewable energy due to its ability to produce electricity without any pollution to the environment .power electronic device use in power converters create power quality problem such as harmonic distortion .

PV system performance in term of power quality strictly depended on the use of the inverters, solar irradiance and temperature that may affect the power generated, voltage and current profile. Inverters connected with renewable energy sources, non-linear customer loads and power electronics devices introduce harmonics in the distribution network that causes overheating of transformers, tripping of circuit breakers, and reduces the life of connected equipment .Therefore, harmonics is one of the most dominant attributes that need to be kept in a minimum level to ensure power quality of the network [12,13]

Chapter 3:Photovoltaic

3.1 :ON-Grid System

The term on grid is referred to as network-related systems. These systems supply the loads in the customer with the electrical energy generated by the solar cells during daylight hours through the network adapter, and the surplus is sold to the electricity company of the distribution company. On grid system characterized by no batteries so they work only in daylight hours. The inverter is the most important part of this system [14].

3.2 :Components

- **Photovoltaic Modules.**
- **Junction Box**

  The junction boxes were used majorly in two different places in PV systems i.e. one is at the interconnection power converter. Here all the PV strings are joined together. Another place is at solar PV enclosure where this junction is used comprises the bypass diodes allowing the power flow only in one direction i.e. from solar panel to the utility system [15].

- **On-Grid Inverter**

  On-grid inverter is the one which converts the DC power to AC power. This is one of the essential components of PV system to inter connect with the present day power sector. We have various type of inverter available in the market whose rating is from small kVA to larger kVA. The present available inverter are coming with MPPT enabled and wider input V dc range.

- **AC disconnect & Main Panel**

  In photovoltaic systems DC and AC disconnect are the two boxes where AC disconnect role is to separate the on-grid power converter i.e. DC-AC inverter from the electrical utility grid. Output currents of the inverters have to be taken into consideration while sizing the AC disconnect and it simply be circuit breaker. This is generally placed in Main panel. Main panel comes into picture before the electrical system can be integrated to electrical power grid. This generally consists of electro mechanical devices that are used to disconnect the photovoltaic system from the electric grid.

- **Net meter is a device**

  That is used to monitor the inflow and outflow of electricity between the electrical powers generating system to electric utility grid. In photovoltaic systems if excess energy is generated that can be sold to the utility by means of this.

- **Electrical Grid**

  It is an electrical power network interconnecting the load centers and energy providers. It is one of major parts of electrical power system network acting as interface between power generation plant, power transmission line, and distribution lines. It transmits electric power that is generated using any source (renewable or non-renewable) at any place and distributes finally to the consumers as per the requirement [15].

3.3 : Procedures and instructions for installing PV Module

• Know the available space and its suitability to the size of the system as well as the conditions of the climatic location.

• Consultation with the distribution or transmission network for the possibility of installation in terms of distance of the system from the electrical grid and the point of connection and the extent of the existing network absorption of the size of the system.

• Provide a complete electrical scheme of the system and includes the number of solar panels, transformers, the method of connecting, the cross sectional area of cable.

• Provide a detailed outline showing the system accounts with monthly and annual reports.

• Provide a copy of the technical manual (catalogue) for panels and inverters.

• Provide the scheme of the earthing system, which explains the sources of earthing, the method of binding and earthing bridge.

3.4: Evaluation of location and area

- **Evaluation of location**

These systems are usually built on the ground directly or on the roofs of houses, and the most important things that must be taken into account when choosing the site and the initial visit to the place to install the system in it.

1. There is no shading on the solar cells from 8 am to 4 pm, such as the presence of high buildings, trees, or the height of the shelves of the roofs of houses, because the shade leads to reduced production capacity.
2. It is usually preferred to install the system tightly so that the solar panels are not liable to steal or throw stones at them.

- **Evaluation of area**

Estimating the area depends mainly on the efficiency and type of solar cells. As we know that the energy of the sunlight that reaches the solar cells through space and the atmosphere (1kW/m2), this in turn helps us to know the approximate area of each Kw so that the space can be estimated as follows:

The area needed by the installation of 1 kW solar cells = Solar Irradiance / Efficiency of solar cells Solar Irradiance 1kW/m2 [15]

- **Energy produced from the system**

The global formula to estimate the electricity generated in output of a photovoltaic system is:

$$E=A^* r^* H^*PR \qquad (3.1)$$

Where:

E = Energy (kWh)

A = Total solar panel Area (m2)

r = solar panel yield or efficiency (%)

H = Annual average solar radiation on tilted panels (shadings not included)

PR = Performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75) [16].

- **Estimating the total cost of the project**

After the initial visit of the site to be installed system and estimate the size of the system in kilowatt, take measurements and dimensions of the place can estimate the cost of the project to include:

1. The price of PV modules and the price of bases based on them.
2. Number of grid inverters.
3. Cable prices are used by determining the path, length and cross section area of the cable.
4. The prices of protective devices such as circuit breakers, lightning arresters, and assembly box.

Chapter 4: Grid modelling

4.1: Procedure for Grid Modelling

In this chapter will be displayed grid modelling and how data was collected including transmission lines and loads. This step is the most difficult step because we started the network from zero. Moreover the village council does not have enough information about the network and there is no electrical engineers in it.

In the beginning, all the electricity columns and the houses of the selected transformer was identified. With the help of the electricity technician in the village council, we had to identify all the columns and loads that relates to the transformer and then transfer the information to the aerial image on the ATOCAD program in order to inventory grid data.

The second step was to collect all the electricity bills for the homes of the selected transformer and to give each house a special number and then to transfer these numbers to the aerial image so that we can locate the exact loads. Then we numbered each column of the transformer to know the number of loads that are connected to each column.

The next step was to find the distance between each column and the selected transformer, and the distance between the houses and the column, then we neglected the distances that are less than 20 meters to facilitate network modelling.

After that we moved to the stage of finding resistance and reactance through the data sheet of the cable and wire used , we found it difficult to get the data sheet because it’s not available to the village council then we could bring it from the South Electricity Company after making sure of the types of wire .

After completing this work, we have drawn the grid with all its details and its correct dimensions on the ATOCAD program so that we can model it on the E-TAP program. This is for analyses the network.

Then we found a value of resistance per kilometer from data sheet but there is no value for reactance so we look for ways to find the reactance and find that it needs complex equations, so we used a method of these methods to find and calculate it. We will display it in this chapter.

4.2 :Distribution Grid Area

The distribution grids to study are area from AL-KUM village in DURA city, the distribution grid are radial, and the characteristic of the loads in this area is entirely residential loads. These area have potential for solar PV power installation. There is a specific land in the village that we will put the PV on it with an area of $5000m^2$.

Figure 4.1 shows the area for the distribution grid under study (capture on google maps [17]). This area is fed from a transformer rated at 250 KVA, 33KV .The area has a total of 138 housing units that are taken in the study. The power distribution grid are entirely by cable grid feeders.

Figure 4-1 AL-KUM Grid area.

4.3 :Grid models

The models for the processed data. We have modelled the network after analyzing it and drawing the final network for the grid on the OUTOCAD program as shown in the figure below.

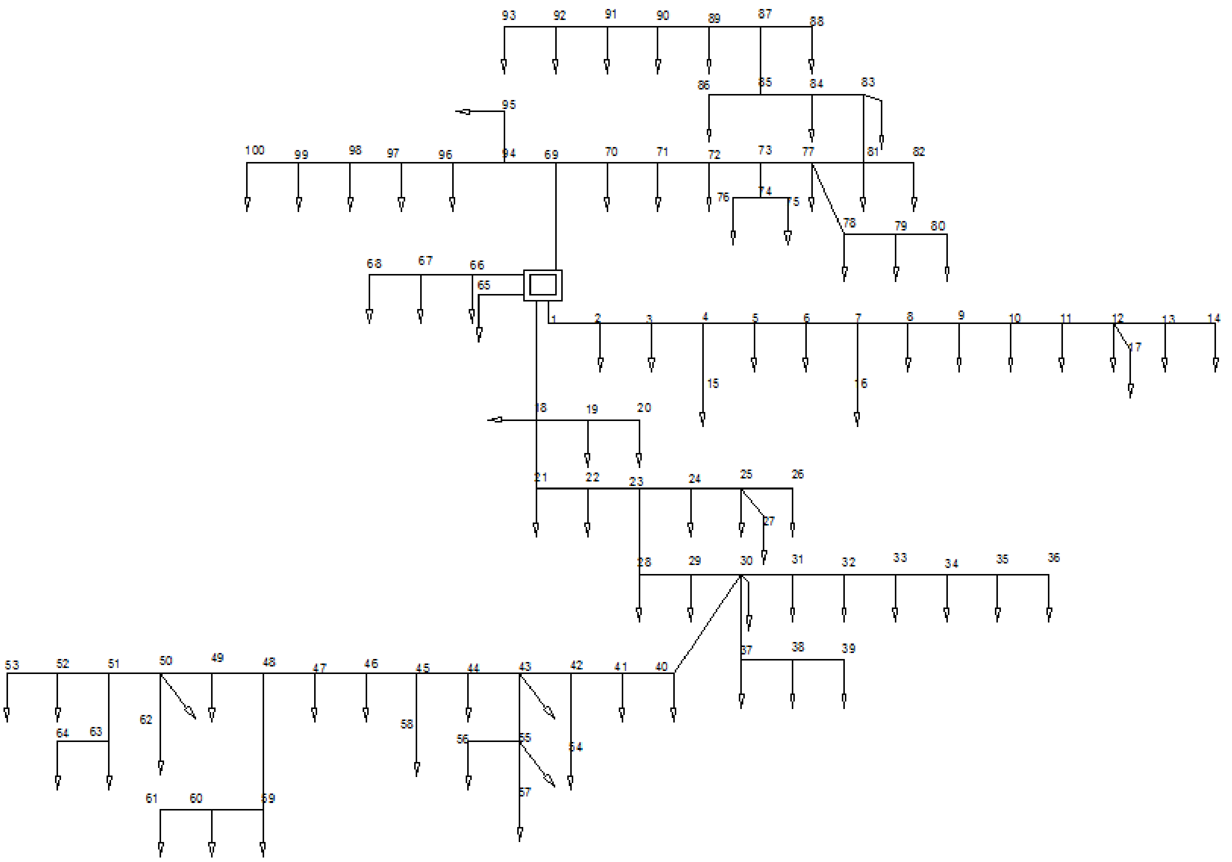

Figure 4.2 AL-KUM Grid models.

This table contains explanatory data about the network, as it shows each node and corresponding average loads in kW.

Table 4-1 loads of AL-KUM networks.

Nodes	Loads
1	0

2	1.65
3	1.83
4	0.55
5	0.2232
6	1.033
7	1.168
8	0.5704
9	0.618
10	0.5087
11	0.618
12	0
13	0.4458
14	0.4333
15	0.4464
16	0.6319
17	1.558
18	2.5244
19	0.5555
20	1.8555
21	0.08333
22	1.984
23	1.3293

24	0.868
25	2.5476
26	1.24007
27	0.496
28	1.488
29	2.0168
30	0.3869
31	1.2472
32	0.5555
33	1.0664
34	0.248
35	1.1569
36	0.124
37	2.7882
38	2.71183
39	1.7388
40	0.13888
41	0.7444
42	0
43	1.5541
44	1.4041
45	0

46	2.911
47	0.5376
48	0
49	1.3888
50	0.0416
51	0
52	0.248
53	1.9227
54	0.7615
55	1.0041
56	0.0418
57	1.2666
58	1.8638
59	0.8097
60	0.9722
61	0.5952
62	1.7608
63	0.372
64	0.496
65	0.248
66	3.9383
67	1.6999

68	0.4216
69	0
70	0.8647
71	0.9722
72	0.4166
73	0
74	0
75	0.6722
76	0.7833
77	0.8928
78	5.0554
79	1.488
80	1.0361
81	0
82	1.2027
83	0.7388
84	1.5805
85	0
86	0.6944
87	0
88	0.0416
89	2.793

90	0.7347
91	1.9194
92	0.5704
93	0.6722
94	0
95	3.7499
96	0.372
97	0.496
98	0.8333
99	0.1388
100	1.3805

Total Power	97.15861 kW

4.4 Grid data calculation

4.4.1: Calculation for Energy and Power

I. We obtained the load's name and their average consumption that we will study from AL-KUM council for months 4 , 5 and 6 by equation 4.1 : (We have attached it to the appendix)

$$E_{avg} = \frac{E\ April + E\ May + E\ Jun}{3} \tag{4.1}$$

Where:

E avg: is the average energy.

E April: is the energy consumption for April.

E May: is the energy consumption for May.

