Impact Study of Maslamani Photovoltaic System on Tubas Distribution Grid

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الإهداء

معلمنا الأول ومعلم الناس الخير

نبينا محمد صلى الله عليه وسلم

إلى من زرعوا فينا الطموح والمثابرة

أبائنا الأعزاء

إلى من سهرن الليالي

أمهاتنا الحبيبات

إلى من مهدوا لنا طريق العلم

أساتذتنا الأكارم

إلى من يستحق الشكر

مشرفنا الفاضل

إلى من ناضلوا من أجلنا

شهدائنا وأسرانا وجرحانا

إلى الأرض الحبيبة التي نعشق

بلادنا فلسطين

الملخص

تعاني فلسطين من نقص في مصادر إنتاج الطاقة الخاصة بها، لذلك فهيَ تعتمد بشكل أساسي على الشركات الإسرائيلية, مما يجعل الاحتلال يتحكم في سعر الكهرباء ووقت تشغيلها, ومن هنا جاءت الحاجة لإيجاد مصادر طاقة خاصة بنا, مثل أنظمة الطاقة الشمسية.

تعتبر مصادر الطاقة الشمسية من مصادر الطاقة المتجددة الأكثر انتشارا مقارنة بالمصادر الأخرى, ويعود السبب في ذلك لكونها صديقة للبيئة, ومتوفرة بشكل دائم, والكفاءة العالية لهذه الأنظمة. ولحل لمشاكل الطاقة المتفاقمة في بلادنا, توجهنا إلى تنفيذ هذه المشاريع الضخمة وربطها على شبكات التوزيع, ولضمان أعلى كفاءة لمثل هذه الأنظمة, نشأت الحاجة لعمل دراسات لتأثير ربط أنظمة الخلايا الشمسية ذات القدرة العالية على شبكات التوزيع.

يقوم هذا المشروع على عمل دراسة تحليلية مفصلة لعملية ربط محطة خلايا شمسية ذات قدرة عالية مع شبكة التوزيع، والحصول على أعلى إنتاجية من النظام, ودراسة الآثار الجانبية الناتجة عن عملية الربط، وإيجاد أفضل الحلول لهذه المشاكل وتطبيقها على الشبكة .

نقوم في هذا المشروع على عمل دراسة عن تأثير ربط محطة المسلماني الكائنة في مخيم الفارعة جنوب طوباس والتي قدرتها (3MW) مع شبكة التوزيع، حيث تم الحصول على المعلومات التفصيلية الخاصة بالمشروع من شركة الكهرباء ومن المهندسين القائمين على المشروع، وتم عمل محاكاة للمشروع باستخدام برنامج E-Tap.

Abstract

Palestine suffers from a lack of sources of its own energy production, so it depends mainly on Israeli companies, which makes the occupation controls the price of electricity and time of operation, hence the need to find our own energy sources, such as solar systems.

The sources of solar energy from renewable energy sources are the most widespread compared to other sources. This is because they are environmentally friendly, always available, and the high efficiency of these systems. In order to solve the growing energy problems in our country, we have embarked on implementing these huge projects and connecting them to distribution networks, and to ensure the highest efficiency of such these systems, the need arise for impact studies of connecting high-capacity photovoltaic systems to distribution networks.

This project is based on a detailed analytical study of the process of connecting a high-capacity photovoltaic station with the distribution network, and get higher productivity of the system, studying the side effects of the connecting process, and finding the best solutions for these problems and apply these solutions on the network.

In this project, we will study the impact of connecting the maslamani station which located in Al-Faraa camp south of Tubas with the distribution network, the detailed information about the project was obtained from the electricity company and the project engineers. The project was simulated using the E-Tap software.

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Abbreviations	Meaning
AC	Alternating Current
ADAS	Advanced Distribution Automation System
AFD	Arc Flash Detection
BFO	Bacterial Foraging Optimization
CFD	Cable Fault Detection
DC	Direct Current
DDI	Device Driver Interface
DES	Distribution Energy Storage
DG	Distribution Generator
DLG	Double Line to Ground
GA	Genetic Algorithm
HV	High Voltage
HVDC	High Voltage Direct Current
IEC	Israel Electric Corporation
I_{sc}	Short Circuit Current
kV	Kilo Volt
KVA	Kilo Volte Ampere
KW	Kilo Watt (1,000 watt)
KWh	Kilo Watt hour
LBS	Load Break Switch
LL	Line to Line
LOM	Loss of Main
LV	Low Voltage
MCB	Main Circuit Breaker
MCCB	Molded Case Circuit Breaker
MDB	Main Distribution Board
MPPT	Maximum Power Point Tracking
MV	Medium Voltage
MVAR	mega Volt Ampere Reactive
MW	Mega Watt (1,000,000 watt)
OLTC	Load Tap-Changing Transformer
PCC	Point of Common Coupling
PCS	Power Control Systems
PF	Power Factor
PSO	Particle Swarm Optimization
PSS	Power System Stabilizer
PV	Photovoltaic
PVDG	Photovoltaic Distributed Generators
PVG	Photovoltaic Generation
PVPP	photovoltaic Power Plants
RMS	Root Mean Square
RMU	Ringe Main Unit
SA	Simulated Annealing
SLG	Single Line to Ground
STC	Standard Test Conditions

SVC	Static Var Compensator
THD	Total Harmonic Distortion
TS	Tabu Search
TSO	Transmission System Operator
V_{oc}	Open Circuit Voltage
W_p	Watt Peak

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<u>Chapter One</u>

<u>Introduction</u>

1.1 Overview

1.2 the Objectives of Project

1.3 Motivations

1.4 Importance of Project

1.5 Methodology

1.1 Overview

The idea of the project is to study in detail the impact of connecting photovoltaic (PV) system with the distribution network in Faraa camp south of Tubas. The capacity of the photovoltaic station is 3megawatt (3MW), which will be connecting to the main distribution network.

1.2 Objectives of The Project

- Study the Dynamic Analysis & Steady State Analysis.
- Study Reactive and Real Power Loss
- Power Factor Analysis
- Reverse Power Flow
- Voltage Analysis at each Bus
- Study Reactive Power Fluctuations.
- Determining Optimum PV Placement for Voltage Stability Improvement.
- Study Optimal Penetration Level of PV Generation for Distribution System Load Transfer.

1.3 Motivations

Due to increases in an electrical power cost, and Limitations coming from the Israeli Energy Authority; the photovoltaic systems is the ideal solution for this problems; by make a high-capacity photovoltaic station connecting to the distribution network, this project focuses on the problems that will occur and find the best solutions.

1.4 Importance of Project

Explain the importance of the connecting photovoltaic station to the distribution network, and make an impact study for the Faraa camp project south of Tubas, and research about the expected challenges of the connecting process.

1.5 Methodology

1. We visited the Location of the project, and collected data about the PV station and the network.
2. Analyze and simplify the data.
3. Simulation the PV station on the PVsyst software.
4. Using ETAP software to study the system and network.

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Chapter Two

Impact of Photovoltaic System on a Distribution Network

2.1 Introduction

2.2 Distributed Generation

2.3 AC Power

2.4 Solar Irradiance and Power Quality

2.5 Voltage Regulation

2.6 Frequency Regulation

2.7 Dynamic Analysis and Steady State Analysis

2.8 Phenomenon occurs as a Result of the onnecting the Photovoltaic System with a Distribution Network.

2.9 Determine Optimum Photovoltaic Placement and Sizing for Voltage Stability Improvement

2.10 Optimum Penetration Level of PV Generation for Distribution System Load Transfer

2.1   Introduction

Fossil fuel is the main energy supplier of the worldwide economy, but the recognition of it as being a major cause of environmental problems, climate changes, smog, and other human health problems, beside the increasing energy demands, and the scenarios of oil depletion end up in the next centuries, which leads for all these reasons to look for alternative clean and renewable resources in power generation.

One of the most important renewable sources is the solar energy, as the sun is the largest energy source of life while at the same time it is the ultimate source of most of renewable energy sources. Solar energy can be used to generate electricity in a direct way with the use of photovoltaic, or by using solar thermal or concentrating solar power to heat a media or water and generate steam then electricity.

In recent years, the possibility to obtain electrical energy from the sun and to supply electrical energy has been realized due to development of solar panel and power electronic converters. The installations of PV grid-connected systems in many countries have been supported by utilities and government agencies. Electric utilities are seeking new technologies to provide acceptable power quality and reliability to their customers.

As the kind of most competitive distributed generator, both electricity consumer and electric utility can use PV system for various purposes. Consumers can save money as well as improve their power supply reliability by installing PV systems, because they can use their own solar energy at the peak demand when power is at its highest price of the day. Utility may install PV grid-connected systems near substation or the end of feeder.

Grid-connected PV systems are installed to enhance the performance of the electrical network, PV arrays provide energy at the load side or to the distribution system. Despite the many advantages of the photovoltaic's systems associated with the distribution network, the photovoltaic systems can also impose several negative impacts, especially if their penetration level is high.

Photovoltaic's systems are classified based on their ratings into three different categorized, small systems rated at 10kW and less, intermediate PV systems rated 10kW to 500kW, and large PV systems rated above 500kW. The first two categories are usually

installed in the distribution system and the last category is usually installed on the transmission system [1].

2.2   Distributed Generation

Distributed Generation (DG) can be defined as electric power generation within distributed networks or on the customer side of the network. Types of distributed generators are gas and oil reciprocating engines, combustion turbines, steam turbines, or geothermal.

Renewable distributed generators, the more commonly connected, are wind, solar, or hydro. Power from DG is usually contracted to sell power solely to the local load but can be sold back to the utility when the DG system produces more power than the customer load.

One of the great advantages of the increasing connection of DG to the utility distribution system is the increasing implementation of renewable energy in an industry where the majority of the generating plants have harmful environmental consequences [2].

There are two important goals behind using the DG:

- Increase the security of energy sources and decrease the dependency on importing fossil fuels like natural gas, oil and coal.
- Reduce the emissions of gases specially carbon dioxide that dangerously affect the environment, which is known as Green House or Global Warming.

   ❖ Advantages of Distributed Generation:
- High efficiency
- Reliable, reliability improvement
- Flexible
- Decreasing transmission losses.
- Avoidance of overcapacity, eliminating the unnecessary transmission and distribution costs. Reduce maintenance investments.
- Peak load reduction
- Reduction of grid losses
- Power quality support

- ❖ Disadvantages of Distributed Generation:
  - The initial investment in RE systems is often larger than for non RES
  - Specific requirements of the site for power generation
  - The availability of renewable energy (sun, wind, water) largely determines the feasibility of RES.
  - The unpredictability of RES also means a higher cost for balancing the electricity grid and maintaining reserve capacity.
  - Negative impact on the electricity grid at high penetration level and impact the power quality of supply which is a big concern for the NSP"s at the integration points.