E Jun: is the energy consumption for Jun.

Then we change their average consumption from kWh to the Power by equation 4.2:

$$P_{avg} = \frac{E\ avg}{30\ months * 24\ hours} \qquad (4.2)$$

Where:

E avg: is the average energy.

P_{avg}: is the real power.

II. We calculated the total real power in kW by equation 4.3 :

$$\text{Total kW} = \sum P\ avg \qquad (4.3)$$

III. And the total energy in KWH by equation 4.4 :

$$\text{Total kWh} = \sum E\ avg \qquad (4.4)$$

This table shows all loads associated with the selected transformer and the amount of their average consumption of electric energy and power during the last months of 6 and 5 and 4. At the end of this table we have calculated the total energy and power, so that we can know how many solar cell (PV) panels will need for this project.

This table is attached in the appendix A.

Calculation for Resistance & Reactance of Lines

I. We obtained the length of the cable extending from the electric column and the next column, we calculated it through the OUTOCAD program.

Where:

L: the length in km.

II. As for the r of cables that make up the network, we extracted them through data sheets obtained from the South Electricity Company (SELCO).

III. then we calculate the resistance at operating temperature of the cable by equation 4.5 :

$$\mathrm{RAC} = \mathrm{RAC20C}(1 + 0.00393 * (\mathrm{T} - 20)) \quad (4.5)$$

Where:

R_{AC}: AC resistance of the conductor at operating temperature in (Ω /Km).

R_{AC20C}: AC resistance of the conductor at 20c (Ω /Km).

T: operating temperature of the conductor (°C).

IV. we calculate the inductance (X) of the cable by equation 4.6 that we obtained from specific website [18].

$$\mathrm{XL} = \frac{2\,\pi\,f\,K\left(0.1404 \times \mathrm{LOG}\,\frac{\sqrt[3]{A \times B \times C}}{\frac{d}{2}} + 0.0153\right)}{304.8} \quad (4.6)$$

Where:

XL = Conductor inductive reactance (Ω / km).

K = Installation correction factor shown below in Table 4.4.

A, B, C = Spacing per the figure 4.4 below (mm).

d = Diameter of the conductor (mm).

Table 4-2 The correction factor for installation (K).

Air	1
Burruial	1
Steel conuit	1.5
Al. conuit	1.2

IMT conuit	1.5
EMT conuit	1.5
PVC conuit	1.2
Tray steel	1.5
Tray Al	1.2

- We assume that the cable is 3 phase balanced IN=0.
- From data sheet A, B, C = 8.7 mm.

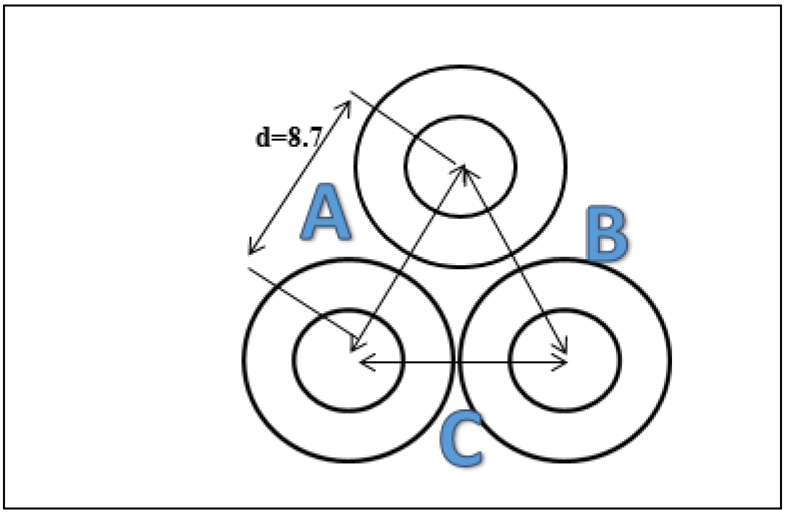

Figure 0-3 Conductor configuration.

This table shows the length of cable in Km between nodes, Resistance and Reactance of the cable that we were calculated.

Where R = 0.65361 Ω/km, XL = 0.09533 Ω/km.

Table 4-3 Data of the cables.

LINE	LENGTH	R	X

0 1	0.02	0.0130722	0.0019066
1 2	0.047	0.03071967	0.00448051
2 3	0.03	0.0196083	0.0028599
3 4	0.065	0.04248465	0.00619645
4 5	0.052	0.03398772	0.00495716
4 15	0.035	0.02287635	0.00333655
5 6	0.085	0.05555685	0.00810305
6 7	0.032	0.02091552	0.00305056
7 8	0.038	0.02483718	0.00362254
7 16	0.026	0.01699386	0.00247858
8 9	0.035	0.02287635	0.00333655
9 10	0.028	0.01830108	0.00266924
10 11	0.033	0.02156913	0.00314589
11 12	0.005	0.00326805	0.00047665
12 13	0.027	0.01764747	0.00257391
12 17	0.0385	0.025163985	0.003670205
13 14	0.235	0.15359835	0.02240255
0 18	0.033	0.02156913	0.00314589
18 19	0.027	0.01764747	0.00257391
19 20	0.04	0.0261444	0.0038132
18 21	0.0305	0.019935105	0.002907565
21 22	0.04	0.0261444	0.0038132

22 23	0.024	0.01568664	0.00228792
23 24	0.032	0.02091552	0.00305056
24 25	0.037	0.02418357	0.00352721
25 26	0.063	0.04117743	0.00600579
23 28	0.031	0.02026191	0.00295523
28 29	0.035	0.02287635	0.00333655
29 30	0.027	0.01764747	0.00257391
30 31	0.04	0.0261444	0.0038132
31 32	0.082	0.05359602	0.00781706
32 33	0.057	0.03725577	0.00543381
33 34	0.03	0.0196083	0.0028599
34 35	0.067	0.04379187	0.00638711
35 36	0.036	0.02352996	0.00343188
30 37	0.037	0.02418357	0.00352721
37 38	0.037	0.02418357	0.00352721
38 39	0.037	0.02418357	0.00352721
30 40	0.04	0.0261444	0.0038132
40 41	0.035	0.02287635	0.00333655
41 42	0.038	0.02483718	0.00362254
42 54	0.077	0.05032797	0.00734041
42 43	0.037	0.02418357	0.00352721
43 55	0.029	0.01895469	0.00276457

55	**56**	0.063	0.04117743	0.00600579
55	**57**	0.024	0.01568664	0.00228792
43	**44**	0.04	0.0261444	0.0038132
44	**45**	0.02	0.0130722	0.0019066
45	**58**	0.035	0.02287635	0.00333655
45	**46**	0.025	0.01634025	0.00238325
46	**47**	0.067	0.04379187	0.00638711
47	**48**	0.22	0.1437942	0.0209726
48	**59**	0.099	0.06470739	0.00943767
59	**60**	0.061	0.03987021	0.00581513
60	**61**	0.061	0.03987021	0.00581513
48	**49**	0.042	0.02745162	0.00400386
49	**50**	0.084	0.05490324	0.00800772
50	**62**	0.04	0.0261444	0.0038132
50	**51**	0.012	0.00784332	0.00114396
51	**63**	0.05	0.0326805	0.0047665
63	**64**	0.046	0.03006606	0.00438518
51	**52**	0.04	0.0261444	0.0038132
52	**53**	0.04	0.0261444	0.0038132
0	**65**	0.022	0.01437942	0.00209726
0	**66**	0.034	0.02222274	0.00324122
66	**67**	0.029	0.01895469	0.00276457

67 68	0.043	0.02810523	0.00409919
0 69	0.04	0.0261444	0.0038132
69 70	0.033	0.02156913	0.00314589
70 71	0.027	0.01764747	0.00257391
71 72	0.047	0.03071967	0.00448051
72 73	0.296	0.19346856	0.02821768
73 74	0.019	0.01241859	0.00181127
74 75	0.018	0.01176498	0.00171594
74 76	0.053	0.03464133	0.00505249
73 77	0.069	0.04509909	0.00657777
77 78	0.028	0.01830108	0.00266924
78 79	0.035	0.02287635	0.00333655
79 80	0.179	0.11699619	0.01706407
77 81	0.026	0.01699386	0.00247858
81 82	0.045	0.02941245	0.00428985
81 83	0.029	0.01895469	0.00276457
83 84	0.026	0.01699386	0.00247858
84 85	0.038	0.02483718	0.00362254
85 86	0.075	0.04902075	0.00714975
85 87	0.116	0.07581876	0.01105828
87 88	0.079	0.05163519	0.00753107
87 89	0.049	0.03202689	0.00467117

89 90	0.482	0.31504002	0.04594906
90 91	0.04	0.0261444	0.0038132
91 92	0.12	0.0784332	0.0114396
92 93	0.12	0.0784332	0.0114396
69 94	0.035	0.02287635	0.00333655
94 95	0.034	0.02222274	0.00324122
94 96	0.034	0.02222274	0.00324122
96 97	0.091	0.05947851	0.00867503
97 98	0.095	0.06209295	0.00905635
98 99	0.038	0.02483718	0.00362254
100	0.309	0.20196549	0.02945697

V. Finally as for zero sequence impedance, It was calculated according to the equation below.

$$Z_0 = Zs + 2\ Zm \quad (4.7)$$

Where :

Z_0 : is the Zero sequence impedance .

Zs : is the Positive sequence impedance .

Zm : on the assumption that it is equal to (Zs / 2.5) .

Table 4-4 Positive and Zero sequence.

Line from to	**Zs**	**Z_0**
0 1	0.0130722+0.0019066j	0.02352996+0.00343188j
1 2	0.03071967+0.00448051j	0.055295406+0.008064918j
2 3	0.0196083+0.0028599j	0.03529494+0.00514782j
3 4	0.04248465+0.00619645j	0.07647237+0.01115361j
4 5	0.03398772+0.00495716j	0.061177896+0.008922888j
4 15	0.02287635+0.00333655j	0.04117743+0.00600579j
5 6	0.05555685+0.00810305j	0.10000233+0.01458549j
6 7	0.02091552+0.00305056j	0.037647936+0.005491008j
7 8	0.02483718+0.00362254j	0.044706924+0.006520572j
7 16	0.01699386+0.00247858j	0.030588948+0.004461444j
8 9	0.02287635+0.00333655j	0.04117743+0.00600579j
9 10	0.01830108+0.00266924j	0.032941944+0.004804632j
10 11	0.02156913+0.00314589j	0.038824434+0.005662602j
11 12	0.00326805+0.00047665j	0.00588249+0.00085797j
12 13	0.01764747+0.00257391j	0.031765446+0.004633038j
12 17	0.025163985+0.003670205j	0.045295173+0.006606369j
13 14	0.15359835+0.02240255j	0.27647703+0.04032459j
0 18	0.02156913+0.00314589j	0.038824434+0.005662602j
18 19	0.01764747+0.00257391j	0.031765446+0.004633038j
19 20	0.0261444+0.0038132j	0.04705992+0.00686376j

18	**21**	0.019935105+0.002907565j	0.035883189+0.005233617j
21	**22**	0.0261444+0.0038132j	0.04705992+0.00686376j
22	**23**	0.01568664+0.00228792j	0.028235952+0.004118256j
23	**24**	0.02091552+0.00305056j	0.037647936+0.005491008j
24	**25**	0.02418357+0.00352721j	0.043530426+0.006348978j
25	**26**	0.04117743+0.00600579j	0.074119374+0.010810422j
23	**28**	0.02026191+0.00295523j	0.036471438+0.005319414j
28	**29**	0.02287635+0.00333655j	0.04117743+0.00600579j
29	**30**	0.01764747+0.00257391j	0.031765446+0.004633038j
30	**31**	0.0261444+0.0038132j	0.04705992+0.00686376j
31	**32**	0.05359602+0.00781706j	0.096472836+0.014070708j
32	**33**	0.03725577+0.00543381j	0.067060386+0.009780858j
33	**34**	0.0196083+0.0028599j	0.03529494+0.00514782j
34	**35**	0.04379187+0.00638711j	0.078825366+0.011496798j
35	**36**	0.02352996+0.00343188j	0.042353928+0.006177384j
30	**37**	0.02418357+0.00352721j	0.043530426+0.006348978j
37	**38**	0.02418357+0.00352721j	0.043530426+0.006348978j
38	**39**	0.02418357+0.00352721j	0.043530426+0.006348978j
30	**40**	0.0261444+0.0038132j	0.04705992+0.00686376j
40	**41**	0.02287635+0.00333655j	0.04117743+0.00600579j
41	**42**	0.02483718+0.00362254j	0.044706924+0.006520572j
42	**54**	0.05032797+0.00734041j	0.090590346+0.013212738j