The connection of DG differs from type to type of the DG. In the following table (Table 2.1) we describes four categories of distributed generation.

Table 2.1: Categories of Distributed System.[29]

Generator	Classification Rating
Micro	< 10 kW
Small	(a) < 500 kW connected on distribution system voltage (b) < 1 MW connected on distribution system voltage
Mid-Sized	(a) > 500 kW connected on distribution system voltage (b) >1 MW < 10 MW connected on distribution system
Large	> 10 MW

Solar photovoltaic generators are measured as distributed generators at various nodes and the impacts that DG produces on real and reactive power losses, voltage profile, phase imbalance and fault level of the distribution system.

Photovoltaic solar systems generate DC power while the sun is shining on them and are interfaced to the utility system through inverters. Some systems do not have the capability to operate stand alone the inverters operate only in the utility-interactive mode and require the presence of the grid [3].

How Distributed Generation Changed the Grid.

The grid has always followed and expanded upon the same centralized structure, power is generated in large quantities (on the order of Megawatts or Gigawatts) in large power plants that are scattered across the region.

The power is then transmitted through transmission lines at high voltages to the towns and cities that purchase the power. These are called load centers. At the load centers, the voltage would be stepping down in substations and then supplied to the end user through the distribution network, this network consists of the roadside power lines atop utility poles that most people are familiar with.

This structure of generation, transmission, and distribution has been the static model for about a century for one major reason; it was always the most economically viable option. Large generation units benefited from the idea of 'economies of scale'; the more power a plant generates means a bigger profit and the cheaper rate it could sell the power at. The most inefficient part of this centralized system is the transmission, transmitting electric power up to hundreds of miles is costly [2] [3].

2.3 AC Power

The difference between load and PV production significantly affects all measured parameters. When the energy produced by photovoltaic systems is comparable to the energy provided by the main source of the network, the behavior of the PV plant is noticeable in the grid, and to study the behavior of AC power, the following parameters should be taken into account:

2.3.1 Active Power

Photovoltaic's system inverters normally operate at unity power factor for two reasons. The first reason is that current standards, do not allow photovoltaic's system inverters to operate in the voltage regulation mode. The second reason is that owners of small residential PV systems in the incentive-programs are revenue only for their kilowatt-hour yield, not for their kilovolt-ampere hour production.

It is better that the inverters operate at unity power factor to maximize the active power generated and accordingly their return. As a result, the active power requirements of existing loads are partially met by PV systems, reducing the active power supply from the

utility. However, reactive power requirements are still the same and have to be supplied completely by the utility.

In Figure 2.1 a), active power profile in 24 hours is shown, and in figure 2.2 a), it is observed how PV plant production affects the flow of energy for several hours at the substation [4].

2.3.2 Reactive Power.

A higher rate of reactive power supply is not preferred by the utilities because in this case distribution transformers will operate at a very low power factor. 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

There was an increase in the reactive power consumption in the network with PV system Figure 2.2 b) compared with the first period Figure 2.1 b).

The PV inverters are subject to the action of control systems aimed at providing zero reactive power at the fundamental frequency, but several experiences has shown that the filters of inverters are not disconnected consuming reactive power, even when the PV plant is not operating. This fact does not justify such a reactive power consumption, which may be due to increased loads on the grid [4].

2.3.3 Power Factor

As can be observed in Figure 2.1 c), the power factor values are always above 0.85 and only fell below this number at night when the load profile is low, however in Figure 2.2 c), power factor decreases to unacceptable levels during PV system operation

When the PV system works with high power values close to rated ones, most active power demanded by the customers is supplied by the PV plant, reducing the demand of active power from the grid, but reactive power demand is the same, so it causes a low power factor measured at the substation [4].

a)   b)   c)
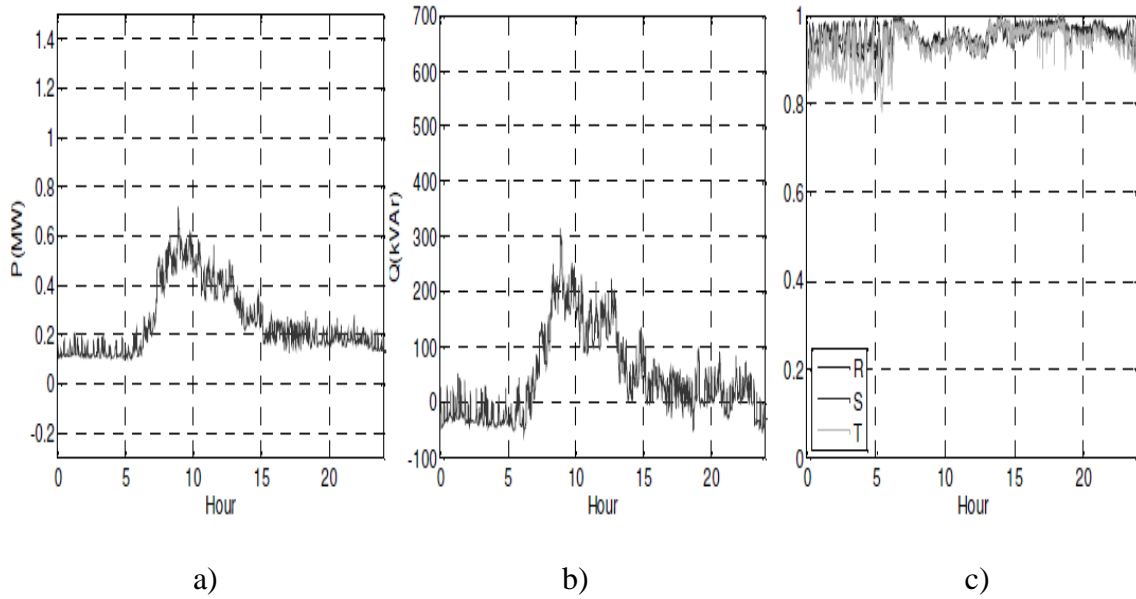
Figure 2.1: Measures at the substation in 24 hours. a)Active power without PV, b)Reactive power without PV, c) Power factor without PV.

a)   b)   c)
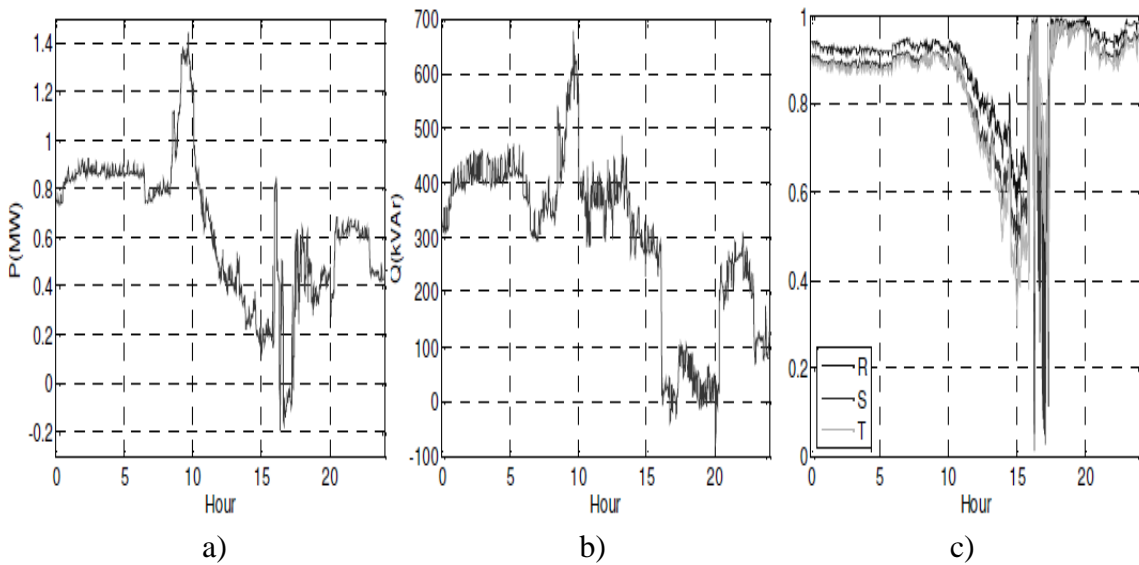
Figure 2.2: Measures at the substation in 24 hours. a)Active power with PV, b)Reactive power with PV, c) Power factor with PV.

2.4   Solar Irradiance and Power Quality

Good power quality translates into obtaining a sinusoidal voltage and current output from a photovoltaic system in order to avoid harmonics, inter harmonics and eventually voltage distortion. The efficiency and good operation of the grid connected PV systems are depending on many factors.

The environmental conditions as well as the design of the PV system are the most important factors to the reliability of PV system. Moreover, these factors have significant effects to the power quality of the PV outputs. We can see that the variability in the output power of the PV systems depends on the variability of the solar irradiance, the temperature and the PV modules type of material. For example, the thin film (amorphous silicon) module has less response to the variation in temperature than the mono and poly crystalline modules.

With large amount of PV systems connected to the distribution grid and with low irradiance condition, there will be undesirable variations of the output power from the PV in both power components (voltage and current) at the point where the PV system is connected to the distribution feeder. These variations might exceed the limits of the grid.

The inverters output has an effect on the power quality, when converting the DC power to AC power in low voltage networks the inverter increases the power quality problems due to the internal circuit of the inverter, even when the inverter works within the acceptable limits. The high sensitive electronic devices in the inverter might be damaged due to the low power quality condition.

In order to improve the performance of PV systems, many maximum power point tracking (MPPT) techniques have been developed. The main goal to supply the maximum available active power from PV to a grid without compensating the harmonic current and reactive power demanded by the load.

Today, non-linear loads are widely used in residential and office buildings. These include computers, modern electrical products, variable speed drives and even normal fluorescent lamps. As a result, the power quality of the grid has been reduced (poor power factor and increasing total harmonic distortion (THD)). Conventional grid-connected PV systems require additional active filters to reduce THD and compensate reactive power [4][29].

Conditions Affect the Outputs for Grid-Tied PV Systems

The unpredictable outputs of the PV system that could be according to the design mistakes or to the weather conditions are explained in these points below:

- Orientation of the panel: Ideally each solar panel should be oriented in Palestine to the south in order to align peak production with the peak solar radiation. Additionally, the panel should be titled at the correct angle according to the latitude. In Palestine, it

must be around 32 as the latitude in Palestine. If these conditions are not met, the output of the panels will be restricted. This is entirely possible if the roof of the house is unsuited to PV installation.

- Shading over the PV system may be unavoidable on certain roofs and this will limit PV panel output.

- Many systems have underrated panels to make optimum use of the inverter

- Cloud cover will also limit PV output

- Solar potential is also different between seasons as the sun is father distance changes with the earth's rotation. Thus in the winter months PV output tends to be less than in the summer.