42 43	0.02418357+0.00352721j	0.043530426+0.006348978j
43 55	0.01895469+0.00276457j	0.034118442+0.004976226j
55 56	0.04117743+0.00600579j	0.074119374+0.010810422j
55 57	0.01568664+0.00228792j	0.028235952+0.004118256j
43 44	0.0261444+0.0038132j	0.04705992+0.00686376j
44 45	0.0130722+0.0019066j	0.02352996+0.00343188j
45 58	0.02287635+0.00333655j	0.04117743+0.00600579j
45 46	0.01634025+0.00238325j	0.02941245+0.00428985j
46 47	0.04379187+0.00638711j	0.078825366+0.011496798j
47 48	0.1437942+0.0209726j	0.25882956+0.03775068j
48 59	0.06470739+0.00943767j	0.116473302+0.016987806j
59 60	0.03987021+0.00581513j	0.071766378+0.010467234j
60 61	0.03987021+0.00581513j	0.071766378+0.010467234j
48 49	0.02745162+0.00400386j	0.049412916+0.007206948j
49 50	0.05490324+0.00800772j	0.098825832+0.014413896j
50 62	0.0261444+0.0038132j	0.04705992+0.00686376j
50 51	0.00784332+0.00114396j	0.014117976+0.002059128j
51 63	0.0326805+0.0047665j	0.0588249+0.0085797j
63 64	0.03006606+0.00438518j	0.054118908+0.007893324j
51 52	0.0261444+0.0038132j	0.04705992+0.00686376j
52 53	0.0261444+0.0038132j	0.04705992+0.00686376j
0 65	0.01437942+0.00209726j	0.025882956+0.003775068j

0 66	0.02222274+0.00324122j	0.040000932+0.005834196j
66 67	0.01895469+0.00276457j	0.034118442+0.004976226j
67 68	0.02810523+0.00409919j	0.050589414+0.007378542j
0 69	0.0261444+0.0038132j	0.04705992+0.00686376j
69 70	0.02156913+0.00314589j	0.038824434+0.005662602j
70 71	0.01764747+0.00257391j	0.031765446+0.004633038j
71 72	0.03071967+0.00448051j	0.055295406+0.008064918j
72 73	0.19346856+0.02821768j	0.348243408+0.050791824j
73 74	0.01241859+0.00181127j	0.022353462+0.003260286j
74 75	0.01176498+0.00171594j	0.021176964+0.003088692j
74 76	0.03464133+0.00505249j	0.062354394+0.009094482j
73 77	0.04509909+0.00657777j	0.081178362+0.011839986j
77 78	0.01830108+0.00266924j	0.032941944+0.004804632j
78 79	0.02287635+0.00333655j	0.04117743+0.00600579j
79 80	0.11699619+0.01706407j	0.210593142+0.030715326j
77 81	0.01699386+0.00247858j	0.030588948+0.004461444j
81 82	0.02941245+0.00428985j	0.05294241+0.00772173j
81 83	0.01895469+0.00276457j	0.034118442+0.004976226j
83 84	0.01699386+0.00247858j	0.030588948+0.004461444j
84 85	0.02483718+0.00362254j	0.044706924+0.006520572j
85 86	0.04902075+0.00714975j	0.08823735+0.01286955j
85 87	0.07581876+0.01105828j	0.136473768+0.019904904j

87 88	0.05163519+0.00753107j	0.092943342+0.013555926j
87 89	0.03202689+0.00467117j	0.057648402+0.008408106j
89 90	0.31504002+0.04594906j	0.567072036+0.082708308j
90 91	0.0261444+0.0038132j	0.04705992+0.00686376j
91 92	0.0784332+0.0114396j	0.14117976+0.02059128j
92 93	0.0784332+0.0114396j	0.14117976+0.02059128j
69 94	0.02287635+0.00333655j	0.04117743+0.00600579j
94 95	0.02222274+0.00324122j	0.040000932+0.005834196j
94 96	0.02222274+0.00324122j	0.040000932+0.005834196j
96 97	0.05947851+0.00867503j	0.107061318+0.015615054j
97 98	0.06209295+0.00905635j	0.11176731+0.01630143j
98 99	0.02483718+0.00362254j	0.044706924+0.006520572j
99 100	0.20196549+0.02945697j	0.363537882+0.053022546j

4.4.2: Some Notice

- We have made these calculations on the assumption that the network will be converted into twisted wire in the near future.
- We have been attached the data sheets [3] that we used in the calculations at the Appendix.

Chapter 5 :PV Design

5.1: Introduction

Solar photovoltaic system or solar power system is one of renewable energy system which uses PV modules to convert sunlight into electricity. The electricity generated can be either stored or used directly. Solar PV system is very reliable and clean source of electricity that can suit a wide range of applications such as residence, industry, agriculture, livestock, etc. But in this project all loads are residential loads.

Work was in this chapter to design the solar system of the selected area. The total capacity of the system was 100 Kw. A capacity that was calculated by compiling the electricity bills of the desired transformer where the work was on a low voltage network. Based on the laws of installing the solar cell on grid systems, only 25% of the system's capacity is allowed to be covered, so we designed a 25 kW solar system using the PV System program. The first step was to obtain the coordinates of the selected area of the NASA site. And then introduced the capacity of the system and the type of solar panels and the program provided us with all other details. The last step was to calculate the cost of the system using scientific papers and the companies' sites for the manufacture of the used parts and with the help of the local companies which install solar cell systems.

5.2:Principles of PV cells operation

Photovoltaic cells are manufactured from semiconductor materials such as Si, GaAs .These materials are classified between conductors and insulators. According to Quantum theory, the electrons present in the conduction band contribute to the electrical conduction process. The conductors have a large number of electrons in their conduction band either the insulators do not have any electrons in it, on the other hand Semiconductors contain electrical conductors between conductors and insulators. When the temperature is absolute zero, there are no electrons in the connection band. Either at room temperature, some electrons will jump to the conductivity due to the absorption of some heat as shown in the figure below .The electrons can move from the valence band to the conduction band if they receive enough energy from the photons that are larger than the Band Gap energy, resulting of the absence of electrons in the valence band, which creates the holes. In the end, this electron creates holes in semiconductors, free electrons, and drills that travel within the material without producing any useful electrical effect. In order to produce electricity, a potential barrier must be placed inside the material. In order to create this barrier two semiconductors with different characteristics must be formed called P-N junction [19].

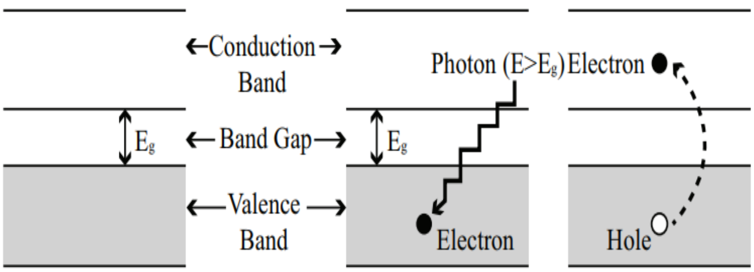

Figure 5-1 the Principles of PV cells operation.

5.3:Main Components of PV Station

5.3.1 :Combiner Box

The combiner box's role is to bring the output of several solar strings together. Each string conductor lands on a fuse terminal and the output of the fused inputs are combined onto a single conductor that connects the box to the inverter. However, there are additional features typically integrated into the box. Disconnect switches, monitoring equipment and remote rapid shutdown devices are examples of additional equipment.

Solar combiner boxes also consolidate incoming power into one main feed that distributes to a solar inverter. This saves labor and material costs through wire reductions. Solar combiner boxes are engineered to provide overcurrent and overvoltage protection to enhance inverter protection and reliability.

Combiner boxes can have advantages in projects of all sizes. In residential applications, combiner box can bring a small number of strings to a central location for easy installation, disconnect and maintenance. In commercial applications, differently sized combiner boxes are often used to capture power from unorthodox layouts of varying building types.

Little maintenance is required for combiner boxes. The environment and frequency of use should determine the levels of maintenance, and it is a good idea to inspect them periodically for leaks or loose connections, but if a combiner box is installed properly it should continue to function for the lifetime of the solar project [20].

5.3.2:Molded Case Circuit Breakers

What are Molded Case Circuit Breakers?

Simply put, these are electrical protection gadgets that can be used with a wide range of voltages. MCCBs, as they are commonly known, have adjustable trip settings and can hold as much as 2,500 amps in current ratings. They are also used with frequencies that are 50 and 60 Hz and have the following 3 jobs [21]:

i. They offer protection in case of electrical faults by immediately interrupting a current that is extremely high due to a line fault or a short circuit.
ii. They protect in the event of an overload where the current is higher than the rated value and lasts a longer time than normal.
iii. The on and off function can be used to switch the circuit on or off for repairs and replacements.
iv. So High current applications need to have molded case circuit breakers. Getting the right size and ensuring that proper maintenance is carried out means that you will have a reliable MCCB that is safe.

5.3.3:Main Distribution Boards (MDB)

Power Distribution is a system, consisting of a Main Distribution Board (MDB), Sub Main Distribution Boards (SMDBs) and Final Distribution Boards, by which the electrical energy .is transmitted via branches to reach the exact end user

An MDB is a panel or enclosure that houses the fuses, circuit breakers and ground leakage protection units where the electrical energy, which is used to distribute electrical power to numerous individual circuits or consumer points, is taken in from the transformer or an upstream panel. An MDB typically has a single or multiple incoming power sources and includes main circuit breakers and residual current or earth leakage protection devices. A MDB is comprised of a free standing enclosure, a bus bar system, MCCB's, metering and support equipment and required current transformers. Panels are assembled in a systematic manner [22].

5.3.4Ring main unit

In an electrical power distribution system, a ring main unit (RMU) is a factory assembled, metal enclosed set of switchgear used at the load connection points of a ring-type distribution network. It includes in one unit two switches that can connect the load to either or both main conductors, and a fusible switch or circuit breaker and switch that feed a distribution transformer. The metal enclosed unit connects to the transformer either through a bus throat of standardized dimensions, or else through cables and is usually installed outdoors. Ring main cables enter and leave the cabinet. This type of switchgear is used for medium-voltage power distribution, from 7200 volts to about 36000 volts.

The ring main unit was introduced in the United Kingdom and is now widely used in other countries. In North American distribution practice, often the equivalent of a ring main unit is built into a pad-mounted transformer which integrates switches and transformer into a single cabinet [23].

5.3.5:Load break switch (LBC)

Load break switch is a disconnect switch that has been designed to provide making or breaking of specified currents.

This is accomplished by addition of equipment that increases the operating speed of the disconnect switch blade and the addition of some type of equipment to alter the arcing phenomena and allow the safe interruption of the arc resulting when switching load currents.

Disconnect switches can be supplied with equipment to provide a limited load switching capability. Arcing horns, whips, and spring actuators are typical at lower voltages.

These switches are used to de-energize or energize a circuit that possesses some limited amount of magnetic or capacitive current, such as transformer exciting current or line charging currents [24].

5.3.6: Relay REF615

The REF615 is a dedicated feeder IED perfectly aligned for the protection, control, measurement and supervision of utility substations and industrial power systems. REF615 is a member of ABB's family and a part of its 615 protection and control product series. The 615 series IEDs are characterized by their compactness and withdrawable design. Engineered from the ground up, the 615 series has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability of substation automation devices [25].

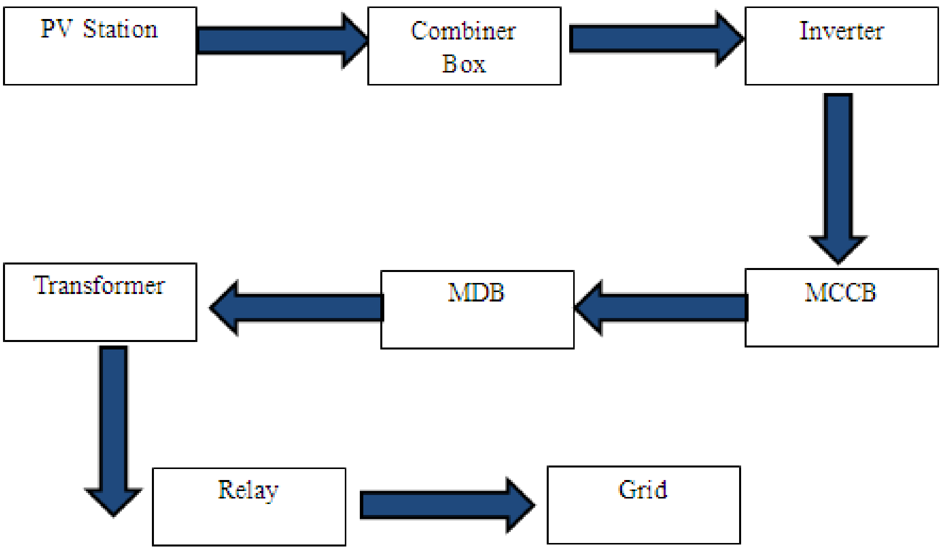

Figure 5-1 Block diagram for the PV power plant.