- PV output is sometimes lowered in order to comply with limitations, due to stability conditions when the voltage decreased in the grid, the output voltage from the PV system must be decreased.

- The high ambient temperature, which will strongly affect the output of the PV if the difference in temperature is huge [3] [29].

2.5 Voltage Regulation

PV plants frequently operate at unity power factor and for this reason, only few articles focus attention on the limitation of voltage fluctuations at the point of common coupling by means the regulation of reactive power because in many cases over-voltages are damped by limiting the active power fed into the grid.

Grid-connected PV plants with a power rating (P_n) greater than 3kW have to provide the voltage regulation service through the injection of positive or negative reactive power.

For HV overhead lines, generally, the phase shift between the voltages at the beginning and at the end of the line is very small. Under this assumption, under static operation, the voltage regulation can be carried out by adjusting the reactive power.

This statement is not entirely true for LV lines and then there is a coupling between the control channels of voltage and frequency. Generally the active and reactive power impacts on node voltage in a LV line is almost the same. In particular, for overhead lines the

reactive powers impacts on node voltage is greater than that of active power while in underground cable lines the opposite occurs.

PV plants have to perform voltage regulation by regulating reactive power. When the adjustment of active power is not sufficient to keep the voltage of the node below the 110% of V_n, the active power injected into the network is limited.

The reactive power is used to limit the over/under voltages caused by the PV plant during the injection of active power into the grid. The inverters used in these plants have to be capable of delivering reactive power automatically. The power factor of the PV grid connected plants, and then the reactive power delivered or absorbed.

In fact, particularly in weak radial distribution networks, with long distances to be covered and high R/X ratios in network impedance, the voltage rise can be considerable.

The voltage regulation problem is described by Figure 2.3, where a generator and a load are connected at the end of the line.
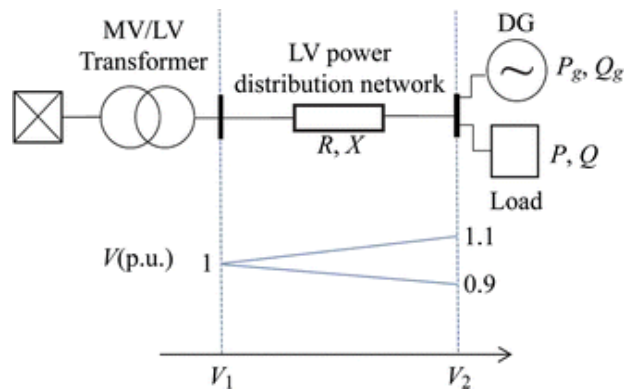
Figure 2.3: Voltage rise effects in radial weak distribution networks

The voltage variation in the feeder can be expressed by Eq.(2.1).

$$\Delta V = V_1 - V_2 = \frac{R(P-P_g) + X(Q^{\pm}Q_g)}{V} \tag{2.1}$$

Where:

V_1 the voltage at the begin of the feeder.

V_2 the voltage at the end of the feeder.

R the resistance of the feeder.

X the reactance of the feeder.

P the active power absorbed by the load at the end of the feeder.

Q the reactive power absorbed by the load at the end of the feeder.

P_g the active power generated by DG at the end of the feeder.

Q_g the reactive power absorbed/generated by DG at the end of the feeder.

V is the secondary value of the low voltage transformer.

In case of no load condition (P = Q = 0), equation (2.1) can be rewritten as in equation (2.2), that shows the relationship between the injected power and the voltage at the point of common coupling (PCC).

$$V_2 = V_1 + \frac{R(\,P_g) + X(^{\pm}Q_g)}{V} \qquad\qquad (2.2)$$

The PV power generation could not only offset the load, but also cause reverse power flow through the distribution system with operational issues, including overvoltage and loss of voltage regulation.

Managing the active and reactive power generated by the PV system, in an intelligently coordinated way, can mitigate the adverse impact on the voltage at the end of the line, limiting overvoltage and improving voltage regulation.

The operation of a production plant (photovoltaic station) in parallel with the distribution network must respect the following conditions defined by the standards.

1) Do not cause disturbances to the service on the distribution network.
2) Stop immediately and automatically in the absence of power supply or if the mains voltage and frequency values are not within the values specified by the Distributor.
3) The parallel device of the production plant must not allow the parallel with the network in case of power failure or voltage and frequency values outside the values specified by the Distributor.

To ensure the separation of the production plant from the distribution network in case of power failure, an Interface Device (DDI) must be installed. The DDI is controlled by interface protection relay (SPI), that is a grid feeding monitoring relay with overvoltage protection (59), undervoltage protection (27), over frequency protection (81>), under

frequency protection (81<), protection codes 59, 27, 81>, 81< are defined by ANSI /IEEE Standard C37.2 [5] [29].

2.6 Frequency Regulation

The frequency is one of the most important factors in the power quality. So, it must be uniform throughout an interconnected grid. The way to control the frequency is by maintaining a balance between the generation part of the grid and the load which is connected to the grid. The frequency is controlled within a small deviation.

There are some examples taken from Japan and Europe about the deviation to control the frequency in their networks. In Japan the standard is 0.2-0.3 Hz; in the U.S. it is 0.018-0.0228 Hz and in the European UCTE it is 0.04-0.06 Hz. The state of unbalance between the generation and the demand of electricity could lead to what we can call a frequency fluctuation.

The fluctuation will fall when the demand exceeds the generation and it will rise when the generation exceeds the demand. With the increasing penetration of grid connected PV systems, frequency control becomes more difficult.

As the number of grid-tied PV systems increases, the impacts of frequency fluctuation will become more significant. Inverters can provide frequency control in short time, sometimes milliseconds, which is significantly faster than conventional generation. Moreover, the inverter may cause harmonics and inject it to the distribution network which makes losses and disturbance in the power (voltage and current).

The frequency regulations affect the distribution system stability, so it's important to avoid this issue. In some grid connected PV systems, the inverter must disconnect the PV system from the grid when the output frequency breaks the limits to avoid the instability of the distribution system.

Frequency regulation can be performed by acting only on the active power. Frequency regulation is less critical than voltage regulation because grid frequency is very sensitive to variation of the active power and less sensitive to those of reactive power. For this reason the

frequency regulation has to be performed acting only on the active power injected into the grid.

❖ To perform active power regulation in grid connected PV system three approaches have been proposed:
1. Using an energy storage system while keeping the PV system to work in the MPP
2. Using a damp load bank to absorb surplus energy produced by PV plant
3. Change the converter control strategy to modulate the power extracted from the PV array.

The latter approach is certainly the most economical because it does not require any additional component [5].

DC/AC converter it produces sinusoidal AC current and voltage output whose magnitude and frequency can be controlled.

❖ Under normal condition the control strategy of inverter determines:
1. The level of the active power injected into the grid.
2. The synchronization of the inverter.
3. The connection to the grid. When an over/under voltage occurs, the inverter control strategy acts on adjustment of reactive power flow.

When a frequency transient occurs, the injection of active power into the grid has to be adjusted in accordance with the characteristic of Figure 2.4.
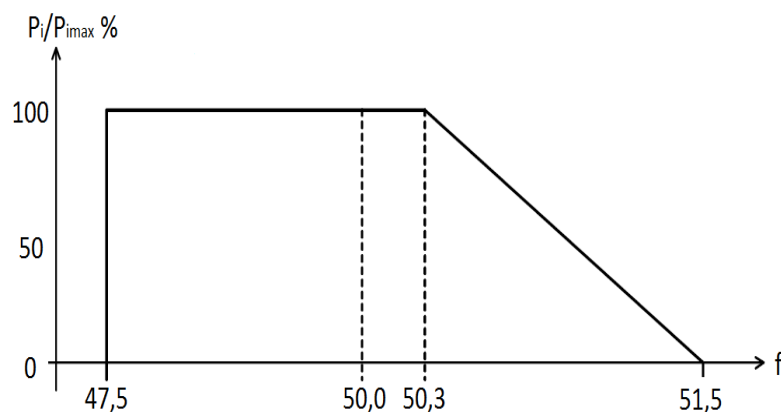
Figure 2.4: Reduction curve of active power with frequency

When frequency ranges between 47.5 Hz and 50.3 Hz, grid connected PV systems have to inject the maximum power into the grid.

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When the grid frequency exceeds the threshold of 50.3 Hz, grid connected PV plants have to reduce the active power, Pi_{max}, injected into the grid according with the regulation statism and the value of over-frequency [5] [29].

2.7   Dynamic Analysis and Steady State Analysis

The integration of renewable energy systems into the electric grid creates several technical challenges. To investigate the impact of renewable energy injection into the electricity network, it is necessary to examine the static and dynamic behavior of power systems. These studies are important to ensure the system stability and secure operation of the electric network under fault disturbance.

Dynamic system characteristics are examined when three-phase fault occurs, and the study state analysis characteristics examined when voltage variations occurs; due to irradiance changes.

2.7.1 Dynamic Analysis

The interconnection of the power generations can cause the deterioration of power quality and reliability and threaten protection coordination, transient stability, and etc.
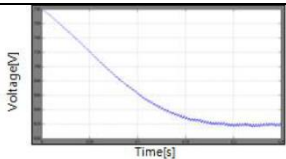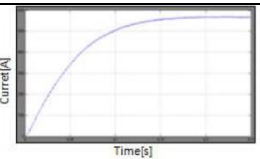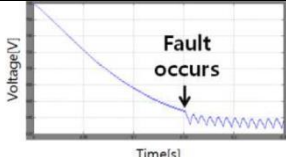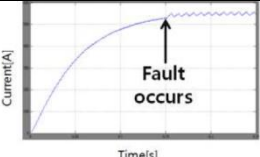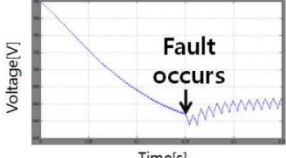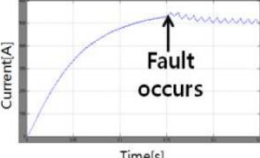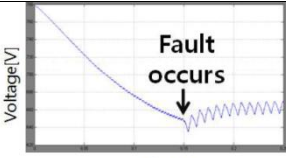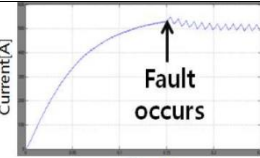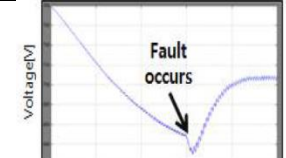
The dynamic stability study is conducted to determine the power system behavior when a three-phase fault is applied, at critical connection points of distributed generators, to the grid. In addition, this work identifies the critical fault clearing time of various power stations.