5.4 : PV system design

A solar PV system design can be done in these steps:

1. Estimation of number of PV panels.
2. Estimation of number of inverters.
3. Cost estimation of the system.

These Estimations were made using PV sys program:

- The first step in the design process of the solar system is to determine the latitude and longitude of the comet area by using NASA site and Google earth as shown in the picture below [26].

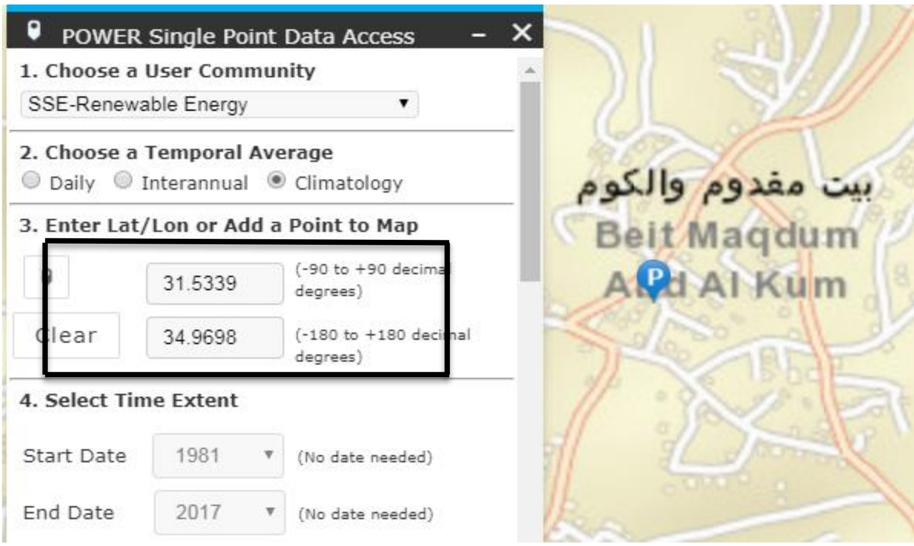

Figure 5-2 latitude and longitude for AL-KUM.

- The second step is to insert the latitude and longitude into the PV SYS program to perform the design of the system

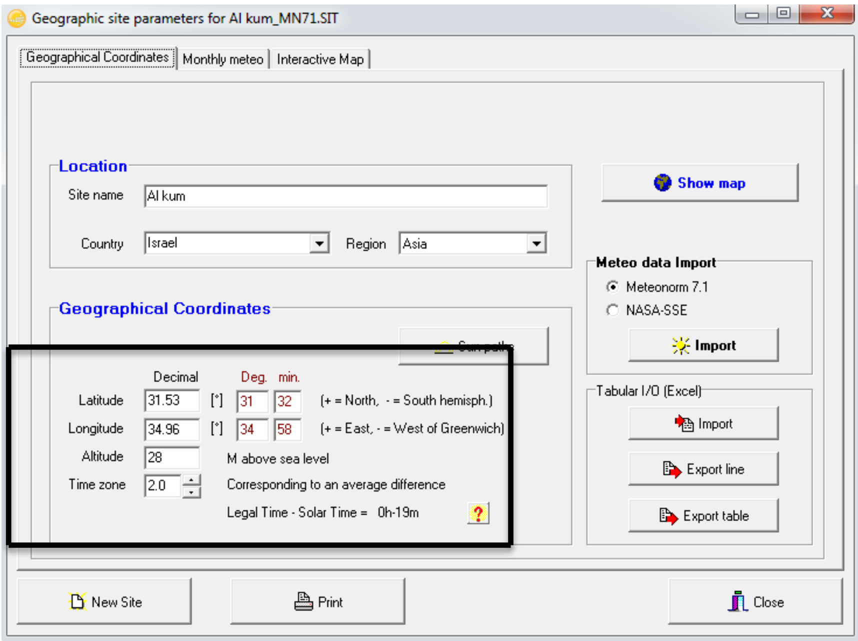

Figure 5-3 latitude and longitude for AL-KUM in the program.

- The third step was to enter the planned power of 25 Kw and then choose the type of panels and the type of inverter and the power of each.

The panels were chosen from the design of the LG electronics company (LGElectronics_LG400_N2W_A5.PAN) the panel that used in the project was selected, The (datasheet) with efficiency profile vs input power curve are attach as Appendix [27].

Figure 5-4 LG400_N2W_A5.PAN.

The inverters were chosen from the design of ABB company ABB_TRiO-27-6-TL-OUTD-400(27.6KWac max), the inverter that used in the project was selected, the (datasheet) with efficiency profile vs input power curve are attach as Appendix [28].

Figure 5-5 ABB_TRiO-27-6-TL-OUTD-400(27.6KWac max)

As shown in the picture, the program give the number of panels needed , number of inverters , number of string and the number of module in series in each string .

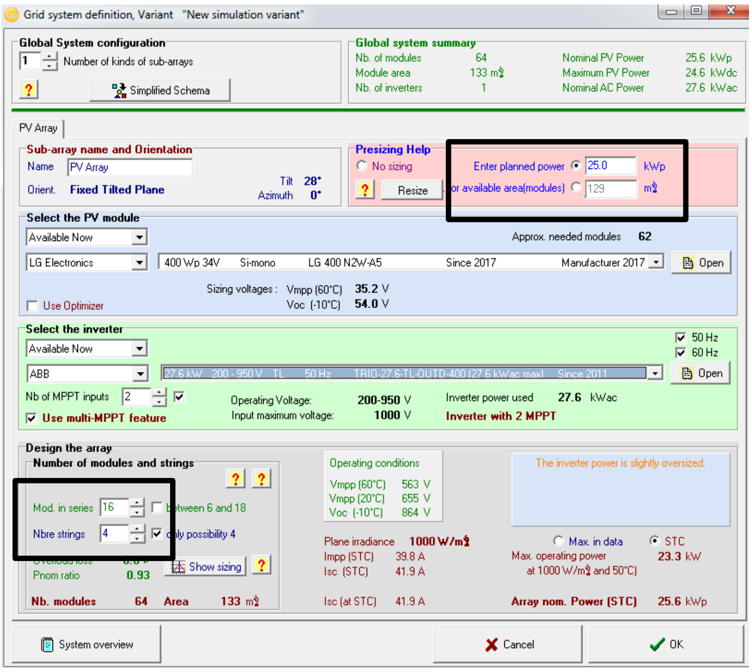

Figure 5-6 information and parameters of PV system.

- The fourth step is to determination the plant Tilt and the Azimuth angle, In Palestine the Tilt angel equal 28°, and for the Azimuth angle we assume it equal 0° on the assumption that there is no shading.

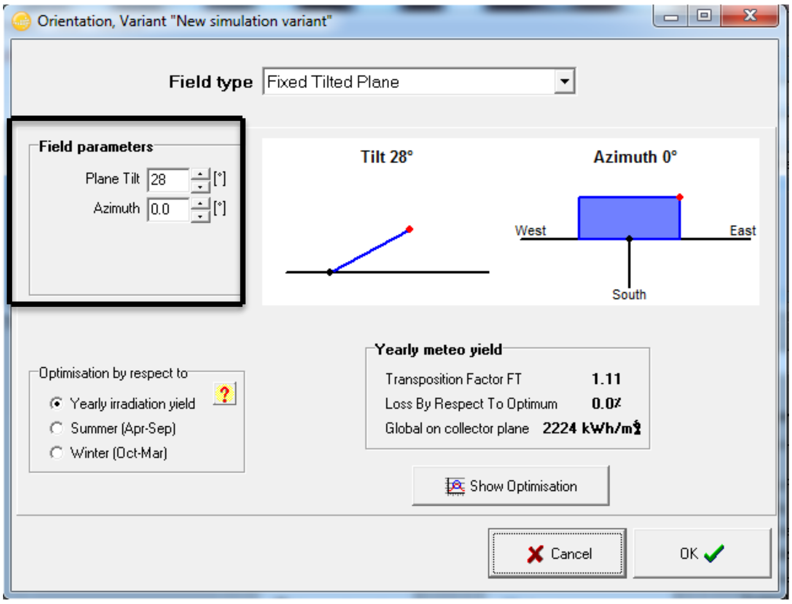

Figure 5-7 Specify latitude and longitude.

- The last step is to simulate the system and print the report (The resulting report has been attached to theAPPENDIX) .

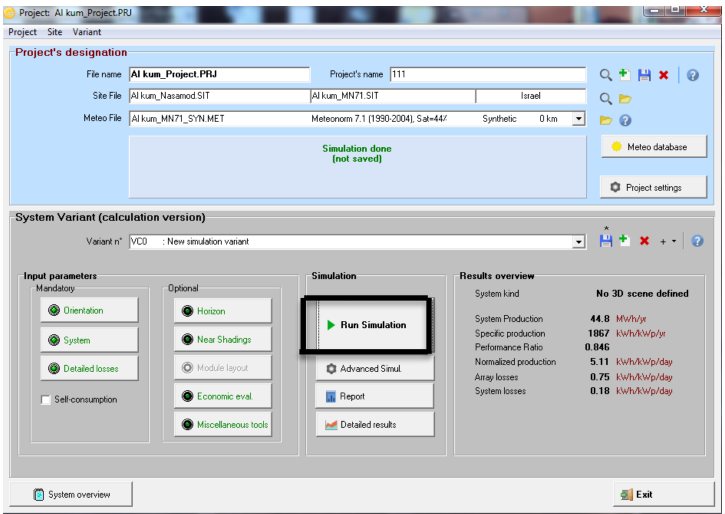

Figure 5-8 simulation.

5.6: Irradiation and solar path curves

Sun path, sometimes also called day arc, refers to the daily and seasonal arc-like path that the Sun appears to follow across the sky as the Earth rotates and orbits the Sun. The Sun's path affects the length of daytime experienced and amount of daylight received along a certain latitude during a given season.

The relative position of the Sun is a major factor in the heat gain of buildings and in the performance of solar energy systems. Accurate location-specific knowledge of sun path and climatic conditions is essential for economic decisions about solar collector area, orientation, landscaping, summer shading, and the cost-effective use of solar trackers. [29]

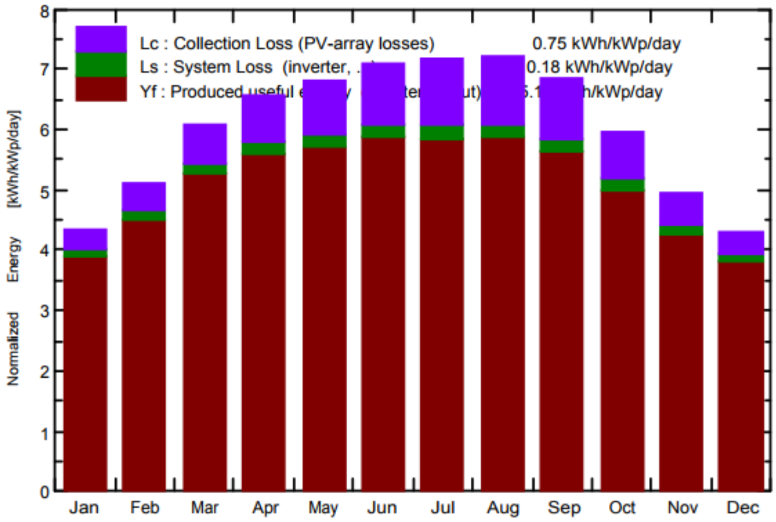

Figure 5-9 Irradiation diagram .

Solar irradiance varies significantly from one place to another and changes throughout the year. In order to come up with some reasonable estimates, you need irradiance figures for each month of the year for your specific location.Thanks to NASA, calculating your own solar irradiance is simple. NASA’s network of weather satellites has been monitoring the solar irradiance across the surface of the earth for many decades. Their figures have taken into account the upper atmospheric conditions, average cloud cover and surface temperature, and are based on sample readings every three hours for the past quarter of a decade. They cover the entire globe.[30]

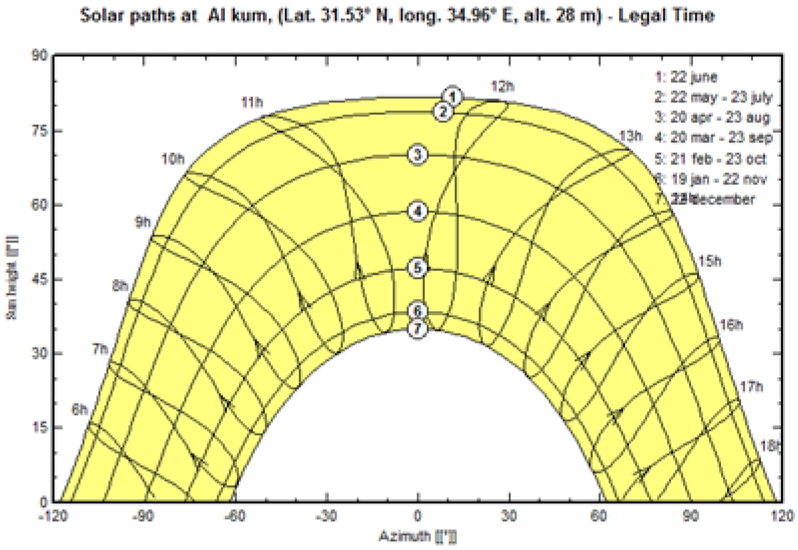

Figure 5-10 Solar path.

5.6: Results and Simulation

After building the design of the project, we have to looking to the results of the PVsyst.

- Geographical site = al-kum.
- Situation = latitude 31.35 N, longitude 34.96 E.
- Number of modules = 64 modules power 400 Wp.
- Modules area = 133m^2.
- Number of inverters = 1 inverters.
- PV module in series = 16 module .
- Number of strings = 4 .
- Collector plane orientation = Tilt 28 °, Azimuth 0°.

PV array characteristic:

PV module Si- mono, Model LG 400 N2W-A5.

Inverter characteristic:

ABB_TRiO-27-6-TL-OUTD-400 (27.6KWac max), Manufacturer ABB company.

NOTE: All other parameters that produced from the program has been attached to the APPENDX .

5.7: Cost estimation of the system

The aim of the financial analysis is to determine and compare the profitability of the construction of the PV plant in AL-KUM village.

Table 5-1: Cost for the project.

Description	Quantity	Unit price ($)	Total price ($)
Electrical plates water prof ABB4	5	22	110
Electrical plates water prof ABB12	5	31	155
ABB Inverter 27.6 kW	1	3900	3900
Solar panel 400 W	64	270	17280
Cable DC 6 mm2	80	9	720
Single Phase Cable AC 6 mm2	110	9	990
earthing cable 10mm2	80	9	720
earthing cable 16mm2	110	9	720
AC- surge Arrestor single phase	1	100	100
DC-*surge Arrestor 1000V	2	135	270
MC4	40	11	440
Iron 40*40	—	—	2500
C.B - DC	5	30	150
single Phase Meter Counter	1	110	110
Screws and Boxes and connecter	—	—	600
Engineers and employees fees	—	—	2800
Transportation fee	—	—	200
Others	—	—	300

Total cost = 32065 $

5.8: PV system Diagram

After we reached the results from the program, final system diagram was drawn as shown in the figure below.

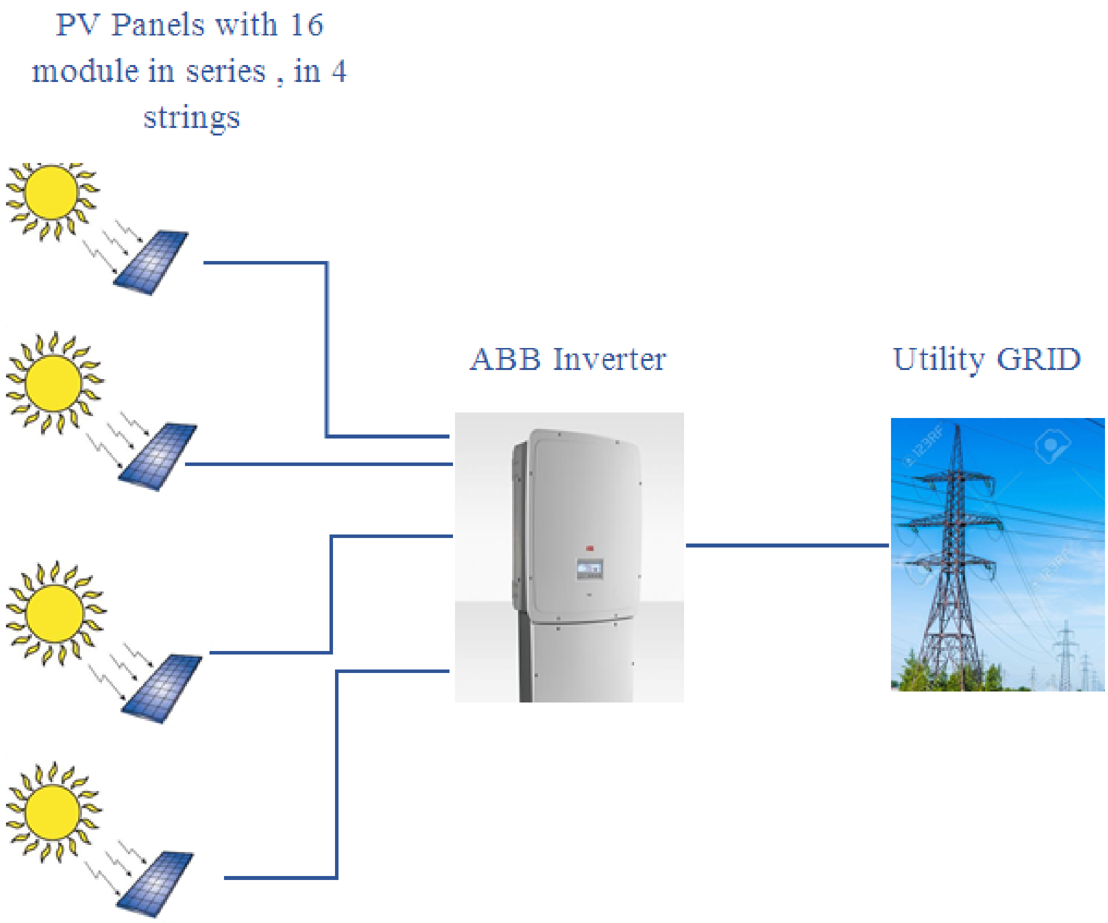

Figure 5-11 PV system Diagram.

Chapter 6:Simulation and results

6.1:Introduction

The design of the photovoltaic system and the distribution network in AL-KUM village south of Hebron have been applied on ETAP software version 12.6. ETAP offers specialized engineering services in power systems including analytical services, research and development, conceptual design and preliminary engineering, planning, optimization, dynamic modeling, field-measured parameter tuning, and data exchange services. Why using ETAP program in simulation?

- Simple to modeling.
- Simplicity in data entry.
- Don't need per unit data.
- Graphic user interface.
- Total integration of data.

The design shown in the following Steps to use the ETAP program and make the settings for the station and the network as Appendix and the result that we reach from simulation.

6.2: Simulation steps

The network model was executed in steps and will be explained in detail in this section.

- The first step was to apply the network as it is in figure 4.2 on the E-TAP with the same network bath and numbers of loads and numbers of cables.
- The second step was to inter the input data for each element in network.
    i. First represented by filling the network data as shown in the figure below, AL-KUM network and obtained its data from the village council.

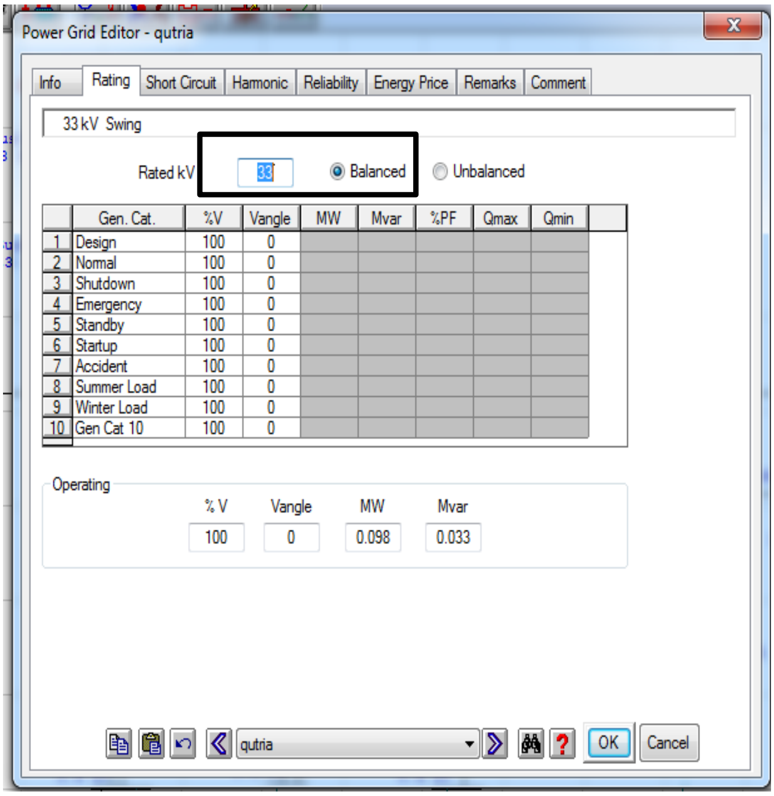

Figure 6-1 Rating Data for grid.

ii. After that , data was entered for transformer that used in the network.

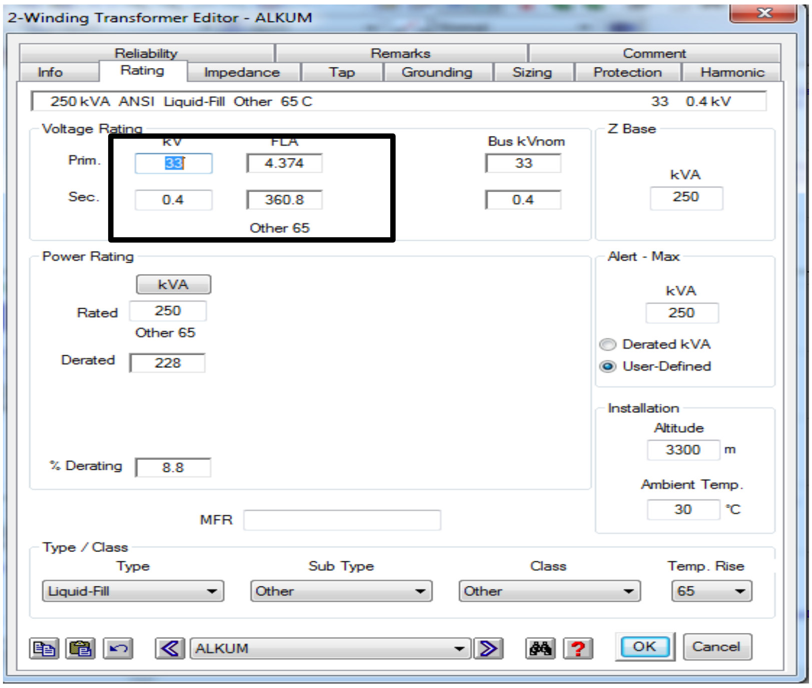

Figure 6-2 Rating Data for transformer.

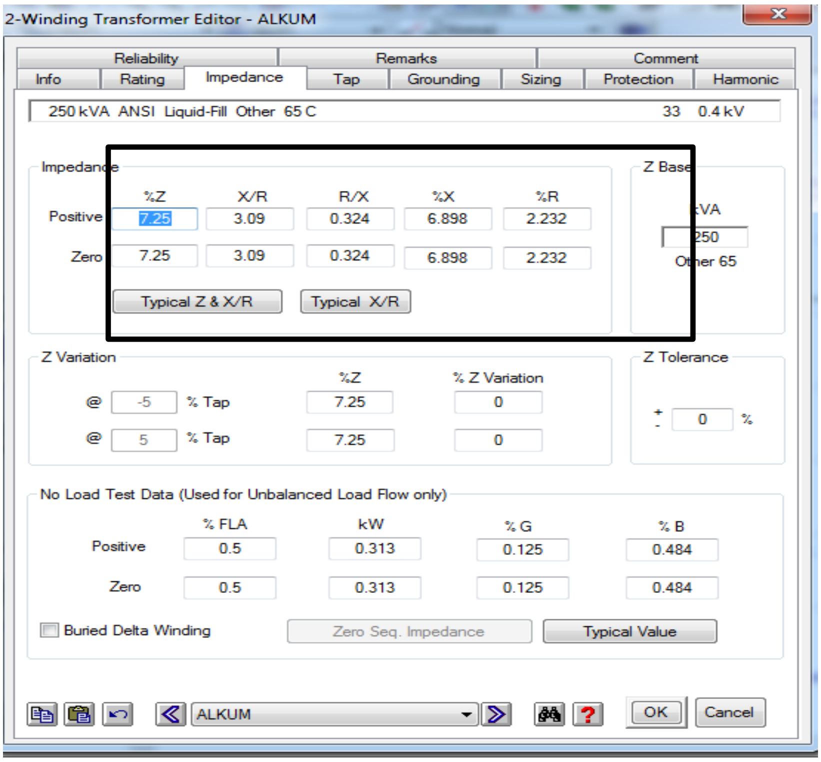

Figure 6-3 Impedance for transformation.

iii. As for the loads ,we chose the lumped load ,single phase , then we enter their numbers and there consumption of power in Kw as it calculated in table 0-1 , We have assumed that the PF is 0.95 and it is static for all loads in the network.