An increase in PV capacity results in an increase in the loads served by PV, and hence the stability of PV systems becomes important. However, the PV system suffers from nonlinear behaviour, such as the faults and transients of a power system, which does not occur with a generic inverter, and this may cause the output of the PV system to become unstable. Therefore, it is necessary to analyze the output of a PV system with regard for the nonlinear phenomenon of a power system.

Table 2.2 shows the output voltage and current of the PV array for each fault type for the fault at the distribution system side. In all cases, the oscillation of voltage and current occurs after the initiation of the fault. When the three-phase fault occurs, the new operating point of voltage is increased to the open circuit voltage after instantaneous reduction and the current is reduced after increasing instantaneously.

Table 2.2: the output voltage and current of the PV array for each fault type when considering the fault on the distribution system side [6].

When the disturbance applied to the system, the solar irradiation is set to constant $(1000\,\text{W/m}^2)$. The simulation work to be conducted starts with a three-phase short circuit fault set to occur at bus 361. It can be observed that the PV generation provides the necessary reactive power compensation during system fault transient.

2.7.2 Study State Analysis

Steady state analysis focus on the impact induced by any power unit added to the power system through power flow calculation and transient stability. The objective of the performed steady state analysis is to calculate the load flow on the transmission lines, transformers and the voltage profile of system buses.

At first, PV array's VI and P-V characteristics are compared with that of manufacturer's data. The nonlinear nature of PV cells is obvious, i.e., the output power and current of Photovoltaic cell depend on the cell's terminal operating voltage and temperature, and solar irradiance as well.

It is clear that with increase of solar insolation, the short-circuit current of the Photovoltaic array increases, and the maximum power output increases. This is because, the open-circuit voltage is logarithmically dependent on the solar irradiance, yet the short-circuit current is directly proportional to the radiant intensity.

For different solar irradiance levels from G=1 to G=0.25, if G=1 it means that solar panel is receiving solar energy at the rate of 1000 W/m². As the value of 'G' drops, thus the net energy received by the solar panel also drops. It is important to note that the developed module's outputs that are current and power depend on the irradiance and cell's temperature.

The maximum output power for the solar panel (according to available elements from the PV datasheet) respects the maximum operating point achieved [28].

2.8 Phenomenon Occurs as a Result of The connecting the Photovoltaic System with a Distribution Network.

As we mentioned at the beginning of the chapter, despite the usefulness of the process of connecting the photovoltaic system with the distribution network, there are several negative effects and phenomena that will probably result from the connecting process, In this section, we will focus on the most important of these phenomena, and try to find the optimal solutions to these problems.

2.8.1 Phase Unbalance

The Inverters used in small residential photovoltaic's system installations are mostly single phase inverters. If these inverters are not distributed evenly among different phase, phase unbalance may take place shifting the neutral voltage to unsafe values and increasing the voltage unbalance.

Based on the Maximum PV penetration level, the base case cable (e.g. 185 mm²) for Feeder was replaced with a cable have lower and higher rating (e.g. 70 mm² and 300 mm²), respectively. The objective of this study is to assess the impact of changing the cable size on voltage profile with the given PV penetration level.

70 mm² and 300 mm² cable sizes were used to replace the 185 mm² cable used in the base case. This is to determine the effect of cable size to voltage profile with the given demand and PV generation. Figure 2.5 shows that a smaller cable size will lead to higher voltage rise. Therefore, changing to a larger sized cable might be an alternative to solve the voltage rise problem.
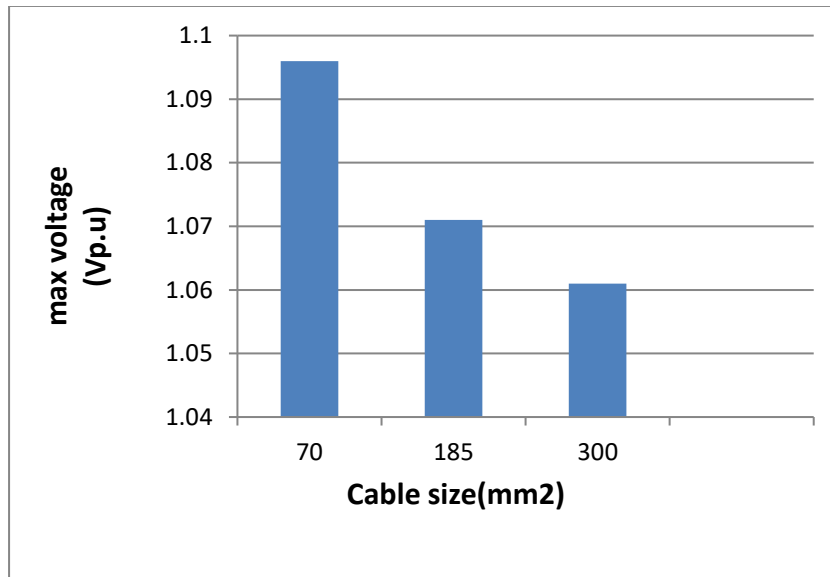
Figure 2.5: Maximum voltage rise with different size of cable

Balanced Photovoltaic System VS Unbalanced Photovoltaic System Connection.

To understand the potential issue of unbalanced PV integration, Let's take the following simple example.

If we have 9 units of 4kWp PV were integrated to the Feeder. In the first scenario, the 9 units 4kWp PV were connected equally to all the three phases at the Feeder. This means that every phase has 3 units of PV. In the second scenario, the 9 units 4kWp PV were only connected to the red phase of the Feeder.

The effect of a balanced connection and an unbalanced connection of PV is shown in Figure 2.6. Essentially, the distribution network is not balanced given the service connection of the load is not purely balanced. The same situation is expected of the installation of the PV system at consumer premises.

Through the simulation, it was noted that the unbalanced connection of PV increased the unbalances of the network. In this study, the unbalanced connection of PV would increase the voltage unbalanced by 21% from the balance connection case from 9 units 4kWp PV distributed evenly across the three-phase to 9 units 4kWp PV connected at red phase [1].
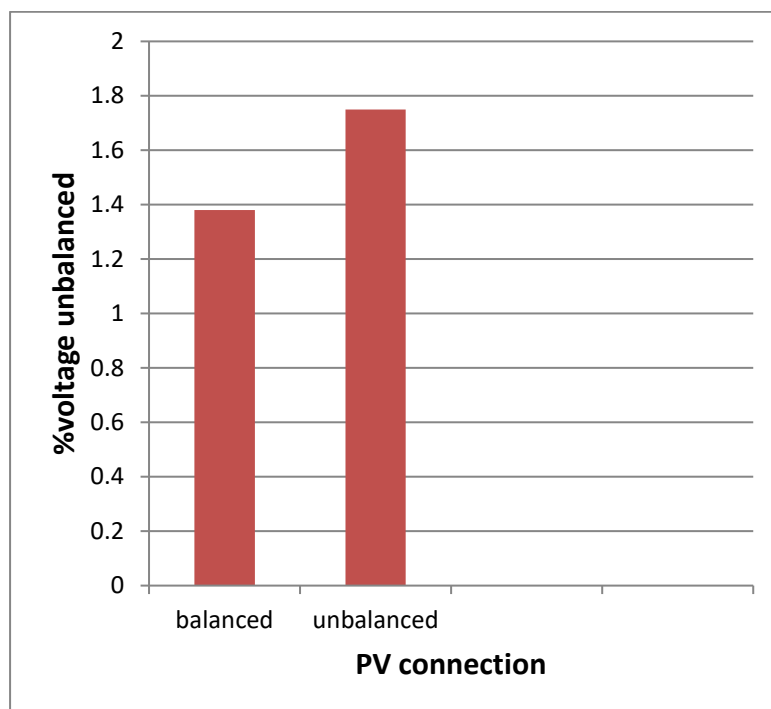
Figure 2.6: Maximum percentage of voltage unbalanced for balanced connection of PV and unbalanced connection of PV

2.8.2 Power Losses

Distributed Generation (DG) systems in general reduce system losses as they bring generation closer to the load. This assumption is true until reverse power flow starts to occur.

A study showed that distribution system losses reach a minimum value at a penetration level of approximately 5%, but as the penetration level increases, the losses also increase.

Since we can only measure the output power that is already affected by several loss factors such as module temperature rising, the effect of shadow, wiring, inverter, and so on, only the effect of the high grid voltage needs to be excluded from the actual system output power in order to calculate the expected output power that should be obtained if there is no restriction on the grid voltage. Employing the SV method, the expected output power without the effect of the high grid voltage can be calculated.

It is supposed the total grid losses of the distribution system are P_{loss}, which is obtained from Equation, where N number of PV systems:

$$P_{loss} = \sum_{i=1}^{N} P_{i\ loss} \qquad (2.3)$$

Simulation results indicate that the grid losses are related to the amounts and locations of the grid connected PV systems. As the amount of PVs increases from zero, the variation of the grid losses reduces first and then increases. There exists a grid-connected amount at which the grid losses are minimum.

When the amount of PV is small, the net transmission power of feeder line lessens, resulting in the reduction of grid losses. When the amount of PV continues to increase until exceeds the loads of feeder line, PV supplies active power to other feeder lines or even external grid. Then the grid losses increase as the amount of PV increases.

Furthermore, feeder lines with long electrical distances and heavy load power, exhibit significant grid losses reduction compared with other lines. It is appropriate to configure PV's at these feeder lines [4].

2.8.3 Reactive Power Fluctuations

In case of power transmission systems, dynamic response compensator is developed to provide fast and smooth reactive power compensation to solve a variety of industrial network power quality problems connected with fast variable loads such as, power sags, flicker, high harmonic levels and low power factor.

In LV distribution systems at higher PV penetration, power quality problems as reverse power flow or voltage increases may occur because the increasing active power feed-in on the low and medium voltage levels, which makes the connection of additional power generation plant more impossible Then, existing phase shifts and reactive power percentages in the grid reduce its transmission capacity and increase the collected transmission losses.

To solve the problem voltage within all grid levels ,especially in the distribution grid and to secure a reliable combination of distributed PV generation into distribution systems . A current solution is the use of PV inverter reactive power as a promising inexpensive concept to solve this problem caused by PV penetration [7].

To control the reactive power provided by PV inverters. The main strategies to control PV systems can be classified as local, decentralized and central control strategies.

- Local control schemes (also known as droop-based regulation strategies) make autonomous control of the reactive power supply via characteristic curves.
- Decentralized control is based on the control of the reactive power of PV and the interaction with on-load tap-changing transformer (OLTC) in the substation, In this case some local communication is necessary to enable the interaction between the inverters and the decentralized methodology.
- The central control scheme can be described as a communication based control methodology that allows to optimize the LV distribution grid operation not only locally but also regionally with a common beneficial level for producers and consumers.

The Central control strategy aims for coordinated control of the complete LV distribution system by using the static and dynamic system information.

However, the reactive power fluctuations of PV systems for an optimal power flow method exceed the performance of the PV active power injection due to the influence of the minimization voltage rise function, which attends to deal with the deviation of the voltage magnitude, even for negatives values [8].

2.8.4 Reverse Power Flow

As renewable distributed generation connects with the distribution network, the power demand from the electric grid is reduced. As DG becomes increasingly present, it can actually supply more power than the load demands and feed power back into substation and transmission grid. This would not only create instability of the system, but would result in overvoltage in the system as seen in Figure 2.7.

The power flow is usually unidirectional from the Medium Voltage system to the Low Voltage system. However. At a high penetration level of photovoltaic's systems, there are moments when the net production is more than the net demand, especially at noon. And as a result, the direction of power flow is reversed, and power flows from the Low Voltage side to the Medium Voltage side.

This reverse power flow results in overloading of the distribution feeders and excessive power losses. Reverse flow of power has also been reported to affect the operation of automatic voltage regulators installed along distribution feeders.

Reverse power flow may have adverse effects on online tap changers in distribution transformers especially if they are from the single bridging resistor type. The following figure shows the Reverse Power Effects on Overvoltage [1] [5].
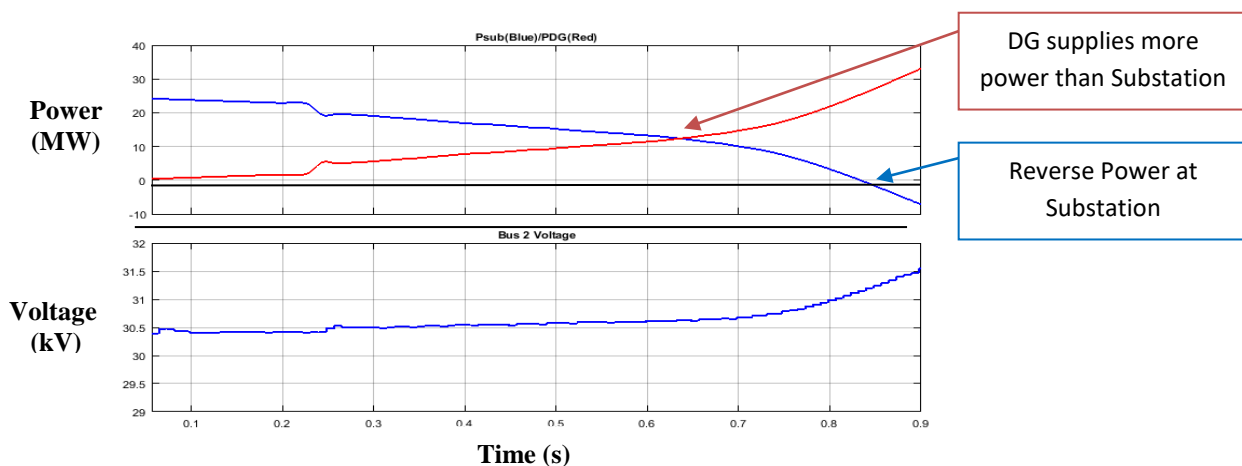
Figure 2.7: Reverse Power Effects on Overvoltage

❖ Reverse power flow has been known to cause problems such as:
1. Overvoltage on the distribution feeder.
2. Increased short-circuit currents.

3. Protection desensitization and potential breach of protection coordination.

4. Incorrect operation of control equipment.

Reverse Power Flow Solutions

▪ **Reverse Power Relay**

A reverse power mitigation system was created, that composes of a relay. The one-line diagram of the system being implemented in a distributed network is seen in Figure 2.8.
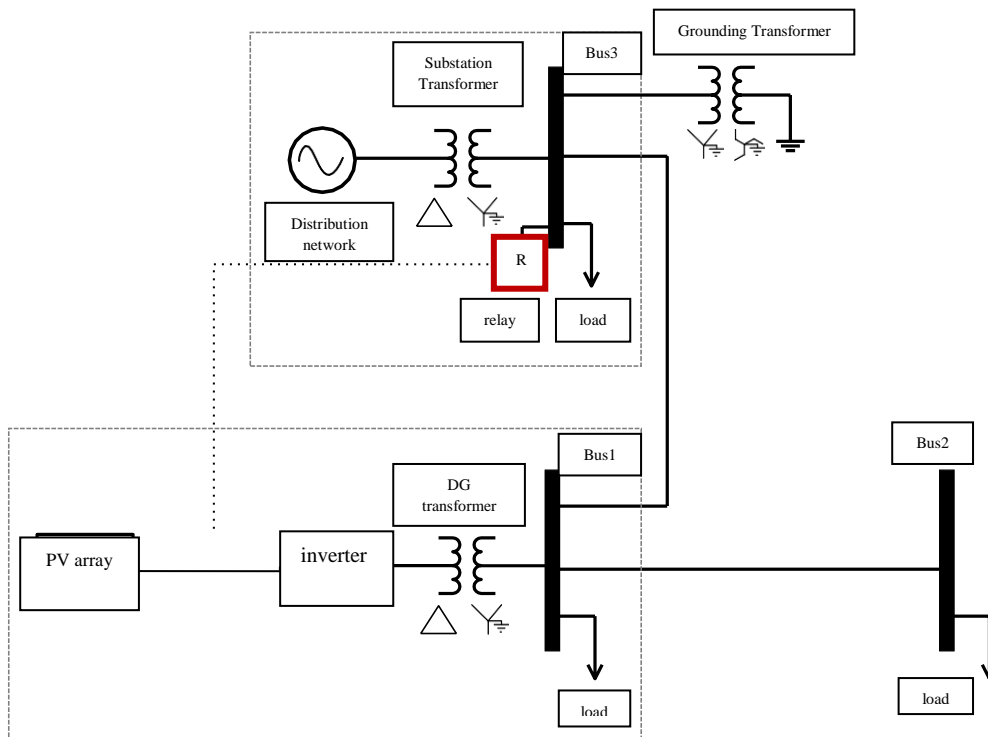
Figure 2.8: One-line Diagram of Reverse Power Mitigation System Integration

❖ The relay contains two logic systems:
  (1) phase detection.
  (2) under-current detection.

The phase detector measures the phase difference between the voltage and current waveforms taken at the substation and triggers the relay when the phase difference is 180 degrees [1].

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However, because real distribution systems have inherent phase shifts due to non-unity power factors, the phase detector also compares the measured phase difference to a value calculated from a power factor tolerance input.

To completely avoid a reverse power flow situation, the current should never be allowed to flow back into the substation. This means that the current output from the substation should never be below a certain threshold. The under-current detector is responsible for just this. The under-current detector outputs a trip signal to the buck converter when the magnitude of the current drops below a set value.

Figure 2.9, shows that with increasing radiance, the power output from the PV inverter increased and became larger than the power output from the substation at about 0.83 seconds. Without the mitigation system implemented, overvoltage on a distribution feeder occurred.
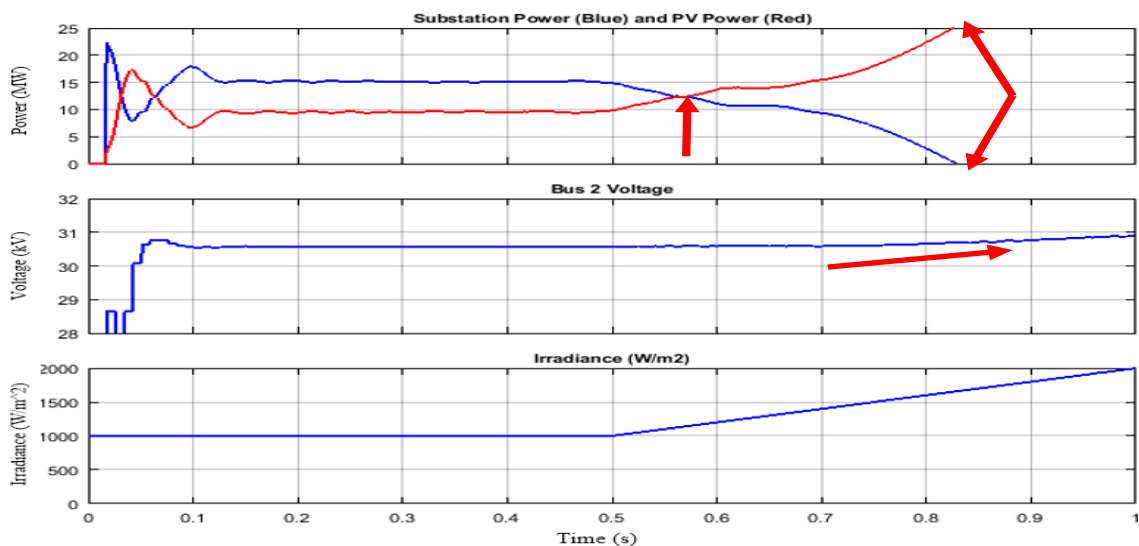
Figure 2.9: Voltage Measurement at Substation Bus with Increasing Irradiance and No Mitigation System

Now the same irradiance input was applied to the PV array, but the mitigation system was implemented in the system. The mitigation system was set so that the substation output should not drop below 80% of the total load.

Figure 2.10 shows that although the irradiance input to the PV increased, the output from the substation PV, and the substation bus voltage did not experience substantial effects.
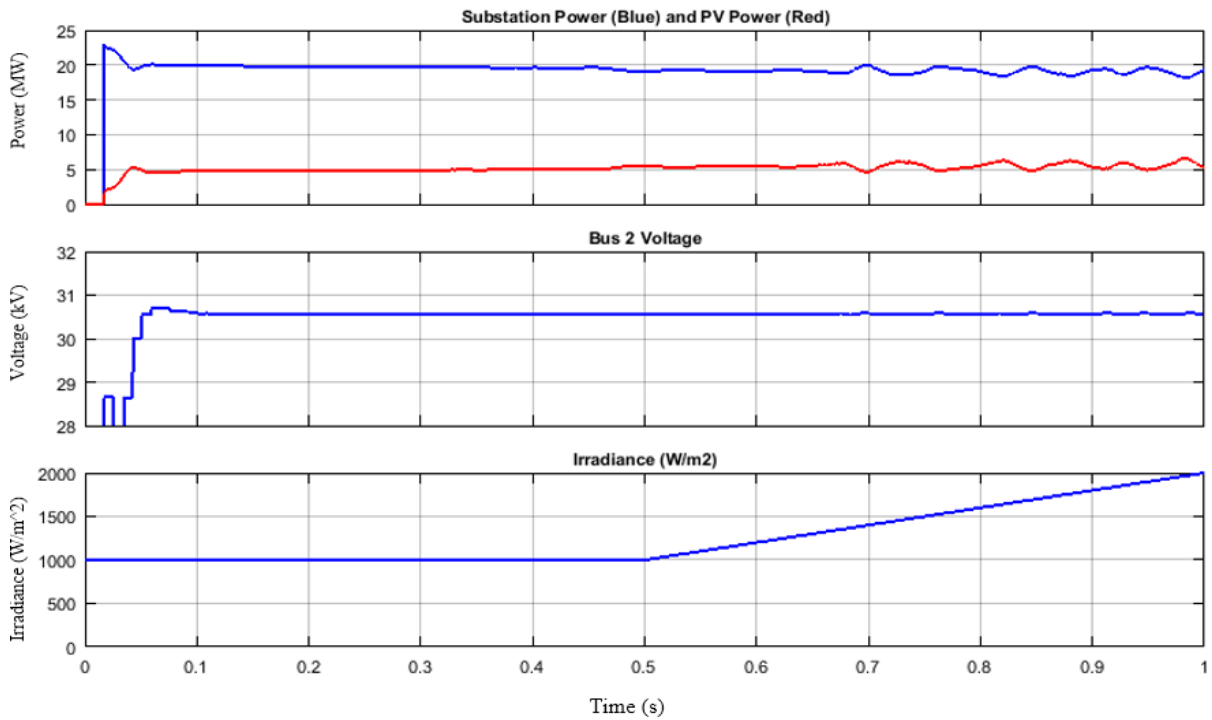
Figure 2.10: Voltage Measurement at Substation Bus with Increasing Irradiance and Mitigation System Implemented.