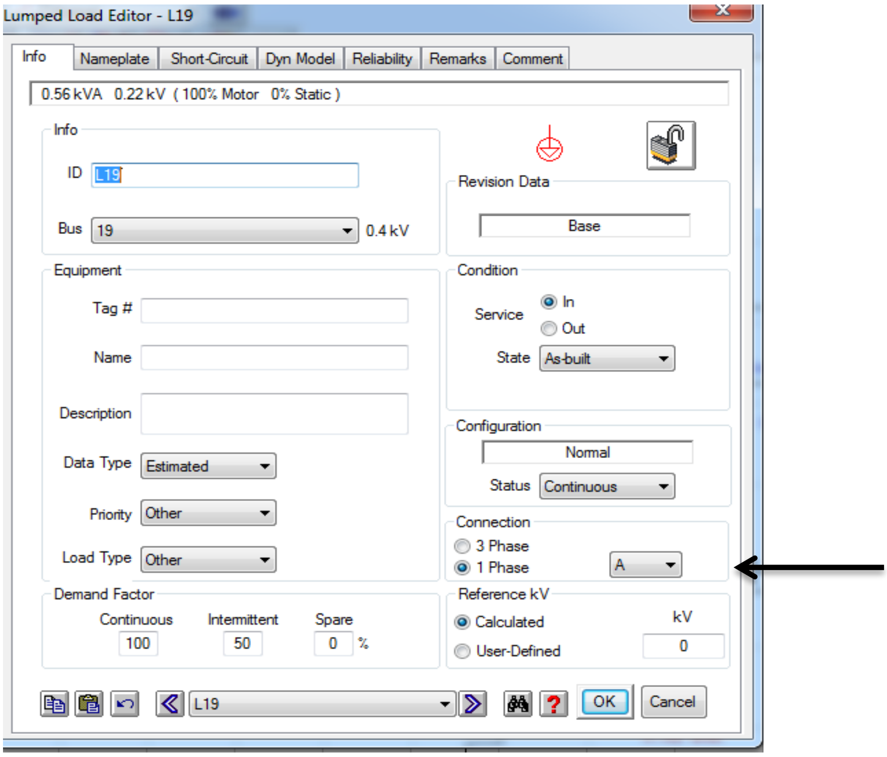

Figure 6-4 Information for loads chosen

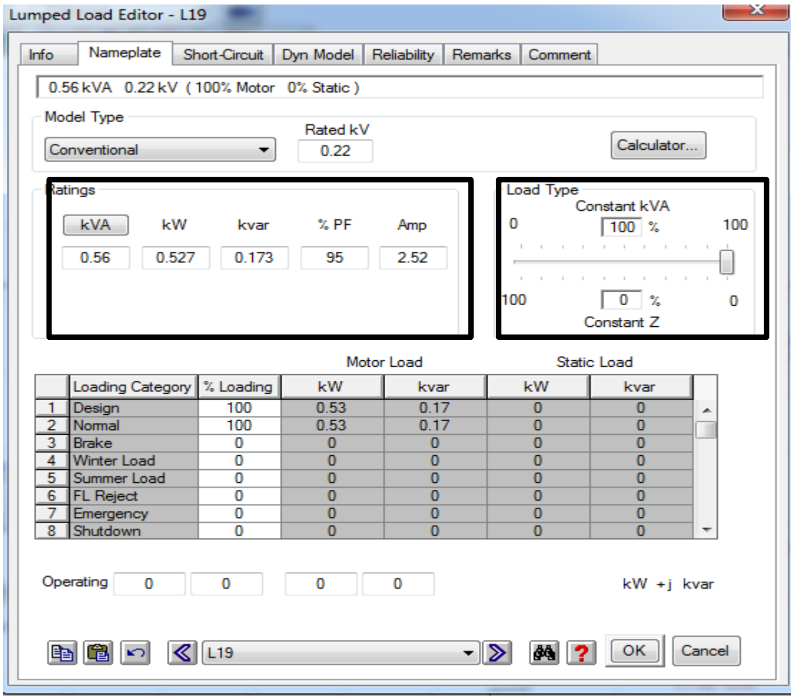

Figure 6-5 Nameplate for loads chosen.

iv. As for cables, their data were entered in terms of their name, length, tolerance, temperature and positive and negative sequence impedance as calculated in table 0-3 .

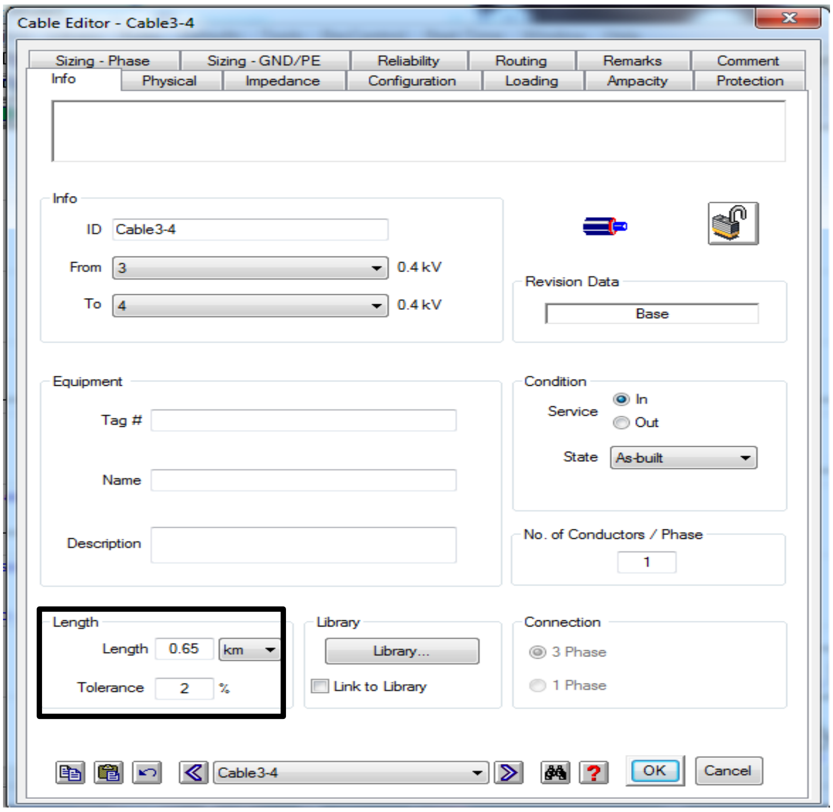

Figure 6-6 Information for cables .

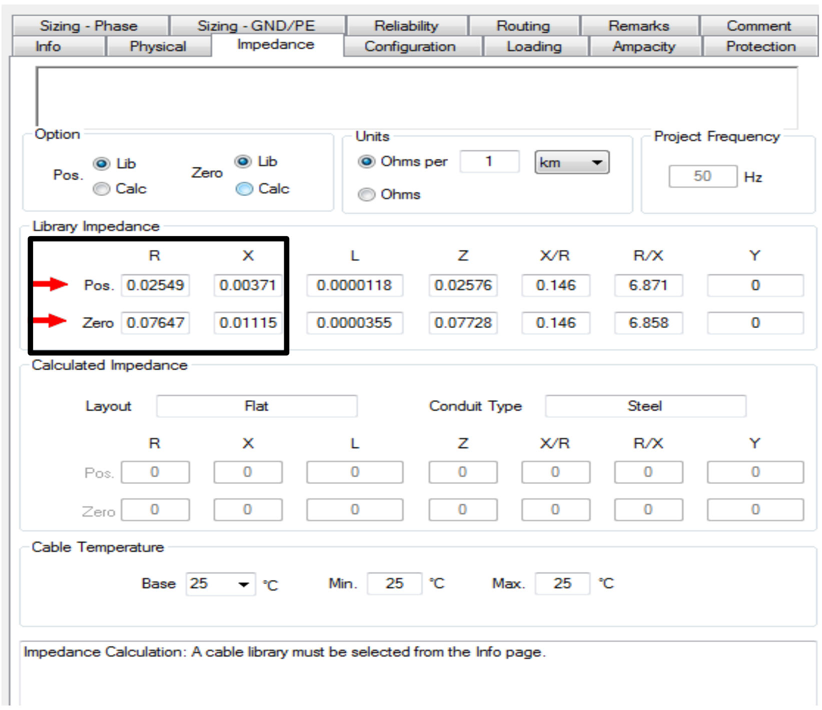

Figure 6-7 Impedance for cables.

- After completing the steps of the network model and make sure that the data enter is correct, The PV input data was inter for both solar panels and inverter as it is in the data sheet that we used as shown in figure below.

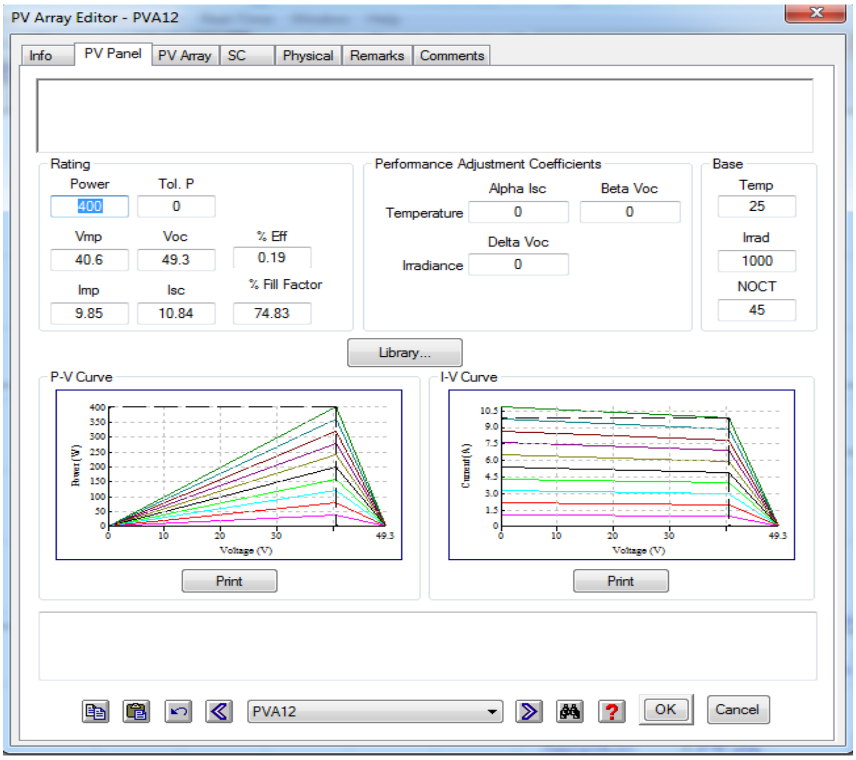

Figure 6-8 Data for PV panels.