The Directional Power Relay (ANSI Designation #32)

The idea of using a relay for reverse power purposes has been around for some time. Figure2.11 shows one example: the BE1-32O/U Directional Power Relay. These relays are marketed to protect machines against the reverse power flow, under power, and over power conditions. Below is a picture of this type of relay.

Figure 2.11: Basler BE1-32O/U Directional Power Relay.

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These relays do a good job at preventing reverse power flow, but these relays are more conventionally used on generator system. A directional power relay is typically used to monitor the power from a generator in parallel with another generator or utility. The relay is used to prevent power flowing from the bus bar into the generator. These relays are used to prevent system failure when one generator fails.

The relay also will have to communicate with a mitigation system at the DG site. Just having a relay that trips the inverter would not work effectively. It would not work effectively because when the inverter trips, a lot of the load is supplied by the DG that is now turned off. This will cause the load flow to shift greatly and could be damaging to households and grid systems.

- **Tap Changer Transformer**

Advanced tap changer voltage controls on transformers and regulators automatically detect a power flow reversal and allow several options of operation when power reversal is detected. However, damaging system conditions can occur if there is an error in detecting the proper regulation direction or in the control action selected for the condition. These conditions occur when the control action.

1. Blocks operation at a time tap change action is required.
2. Results in running the tap position to tap position limits.
3. Requires actions from other system components of which they are not capable.
4. Causes "hunting" of tap position.

Although other variations may exist, the selectable control operation choices discussed for reverse power are:

- Ignore: The control will take the same action as in the forward direction, because it does not use the power direction in the control decisions. This is the same as a control, which does not have the power direction knowledge.
- Block: The control will cease all operations as a controller as long as the power is in the reverse direction and stays in the present tap position. Data recording and all non-regulating features continue as normal. Essentially, the control is in block auto condition.

- Regulate in Reverse: The control will use the source-side voltage (load-side in reverse operation), use the reverse direction settings allowed and operate the taps correctly to control the source-side (no load-side) voltage. It will begin this regulation with no time delay for the initial operations. ("Regulate in Reverse" is only applicable for single-phase regulator applications.

- Run to Neutral: The "run to neutral" operation is included as an alternate operation option for use when different system conditions, which are not locally distinguishable, could cause reverse power flow [1].

2.8.5 Overvoltage Along Distribution Feeders

Reverse power flow leads to overvoltage along distribution. Voltage regulators and capacitor banks used to boost the voltage slightly can now push the voltage further above the acceptable limits.

Voltage rise on MV networks is often a constraining factor for the widespread adoption of wind turbines. Voltage rise in LV networks may impose a similar constraint on the installation of PV systems.

Most of the losses due to the high grid voltage occurred in spring and autumn, which relatively have more fine days with a lot of solar irradiation compared with the other seasons. These seasons also have good weather; thus, electric loads such as air conditioners may not be in use. Consequently, more generation and fewer loads caused a higher grid voltage and a greater output energy loss.

A set of studies has been proven that when the sunlight intensity is more than 5 kWh/m^2, the voltage of individual inverters went up by 2%. Also, the difference between weekly household load and the weekends load demand could shift the voltage profile of the feeder by 1.5% to 2% above the maximum limit.

A voltage analysis of distribution feeder showed that overvoltage along the feeder is highly sensitive to photovoltaic's system penetration level as well as to the point of interconnection of the PV cluster to the feeder.

At high penetration levels, during light load conditions the voltage at the point of interconnection may increase by (2-3)% above the no load voltages, especially when the PV cluster is located far from the distribution transformer [1].

Overvoltage Solution:

The grid overvoltage protection function can be classified into two types, reactive power control and active power control (regulation). Both controls usually have to set values. One is the "starting voltage" of the control, and the other is the "recovery voltage".

The PCS will start the output control when the PCS's output terminal voltage becomes higher than the starting voltage and stop the control when the voltage becomes lower than the set value of the recovery voltage. The starting voltage is normally higher than the recovery voltage in order to prevent an unexpected fluctuation of the output.

2.9 Determine Optimum Photovoltaic Placement and Sizing for Voltage Stability Improvement

Distributed generation in power system networks has rapidly increased as the demand of power system is growing exponentially. DG units are have many advantages over centralized power generation. The optimum DG placement and sizing at planning stage of distribution system is necessary to achieve the reduction of power system losses and improved voltage profile.

There are numerous advantages of implementing PVDG, which includes:

- Increased reliability.
- Losses are reduced.
- Improving the voltage profile.
- The system can bear high loading situations.
- Transmission and/or distribution stress is reduced.
- DG technologies cause lower rate of pollution to the environment with higher efficiency.

The technology is also having its drawbacks. High penetration level of PV may cause reverse power flow at feeder and substation transformer level. A unidirectional protection system in the distribution system may be affected. Thus, it may affect voltages and loading limits of some transformers.

High penetration level of PV may cause voltage fluctuations due to the integrated uncertainty sources. For PV, the fluctuation solar source will cause over or under voltage.

Other drawbacks are high penetration of DG can lead to more harmonic propagation. It may increase the losses and shorten the equipment's lifetime. The Total Harmonic Distortion (THD) will be increased as the interaction among the power electronics interfaced equipment such as the Distribution Energy Storage (DES) with the capacitor bank.

The power system common unidirectional flow patterns will be affected as the DG flows in bidirectional. Thus, a suitable protection scheme is needed, the interconnection of photovoltaic based distributed generation with power systems grid is discussed.

The influences in terms of benefits and impacts for the integration of PV with the distribution system network are investigated by comparing the result of analysis for normal distribution system and distribution system with PV. The location and size of PV are also examined.

One of the impacts for PV are the losses in the system. There are two aspects discussed in this section which are the location of PV and its size. Both of the characteristics will affect on the power losses for the overall system and the assessments have been done with load flow analysis. Locating PV in an optimum location is important as it will increase reliability and stability of the system with reduced losses.

However, installing DG units at non-optimal place may get an opposite effect to what is desired. Selecting the best places for installing DG units and their preferable sizes in large distribution systems is a complex combinatorial optimization problem.

The optimal placement and sizing of DG in distribution networks has been studied in order to achieve the maximum benefits. DG is placed one by one in the network to obtain minimum power loss of the system.

Considering the interests of power supply and users, effectively combining the economy and safety, minimization of real power losses, maximization of voltage stability are considered as double objective for optimum DG placement and sizing.

The methodology to optimize the allocation and sizing of PV requires the assessment of system long-term performance in order to reach the best compromise for both technical and economical aspect.

The technical aspect is related with the improvement of the feeder voltage stability. This enhancement is evaluated by means of the potential rise of loadability limits. The economical aspect is associated with the PV generation profitability and the potential loss reduction on the feeder. Conceptually, the methodology is based on the following phases:

1. Knowledge of the initial condition of the feeder without PV.
2. Definition of different location buses to connecting the PV.
3. Impact evaluation of the PV installation on electric losses and loadability limits of the feeder.
4. Use as an automatic method to find the optimal allocation and sizing of PV on the feeder.

Rofitability and the potential loss reduction on the feeder. Conceptually, the methodology is based on the following phases The best location of connecting the PV with the distribution network is chosen based on the effect of the PV on improving the voltage stability, to reduce the power losses and to locate punctually in each bus of the feeder.

The Effect of the Integrating PV in the Power System:

The strategy used to treat the PV as parasitic sources with only constant active negative power injections (unity power factor) independent of the system voltage at the unit terminal bus.

Nowadays self-commutated inverters used in PV can generate reactive power, utility regulations and international or local standards dictate that PV should operate at a power factor greater than 0.85(leading or lagging) and also advice to move power factor close to unity. If PV inverter output is smaller than 10% of rating, power factor may operate outside of this limit.

The integration of the Solar Photovoltaic's to the grid has its pros and cons on the existing power systems since the traditional power systems were designed without taking into account the penetration of the intermittent energy resources.

Apart from the fact that PV provides clean and interminable power to the consumers, the systems can lead to the maximum reduction of the power losses and improvement of the voltage profile in the system. The proper placement of the PV can also free the transmission lines, and they impact both the active and reactive power unlike the capacitor banks which only affect the reactive power flow.

Distributed generators are beneficial in reducing the power losses effectively compared to other methods employed for the power loss reduction.

The integration of the PV systems can lead to some unexpected conditions such as voltage and power fluctuation issues, harmonic distortions, high transmission and distribution losses, over/under loading of the feeders and the malfunctioning of the protection systems.

Researchers have evaluated the effect of PV and have shown that small scale of PV is considered as negative load and may not affect the operation of the power system while the large penetration of PV into the grid can affect the stability of the power system. the PV penetration beyond 20% of the total power generated will degrade the frequency stability of the power system but they have not considered the optimal placement of the PV.

The dynamic analysis of PV integration showed that change in the temperature and irradiance can affect the performance of the grid and may lead to the voltage collapse due to the sudden change or fluctuation if there is no proper reserve to peak up the load. So many works have proved that the non-optimal and sizing of the PV or non-sizing and optimal placement of the PV can degrade the quality of the power system thus it is important to study the optimal placement under the constraints of active power capacity and voltage limits of the PV in the distribution system.

To achieve the main objective, the following specific objectives of the research are developed and outlined briefly.

1. Model the power distribution system with the solar PV at suitable bus.
2. Formulate the objective function and determine the constraints.
3. Determine the location, size of the PV and the minimum active power losses.

4. Evaluate the performance of the proposed approach with the existing methods.

Impact of PVDG Location and Size on Power Losses

Regarding on power losses, there is evidence that PVDG location and size has effect in 33kV distribution networks as DG injects active power to the network. Adding of the suitable capacity of the PVDG with respect to the feeder's capacity will show a positive effect on the losses. On the other hand, high penetration of PVDG to the distribution network will increase the power losses which cause the reverse power flow.

Power losses (I^2R) are caused by the current flowing through the transmission line, transformer and distribution conductors. It can be decreased by reducing the resistance of the cable conductors or decreasing the load current flowing through them. The closer the distance of generation takes place to the loads, the lower the power losses as the voltage drop decreases at the same time the resistance of the conductors decreases.

In addition to what has been mentioned previously, reduction of current flowing through the distribution and transmission network when installing DG will reduce the power losses too. The DG not only decreases active power but reactive power as it is like installing capacitor bank which aids in supply reactive power.

Sizing

As the size of the PVDG increases, the active and reactive power loss decreases first until to certain limit of size for PVDG and then increases.

Different Approaches used in the Solving the Siting and Sizing of DG.

The challenges due to the integration of DG have received considerable attention and many works have been done up to now to mitigate the effect of DG penetration. These techniques include classical approach, the analytical approach and the meta-heuristics approach such as:

1. The Genetic Algorithm (GA).
2. Tabu Search (TS).
3. Simulated Annealing (SA).

4. Particle Swarm Optimization (PSO).
5. Bacterial Foraging Optimization (BFO).
6. Trial and error.

These methods have their pros and cons given the estimate of how the power losses can be minimized. The results showed different voltage profile improvement and a level of DG integration.

Many techniques were applied to place the DGs in the power system to reduce the losses, and besides, many optimization tools including the artificial intelligence approaches like a Genetic Algorithm, Direct Search Algorithm, Tabu Search, particle swarm optimization(PSO) were also used to achieve the same objective.

The analytical method of reducing energy loss in the basic distribution system has been proposed. The intelligent method, which includes BGA and BFA, has been proposed to place DG in the distribution network, and its approach was to bridge by combining two different algorithms.

The thumb rule technique was presented for the optimal location of the capacitor for reactive power support. This method is easy and efficient, but it failed to analyze the other types of loads or the unbalanced loading systems. The direct search algorithm has been used to obtain a perfect position for PV in distribution systems with three connected DGs.

Optimal placement and sizing of DGs for active loss and total harmonic distortion (THD), reduction and voltage profile improvement using sensitivity analysis and PSO have been presented, and it was presented based on the heuristic approaches, a novel optimal placement of a Photovoltaic system for loss reduction and the improvement of voltage profile.

ABC algorithm was proposed for the reconfiguration of the system power loss reduction. The results were compared to the existing algorithm, and they concluded that the ABC had a better performance than others, such as Tabu search, GA and Simulated Annealing (SA).

The metaheuristic method ABC used for the optimal placement and sizing of DG for power loss reduction and improved voltage profile. The power branch loss formula was used to formulate the objective function, and the results were compared to the grid search method.

The maximum power loss saving technique was introduced to identify the placement and optimal sizing of the DG. Although the results were satisfactory, only the unity power factor was considered throughout the study. And a simple analytical method proposed based on iterative search technique and Newton-Raphson method for the optimal sizing and allocation of DG in a network to lower the cost and loss effectively. They used the weight factors between the loss and cost in the study.

Each approach has its efficiency, advantages and limitations in solving the effect of the integration of the Distributed Generation in the electrical systems. The metaheuristic population-based algorithms are to be fast and required less storage, but they are probably based so their results can't be guaranteed due to so many manipulations of parameters and they depend on the analytical equations.

The analytical methods used as benchmark methods. The analytical methods are more accurate than the meta-heuristic methods for the smooth objective functions [30] [31].

2.10 Optimum Penetration Level of PV Generation for Distribution System Load Transfer

Penetration level of PV generation happens when the output power of the PV system becomes more than the load demand, reverse power flow and voltage fluctuations is the real reasons of this problem.

The progress in new technologies in the last few years has led to a significant decrease in the price of PV panels. However, concerns have appeared for the grid operators about voltage and current violations in the grid as the number of these panels is rapidly increasing, and this also leads to increase the amount of Penetration level [9].

It is necessary to determine maximum penetration of these panels in the existing grid, without violating the grid criteria. It should be mentioned that determining the maximum penetration level of PV panels with respect to voltage and current limitations of the grid, as they are considered to be the most important indices in the grid, Transformer capacity is also an important factor to take into account [10].

High penetration of PV panels causes the overvoltage problem, and it's proposing to solve it using power curtailment or controlling reactive power for a single feeder.

Steady state analysis is conducted for the grid in 15-minute time intervals to determine voltage deviations and power flow of the feeders and transformer, to decide if there is a penetration level or not, To do so, modeling PV panels in an appropriate way is necessary. Different models have been proposed for PV panels.

However, these models are built for specific reasons and have their own parameters and variables which are not a concern from the steady-state point of view. The PV panel as a function of irradiation and ambient temperature, This model covers the main factors which affect the output power of a PV panel.

PV penetration is defined as the ratio of total peak PV power to peak load apparent power on the feeder:

PV Penetration = (Peak PV Power) / (Peak Load Apparent Power)   (2.4)

When increase PV penetration in distribution feeders, the interrupted power generation of PV systems will have a negative impact to the distribution system operation, and the reverse power flow may cause of relay settings and the voltage fluctuation may risk the voltage regulation by conventional tap changers of substation transformers [9] [10].

And so, overvoltage problem may be also encountered in distribution feeders when multi customers install PV systems, Furthermore the operation of load transfer between distribution feeders will introduce even more constraint of PV capacity to be connected to a distribution system, all these things makes the high penetration level a real problem [11].

To mitigate the overvoltage problem introduced by the injection of intermittent DG power generation. Reactive compensation facilities such as STATCOM have been used at the connection point to improve voltage flicker.

An area-based on load tap changing transformers (OLTCs)/voltage regulators coordinated voltage control has been applied for reactive power management. Some technique approaches allow the DG's to absorb reactive power.

A hybrid photovoltaic and battery energy storage system has also been proposed for demand side applications. The proposed active power curtailment techniques are presented for increasing the installed PV capacity and energy yield [12].

To reduce the voltage drop on PV system installed to provide the dispersed generation for the local loads, the penetration level of the PV system is further limited due to the violation of voltage variation introduced by the large intermittent PV power generation when the load transfer is finished.

The installation of a PV generator in the distribution network shows an improvement in the voltage profile and reduction of power losses [11].

The PV inverters applied in the residential and small customers are required in many countries to have the embedded function of overvoltage tripping.

The impact analysis is required for the large PV installation with capacity over 100kWp to ensure that the voltage variation at PCC to be less than 2.5%. To maintain system power quality and achieve better renewable energy utilization by allowing higher penetration of unstable PV power generation. Various impacts on the distribution system with increasing the PV penetration in a distribution network, both positive and negative shown in Table 2.3 [12].

Table 2.3: impacts of increasing PV penetration

Sr. No.	IMPACTS	IMPACTS ON	NATURE	IMPACT WITH 5% PV PENTERATION	IMPACT WITH > 40% PV PENTERATION
1	Voltage rise of reverse power flow	Dist Transformer and Grid	Bad	No problem	Bad
2	Transformer Tap changing	Transformer	Bad	No problem	Bad
3	Phase Imbalance	Distribution Network	Bad	No problem	Bad
4	Transformer Insulation	Transformer	Good	Good	Good
5	Transformer lifetime	Transformer	Good	Good	Good
6	DC bias	Transformer	Bad	No problem	bad
7	Power factor	Dist Transformer and Grid	bad	bad	Bad

8	Fault current	Transformer/ Protection Device	bad	No problem	Bad
9	Protection	Circuit Breaker	bad	No problem	Bad
10	PV System Islanding	Distribution side	bad	No problem	Bad
11	Harmonics	Transformer	Bad	Bad	bad

There are many PV systems installed worldwide with high penetration levels of PV electricity. Most projects are being monitored in order to provide practical into the expect impacts if similar penetrations are to be installed in existing networks.

To further improve system reliability and increase the PV penetration level of the distribution system, the smart distribution system which covers the automation of laterals and customers as well as the primary feeder becomes an important platform to support more advanced functions such as demand response, smart EV charging and smart PV generation.

The voltage control algorithm for PV systems is considered to be included in the advanced distribution automation system (ADAS). The partial PV generation curtailment prevents overvoltage when excessive power is generated by the PV system or when load transfer is performed to restore service after a system fault contingency [11] [12].

When the penetration level of grid tied PV on the grid increased above 50% of the transformer load, the distribution transformer would suffer from very poor power factor values and reverse power flow was detected on the grid towards the source causing the grid to appear as a reactive power source only, which beside the law power factor value would lead to less efficient grid elements and equipment and to heating generation due to the reactive power flow which will decrease their life time.

Although the lines losses decreased as the PV penetration level increased and voltage levels improved at 25% PV penetration level. However after 50% penetration level, over voltage on the grid appeared beyond the acceptable range according to IEC and grid code,

especially on the rural feeder with high impedance and low loads, a significant current swing occurred and exceeded 100 A at 80% penetration level.

No evidence of over voltage values where investigated at any PV penetration levels, but also no significant improving on the voltage level were noted on poor values buses voltages. Power factor of source bus decreased significantly as the penetration of the grid tied PV station capacity increased. Negligible effect of the line losses improvement appeared at all the tested penetration levels. An important current swing occurred beyond 50% penetration level.

Load Transfer

In Electric distribution systems for economic reasons and effective coordination of the protection devices the distribution systems are normally operated in a radial configuration, and for the reliability of such networks is improved by altering the ON or OFF states of the tie and sectionalizing switches during fault conditions, thus providing fast restoration of service to customers.

Network reconfiguration is also often conducted to transfer loads from heavily loaded lines to lightly loaded ones, and the targets of this transferring are isolating faults and for maintenance purposes.

The procedure of transferring load between the two feeders consists of closing the tie switch (that is normally open), then opening a sectionalizing switch (that is normally closed) along the overloaded feeder, thus returning the feeders back to radial operating mode a short time later.

It's necessary before break scheme or feeder paralleling since the network is temporarily operated in a loop configuration during this time is necessary to avoid a temporary power outage and make such changes transparent to the utility customers.

Loop operation during the short time period while conducting load transfer results in a new current flow through the sectionalizing switch that is normally below its load break rating, hence no problems occur during the opening.