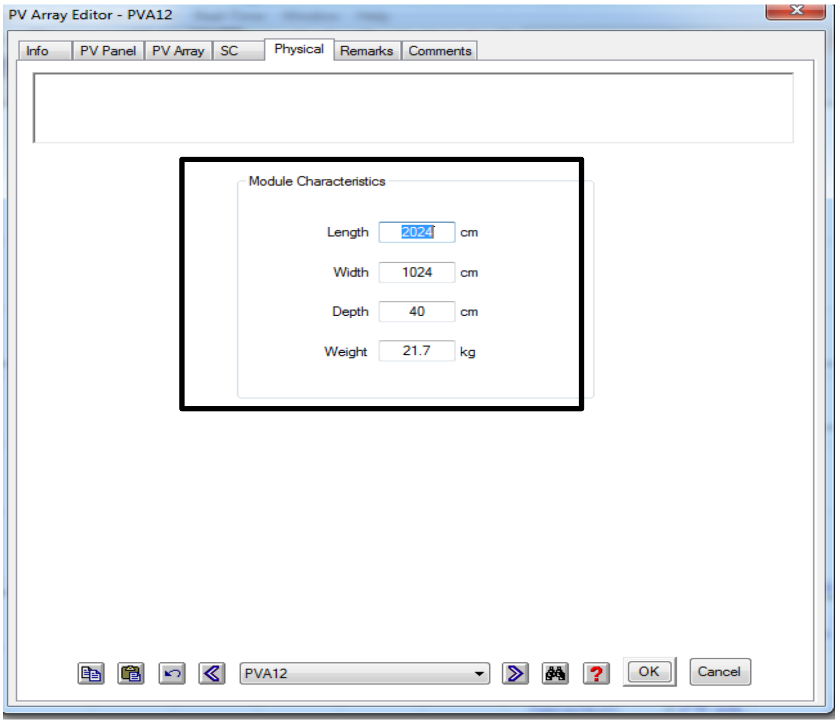

Figure 6-9 Module characteristic.

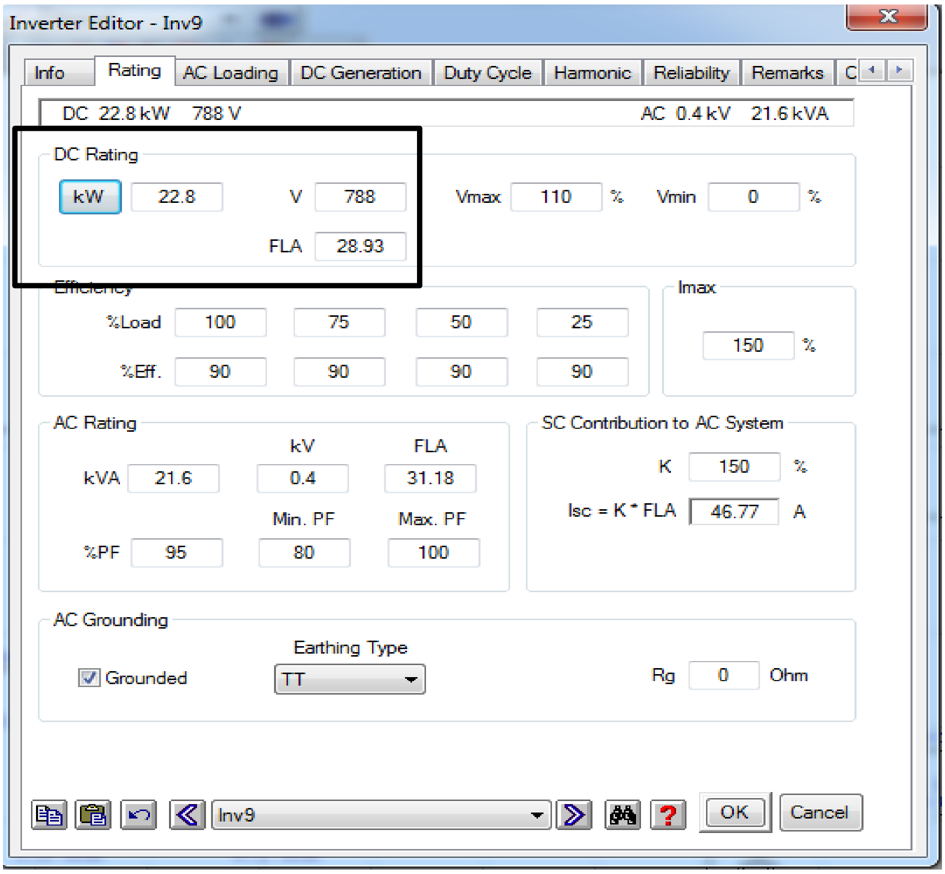

Figure 6-10 rating for inverter.

- In the last step the network was run and the results obtained were attached to the APPENDEX.

6.3: Results

6.3.1:Short circuit

A short circuit is an electrical circuit that allow a current to travel along an unintended path with no or very low electrical impedance This result is an excessive amount of current flowing in the circuit .And a short circuit is the voluntary or accidental connection of two (or more) points of an electrical circuit between which there exists a potential difference by a low resistance conductor. The following short circuit can be distinguished on a network:

- Single phase (80% of cases), where one phase and earth or neutral are connected together .
- Bi-phase (15% of cases), where the two phases are connected together.
- Three-phase (5%of cases), where the three phase are connected together.
- Bi-phase-ground, where two phase and the ground are connected together.

Short circuit current contribution of photovoltaic power plant

The grid integration of renewable energies has greatly affected of the short circuit capacity (SCC) of power systems all over the world .symmetrical or unsymmetrical behavior of short circuit is different between renewable energy sources, e.g. solar energy, and conventional generators .the response of renewable energy generation to short circuit is controlled by the power electronics used in converter system.

In order to see the impact of PV systems on short circuit level and protection system, fault analysis were performed on the modified reactance diagram, first without considering PV and then with PV module .

Fault analysis without PV

Fault analysis were performed by applying single line-to ground fault on bus 89 of the system, The bus on which the PV will be connected.

Table 6-1 single line to ground fault at bus 89 without PV.

From bus	If mag(KA)	If angle
89	2.733	-2.115

The E_TAP simulation showed that the fault current without PV module is equal to 2.733∟-2.115 and also show the result of short circuit current magnitude and angle around the bus that the fault current applied on it, but in this project we are interested in the fault current on PV bus.

Fault analysis with PV

To analyze the result the PV was connected on bus 89 and applying single line-to ground fault on it.

Table 6-2 single line to ground fault at bus 89 after adding PV.

From bus	If(KA) mag	If angle
89	2.780	-2.115

The simulation result showed that the fault current with PV module on 89 bus is equal to 2.780∟-2.115.

The Amount of increase in fault current = 2.780∟-2.115 - 2.733∟-2.115 / 2.733∟-2.115) *100% = 1.72%

The above results show that PV Causes an increase in the magnitude of fault current by 1.7% for fault at base 89 and we can conclude that the PV have very little effect on the fault current .

6.3.2 : Load flow study

Load flow (power flow) analysis is a basic analysis for the study of power systems. It is used for normal, steady-state operation. It gives you the information what is happening in a system. [32]

Load flow objective

- The objective of load flow calculations is to determine the steady-state operating characteristics of the power system for a given load and generator real power and voltage conditions. Once we have this information, we can calculate easily real and reactive power flow in all branches together with power losses.[32]

Load flow effects

- **Voltage profile**

Load flow analysis is a great tool that produces essential computation practice in order to establish the characteristics of power system. load flow analysis for the PV substation which consists of 100 buses , as shown in the single line diagram Figure 4.2. Modelling and simulation are carried out by using ETAP simulation software for two cases :

- First case without PV connection.

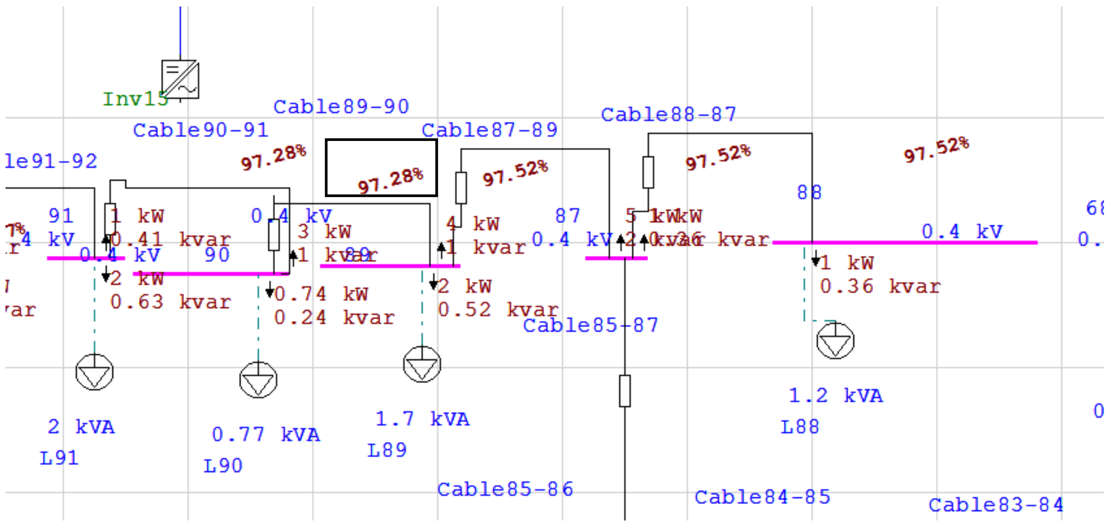

Figure 6-12 section of the network without PV connection.

- The second case with PV connection.

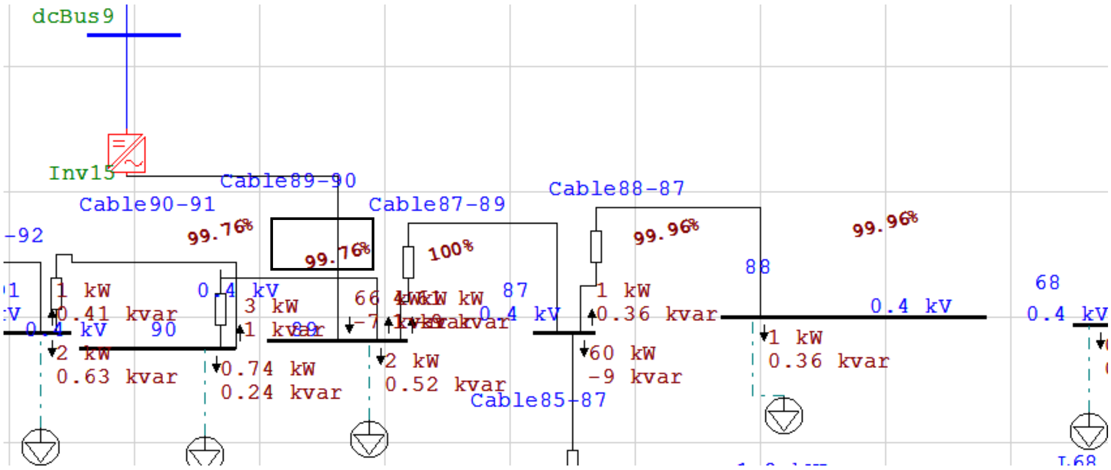

Figure 6-13 section of the network with PV connection.

The PV substation with the 25KW is connected to bus 89. The figure 6.4 and 6.5 shows the load flow results for bus 89. It is important to mention that in figure 6.4 the PV plant is disconnected and the voltage on bus 89 is 97.28 %. While Figure 6.5 shows the system load flow after the connection of PV plant and the voltage increased to become 99.76% while a total of 25 kW is flowing from the PV plant to the system.

The importance of the load flow analysis is to make sure that the distribution network is safe enough to be connected with PV generators. The results obtained from the load flow study of PV substation show that the use of PV generators at AL-KUM network is safe, feasible, and advantageous [33]. It shows that integrating a PV system into AL -KUM network improves the system voltage profile it can improve the voltage stability at each bus of the system, and increase the voltage profile.

It was noticed from the results that the load flow will only affects the bus how is connected the PV on it, and other buses around it, In this project the load flow affects only busses 89,88,87,86,85,84,83,82,81,80,79,78,77,73,72,71,70,69,100 .

The results for load flow study were attached to the Appendix.

- **Real power**

Connection the PV station to a distribution network Contributes to generating the real power with the grids. So integrating the PV station will reduce the active power from the utilities. A higher rate of reactive power supply is not preferred by the utility because, in case of high rate of reactive power to the grid, distribution transformers will operate at a very low power factor, so transformers efficiency decreases as their operating power factor decreases, as a result, the overall losses in distribution transformers will increase reducing the overall system efficiency.

The following tables shows the generation values in KW and KVAR in case of without connection the PV station with the distribution network.

Table 6-3 Real power before adding PV.

Feeding Point	KW generation
Al-akum	102

The simulation result showed that after integrating the PV station to the distribution grid active power consumption in the network decreased by approximately 0.25 from the power that generation before adding PV cells.

- **Under and over voltage**

Table 6-5 below show result before adding PV substation to the network, many of the buses have an under voltage on it, but after adding the PV to the distribution network all busses that have under voltage on it is removed, that means the PV substation has a positive effect on the under voltage cases, It remove all the under voltage cases in the network and according this paper this result is true [34].

The report for this result is attached to appendix.

Table 6-4 under and over voltage before adding PV.

Bus ID	**condition**	**% Operating**
82	Over voltage	102.4
83	Under voltage	97.6
84	Under voltage	97.6
85	Under voltage	97.5
86	Under voltage	97.5
87	Under voltage	97.5
88	Under voltage	97.5
89	Under voltage	97.5
9	Under voltage	97.9
90	Under voltage	97.3
91	Under voltage	97.3
92	Under voltage	97.3
93	Under voltage	97.3

Table 6-5 under and over voltage after adding PV.

Bus ID	**condition**	**% Operating**
82	Over voltage	102.4

Conclusion

The main purpose of this project was to build a solar photovoltaic system to supply electricity to the grid and study the short circuit, load flow effects.

The solar photovoltaic system that was built have 16 panel in 4 strings and the output power was 0.25 Kw, As for the results it was conclude that the short circuit was affected by 1.7% after adding PV and the total load flow from the system was decreased after adding the solar photovoltaic system and all under voltage problems have been solved as for the cost of the project equal to 32065 **$.**

Future study

Harmonics study for this project will be the future study.

References

[1]A. Khelifa, K. Touafek and H. Moussa, "Approach for the modelling of hybrid photovoltaic–thermal solar collector", *IET Renewable Power Generation*, vol. 9, no. 3, pp. 207-217, 2015.

[2]*Publications.lib.chalmers.se*, 2018. [Online]. Available: http://publications.lib.chalmers.se/records/fulltext/218826/218826.pdf. [Accessed: 02- Dec- 2018].

[3]J. Nascimento, F. de Araujo, J. Neto, J. Nascimento, A. Rocha, R. de Lima Neta and A. da Silva, "Studying of the energy quality of a distribution network of Marechal Deodoro-AL with the integration of solar photovoltaic generation", *2018 Simposio Brasileiro de Sistemas Eletricos (SBSE)*, 2018.

[4]A. Gado, "Impact the expansion of the production of generation of solar power on the low voltage network in Egypt", *2015 Saudi Arabia Smart Grid (SASG)*, 2015.

[5]R. Ajdid, M. Ouassaid and M. Maaroufi, "Power output evaluation of polycrystalline PV panel under various irradiances and temperatures in Moroccan regions", *2015 International Conference on Electrical and Information Technologies (ICEIT)*, 2015.

[6]"Short circuit", *En.wikipedia.org*, 2018. [Online]. Available: https://en.wikipedia.org/wiki/Short_circuit. [Accessed: 02- Dec- 2018].

[7]"Feasibility study of solar photovoltaic integration on distribution networks: Case study: Djanet's isolated distribution network, Algeria - IEEE Conference Publication", *Ieeexplore.ieee.org*, 2018. [Online]. Available: https://ieeexplore.ieee.org/document/8266347. [Accessed: 02- Dec- 2018].

[8]T. Neumann and I. Erlich, "Short Circuit Current Contribution of a Photovoltaic Power Plant", *IFAC Proceedings Volumes*, vol. 45, no. 21, pp. 343-348, 2012.

[9]"What is Load Flow Analysis / Power Flow Analysis and Why is it Done | Carelabz.com", *Carelabs*, 2018. [Online]. Available: http://carelabz.com/what-why-load-flow-analysis-power-flow-analysis-done/. [Accessed: 02- Dec- 2018].

[10]2018. [Online]. Available: https://www.ijser.org/researchpaper/LOAD-FLOW-ANALYSIS-OF-POWER-SYSTEMS.pdf. [Accessed: 02- Dec- 2018].

[11]"What is Harmonic Study and Analysis and Why is it Done | Carelabz.com", *Carelabs*, 2018. [Online]. Available: http://carelabz.com/what-how-harmonic-study-analysis-done/. [Accessed: 02- Dec- 2018].

[12]M. Ayub, C. Gan and A. Kadir, "The impact of grid-connected PV systems on Harmonic Distortion", *2014 IEEE Innovative Smart Grid Technologies - Asia (ISGT ASIA)*, 2014.

[13]G. Shafiullah and A. Oo, "Analysis of harmonics with renewable energy integration into the distribution network", *2015 IEEE Innovative Smart Grid Technologies - Asia (ISGT ASIA)*, 2015.

[14]N. Kumar, M. Subathra and J. Moses, "On-Grid Solar Photovoltaic System: Components, Design Considerations, and Case Study", *2018 4th International Conference on Electrical Energy Systems (ICEES)*, 2018.

[15]J. (YA), "How to Calculate the Surface Area Required by Solar Panels | RAYmaps", *Raymaps.com*, 2018. [Online]. Available: http://www.raymaps.com/index.php/how-to-calculate-the-area-required-by-solar-panels/. [Accessed: 03- Dec- 2018].

[16]"How to calculate output energy of PV solar systems?", *Photovoltaic-software.com*, 2018. [Online]. Available: https://photovoltaic-software.com/principle-ressources/how-calculate-solar-energy-power-pv-systems. [Accessed: 03- Dec- 2018].

[17]"Hebron", *Hebron*, 2018. [Online]. Available: https://www.google.com/maps/place/Hebron/@31.5346185, 34.9624741,1799m/data=!3m1!1e3!4m5!3m4!1s0x1502e427ecc463fb:0xbe464d5c6a2f134c!8m2!3d31.5323114!4d35.0999451. [Accessed: 03- Dec- 2018].

[18]I. NEPSI - Northeast Power Systems, "Calculation of Cable Data", *Nepsi.com*, 2018. [Online]. Available: http://nepsi.com/resources/calculators/calculation-of-cable-data.htm?fbclid=IwAR0oDzyWqaneJtbRhBTjFhDW2ixVDmv_0WiH9nCSi-WMEQWgKYIEvBAdi. [Accessed: 03- Dec- 2018].

[19] Vilathgamuwa, M., Nayanasiri, D. and Gamini, S. (n.d.). *Power electronics for photovoltaic power systems*.

[20] SE Solar. (2019). *Solar DC Combiner Box | Schneider Electric Solar*. [online] Available at: https://solar.schneider-electric.com/product/dc-box/ [Accessed 8 May 2019].

[21] Schneider-electric.com. (2019). *Molded Case Circuit Breakers | Schneider Electric*. [online] Available at: https://www.schneider-electric.com/en/product-subcategory/4230-molded-case-circuit-breakers/ [Accessed 8 May 2019].

[22] Schneider-electric.com. (2019). *Distribution Panels | Schneider Electric*. [online] Available at: https://www.schneider-electric.com/en/product-subcategory/88794-distribution-panels/ [Accessed 8 May 2019].

[23Schneider-electric.com. (2019). *Ring main unit for smart grids*. [online] Available at: https://www.schneider-electric.com/en/work/products/product-launch/smart-ring-main-unit/ [Accessed 8 May 2019].

[24] Schneider-electric.com. (2019). *Load Break Switch - RL-series | Schneider Electric*. [online] Available at: https://www.schneider-electric.com/en/product-range/1408-rl-series/8094488068-load-break-switch/ [Accessed 8 May 2019].

[25] Anon, (2019). [ebook] Available at: https://library.e.abb.com/public/8b0b2307af790658c1257895003f917f/REF615ANSI_pg_1MAC105361-PG_ENe.pdf [Accessed 8 May 2019].

[26] Power.larc.nasa.gov. (2019). *ArcGIS Web Application*. [online] Available at: https://power.larc.nasa.gov/data-access-viewer/ [Accessed 8 May 2019].

[27]LG400N2W-A5, L. and Specs, T. (2019). *LG400N2W-A5 | LG NeON®2 72cell Module | Forward Energy | GridReady | Products | Solar | LG USA*. [online] Lg.com. Available at: https://www.lg.com/us/business/solar-panel/all-products/lg-LG400N2W-A5 [Accessed 8 May 2019].

[28] Sungridelectric.com. (2019). *ABB On grid Inverters – Welcome To SunGrid*. [online] Available at: http://sungridelectric.com/solar/buy-abb-ongrid-solar-inverters-india/?i=1 [Accessed 8 May 2019].

[29] Wikiwand. (2019). *Sun path | Wikiwand*. [online] Available at: http://www.wikiwand.com/en/Sun_path [Accessed 8 May 2019].

[30] Boxwell, M. (n.d.). *Solar electricity handbook*.

[31] Impact of Grid Connected PV System on Distribution Networks:A Review. (2017). *International Journal of Recent Trends in Engineering and Research*, 3(7), pp.438-443.

[32] Kierad, A. (2019). *Load flow (power flow) - step-by-step, theory and calculation*. [online] Electrisim.com. Available at: https://electrisim.com/load-flow-power-flow.html [Accessed 8 May 2019].

[33] Docs.neu.edu.tr. (2019). [online] Available at: http://docs.neu.edu.tr/library/6418330644.pdf?fbclid=IwAR37NEs7qdjhO0JT6jJ3mYSyS7cYltzX0yHTqSMYyZ4RR-k9hjdzYdt670 [Accessed 8 May 2019].

APPENDIX

This Appendix contains the load schedule and the amount of consumption of each load and the Datasheet that we used in this project.

Table A-1 load schedule and the amount of consumption power

load number	KW	KWh
1	1.488083333	1071.42
2	0.291666667	210
3	0.892888889	642.88
4	2.665277778	1919
5	2.098611111	1511
6	1.202777778	866
7	0.248013889	178.57
8	0.738888889	532
9	1.580555556	1138
10	0.041666667	30
11	2.793055556	2011
12	0.734722222	529
13	1.919444444	1382
14	0.672222222	484
15	0.620833333	447
16	0.783333333	564

17	0.694444444	500
18	0.555555556	400
19	0.416666667	300
20	0.972222222	700
21	0.582833333	419.64
22	0.555555556	400
23	0.733333333	528
24	0.55	396
25	1.654166667	1191
26	1.594444444	1148
27	0.281944444	203
28	2.158333333	1554
29	0.744041667	535.71
30	0.570833333	411
31	0.421625	303.57
32	1.036111111	746
33	1.027777778	740
34	0.041666667	30
35	2.452777778	1766
36	0.248013889	178.57
37	2.777777778	2000
38	0.972222222	700

39	0.372013889	267.85
40	0.496027778	357.14
41	0.833333333	600
42	0.138888889	100
43	1.380555556	994
44	1.738888889	1252
45	0.744444444	536
46	0.446416667	321.42
47	0.595236111	428.57
48	1.283333333	924
49	0.416666667	300
50	0.555555556	400
51	0.041666667	30
52	0.041666667	30
53	0.248013889	178.57
54	1.736111111	1250
55	2.673611111	1925
56	0.868055556	625
57	1.555555556	1120
58	0.496027778	357.14
59	0.744041667	535.71
60	0.744041667	535.71

61	0.248013889	178.57
62	0.496027778	357.14
63	0.496027778	357.14
64	0.833333333	600
65	0.744041667	535.71
66	0.744041667	535.71
67	0.138888889	100
68	0.496027778	357.14
69	0.791666667	570
70	0.590277778	425
71	1.247222222	898
72	0.555555556	400
73	0.694444444	500
74	0.248013889	178.57
75	0.124	89.28
76	1.156944444	833
77	0.248013889	178.57
78	0.734722222	529
79	0.372013889	267.85
80	0.972222222	700
81	0.833333333	600
82	1.444444444	1040

83	0.138888889	100
84	0.744444444	536
85	0.6375	459
86	0.8125	585
87	0.741666667	534
88	0.041666667	30
89	1.004166667	723
90	1.266666667	912
91	1.404166667	1011
92	0.891666667	642
93	0.972222222	700
94	0.994444444	716
95	0.625	450
96	1.25	900
97	0.041666667	30
98	0.496027778	357.14
99	0.248013889	178.57
100	0.124	89.28
101	0.694444444	500
102	0.694444444	500
103	0.248013889	178.57
104	0.372013889	267.85

105	0.138888889	100
106	0.248013889	178.57
107	1.302777778	938
108	0.041666667	30
109	1.388888889	1000
110	0.486111111	350
111	0.972222222	700
112	0.372013889	267.85
113	0.570430556	410.71
114	0.384513889	276.85
115	0.595236111	428.57
116	0.446416667	321.42
117	0.223208333	160.71
118	0.372013889	267.85
119	0.124	89.28
120	0.496027778	357.14
121	0.620027778	446.42
122	0.323611111	233
123	0.618055556	445
124	0.508333333	366
125	0.656944444	473
126	0.445833333	321

127	0.6	432
128	0.2625	189
129	0.695833333	501
130	0.433333333	312
131	0.816666667	588
132	0.473611111	341
133	0.208333333	150
134	0.423611111	305
135	0.694444444	500
136	0.041666667	30
137	0.992055556	714.28