In some special situations, it is possible that feeder paralleling leads to excessive currents that result in a hazard to the utility personnel opening the switch. Under worst

conditions, loop operation may even lead to feeder currents high enough to trigger over-current relays which result in an outage immediately after closing the tie switch.

Since each switch is rated for certain current that it can successfully break when operated, it is important that such rating is not exceeded during load transfer.

A simplified circuit model that requires only hand calculations is used to predict the current flow through the switches. It found that load break rating may be exceeded under a situation, one of the feeders is fed from a heavily loaded bank of two parallel transformers, and the other feeder is supplied by a lightly loaded stand-alone transformer of similar rating [14] [15].

To simplify the analysis of transferring part of the load of one feeder to another, the following assumptions are made:

- The sub-transmission or transmission network is represented by a Thevenin equivalent (two identical sources with different impedances).
- The transformer taps change is ignored.
- The system is assumed to be balanced so that single phase analysis can be applied.
- Loads and line impedances are lumped, not distributed along the feeder.
- Cable capacitance is ignored.
- Switched shunt capacitors are assumed not to change state.

The above assumptions lead to a simplified diagram in Figure 2.12 below.
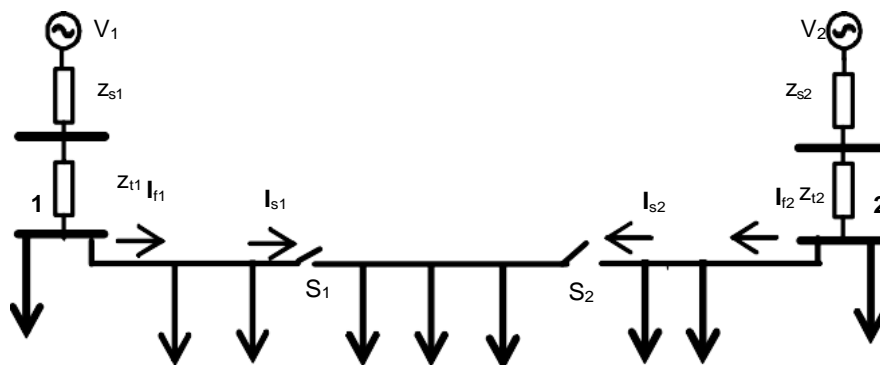
Figure 2.12: Single-Line Representation of Feeders During Load Transfer.[7].

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From the above figure (Figure 2.12), switch S1 is normally closed, while tie switch S2 is normally open. The load between the two switches is to be transferred from feeder 1 (on the left) to feeder 2 (on the right). The centerline section sources (parallel) when both switches S1 and S2 are closed.

3

Chapter Three

Standards of Grid Codes for PV Power Integration

3.1 Voltage Control

3.2 Frequency Control

3.3 Reactive Power Capability

3.4 Power System Stabilizers

3.5 Power Quality

3.6 Active Power Generation

3.7 Grid Disturbance Operation

3.1   Voltage Control

There are a requirement and need for automatic voltage regulation for PV plants. For PV plant technologies use voltage source inverters, automatic regulators may be applied to regulate the reactive output, to maintain a certain voltage. E.g. at the point of interconnection between the PV plant and power system.

In other cases voltage regulation can come from a supervision control system regulating the reactive resources throughout the PV plant. For larger PV installations, SVC coordinated together with a number of mechanically switched capacitors can provide the required voltage regulation. For smaller PV plants in distribution systems, DVAR can be utilized and below table explain (Table 3.1).

Table 3.1: Voltage range

Supply voltage variation		
VDE-AR-N 4015 Germany	RD 661/2007 Spain	Arrêté 2011 France
$0.8Un \leq 1.1Un$	$0.85Un<U<1.1Un$	$0.9Un<U<1.1Un$

3.2   Frequency Control

Frequency control for PVG is possible, but not to the same degree as frequency control with a regulator on a classical generator. PV plants should not actively participate in primary frequency control during under-frequency. Having a "regulator like" control for a PV plant control scheme is a technical possibility and even desirable.

However, it is reasonable to recommend that a PV plant meets an off-nominal frequency operating condition similar to the appropriate operation standards (that is used by many utilities for wind farms and classical generating plants) [19].

Table 3.2: Frequency range versus time

Frequency range (HZ)	Time (second)
>61.7	0
61.6 to 61.7	30
60.6 to 61.6	180
>59.4 to 60.6	Continuous Operation
>58.4to 59.4	180
>57.8 to 58.4	30

3.3 Reactive Power Capability

Reactive power capability requirements and power factor (PF) control for larger PV plants should be similar to those for wind generation.

Reactive power compensation is desirable for PV units. Reactive power capability is measured at the low voltage side of the PV substation.

A PV plant at its full load, should be capable of 0.90 PF lagging and 0.95 PF leading. Automatic voltage regulation that is able to regulate the voltage at this point to a "desired" set-point to within +/-0.5%.

The voltage regulation system should have adjustable gain, sag and a reference set-point. Voltage regulation should be provided to adequately control voltage at the point of interconnection throughout the range of power delivery of the PV plant and coordinated with other voltage regulating devices on the transmission system.

In cases where a good portion of reactive compensation is provided at the PV substation in the form of an SVC such coordination is more easily achieved since it is done through a centralized control.

Moreover, the device may be more easily used for voltage regulation even when the PV is disconnected since it is directly connected to the substation. In general consensus, it is believed that a power factor (PF) requirement of +/- 0.95 at the point of interconnection is a reasonable requirement [20].

3.4   Power System Stabilizers

Power System Stabilizer (PSS), clearly, in the traditional sense, PSS does not apply to PV generation since they are essentially used for synchronous units. PV units are essentially decoupled from the system and do not really participate in electromechanical modes of rotor oscillation.

The fundamental concept behind PSS tuning is to introduce a component of damping torque on the shaft of a generator in the range of frequencies associated with electromechanical modes of rotor oscillation.

However, based on the generalization of concept of power system stabilizer, it may be possible to design stabilizers for a PV plant controller to modulate the output power to improve the damping of inter-area modes. Similar stabilizers have been proposed for SVC and HVDC.

This would be contingent on the location of the PV plant and thus the controllability of the mode from the PV plant location. To be fully effective, a PV plant needs to be online to obtain the full benefit of all stabilizers (the PV output and status are difficult to predict). Therefore, at this time, PSS application on the PV plant controllers it is not generally recommended.

The cost of implementing some of the recommended control functionalities described earlier may very well exceed the benefits. Since such PV size units may not significantly contribute to the bulk system performance (e.g. transmission connected PVs vs. distribution PVs).

The benefits of this section become evident when applied to large PV plants (e.g. 50, 100 MW and larger) connected to a transmission system. Smaller PV systems (e.g. 5 to 10 MW), are less significant to the distribution system and have no net active power delivery into the transmission system. As such, these units may not significantly contribute to the overall system performance [19] [20].

3.5   Power Quality

Power quality relates all the deviations produced by the interaction between the grid and its customers from the ideal supply characteristics. The impact of PV generation onto the distribution system is grasped as an increase of disturbance emissions, which will have a direct influence over the local behavior of the network with the potential of conveying to higher levels if they are not kept under safe limits.

The effect of low emissions should reflect on low losses, reduced possibility of false tripping, increased lifetime of the equipment or even prevent the damage to some parts of the system.

PV plants should be expected to meet the power quality requirements of their respective operator. This is in line with IEEE Std 519. PV plant owners should be responsible for performing studies were necessary to ensure that they avoid low-order harmonic resonance phenomenon on their system due to shunt capacitors (or cable charging) and power electronics.

PV voltage/power variation due to variation in the solar irradiance may also cause voltage flicker. The PV plant owners should take steps to minimize flicker problems from their generation. The standards for voltage fluctuations at the point of connection of the PV plant facility to the power system should, for example, follow the requirement outlined in Table 3.3.

Table 3.3: Suggested Voltage Fluctuations Limits

Voltage Change	Maximum Rate of Occurrence
+/-3% of normal level	once per hour
+5/-6% of normal level	once per 8-hour
Exceeding +5/-6%	As agreed by utility

Voltage and current harmonics can cause telecommunication interference and thermal heating in transformers; that can disable solid-state equipment and create resonant over voltages. In order to protect and mitigate the PV plant equipment (power electronic interface) should not cause voltage and current harmonics on the power system and adhere to IEEE Standard 519 [19] [20].

- Current harmonics

The test and measurements according to the IEEE 1574/IEC 61727 should be done using an electronic power source with a voltage THD<2.5%.

The current limits in the IEC 61000-3-2 are given in amperes and are in general higher than the ones in IEC 61727. In case of PV systems with a higher current than 16A, but lower than 75A the IEC 61000-3-12 standard applies . The standard limits for current harmonics are given below.

Table 3.4: Harmonics limit

IEEE 1547 and IEC 61727					
Individual harmonic order (odd)	h < 11	11 ≤ h < 17	17 ≤ h < 23	23 ≤ h < 35	35 ≤ h	THD (%)
%	4	2	1.5	6	3	5

- Unbalance

In the EN 50160 voltage unbalances produced a 3-phase inverters should not exceed 3% . The VDE-AR-N 4105 allows a maximum unbalance of 4.6 kVA between the three phases and a maximum installed power of 10 kVA for single phase connection.

In case the installed power of the PV system exceeds 30 kVA only three phase connection is allowed. Table 3.5 summarizes the requirements.

Table 3.5: VDE-AR-N 4105 allowed voltage unbalance

L1(kVA)	L2(kVA)	L3(kVA)	Unsymmetrical	Allowed
4.6	0	0	4.6	YES
4.6	2.5	0	4.6	YES
10	6	8	4	YES
10	5	3	7	NO
10	7	11	4	NO
10	10	11	1	NO
50 kVA (3-phase AC)			0	YES

- DC current injection

The limits for the DC component of the injected current shown in Table 3.6 specify that the PVPPs current should be measured using harmonic analysis, but in some of the standards there are no specifications about the maximum trip time condition.

Table 3.6: DC current monitoring

IEEE 1574	IEC 61727	VDE 0126-1-1
IDC < 0.5 [%]	IDC < 1 [%]	IDC < 1A Max Trip Time 0.2 s

In other regulations like EN 50438, systems which inject currents with DC components are not allowed to be connected to the grid.

- Flicker

In IEEE 1547 is mentioned that the PVPP shall not create observable flicker for other customers while in the IEC 61727 and EN 50438 different rules are applied:

- For systems <16 A, IEC 61000-3-5 shall be applied.
- For systems >16 A, IEC 61000-3-5 shall be applied.

3.6 Active Power Generation

The system control center (transmission system operator - TSO), through telemetry, should have a means at all times to monitor the megawatt output of a PV plant and whether or not it is on or off-line due to solar irradiance.

The 15 minute average megawatt output of a PV plant must not at any time exceed the specified maximum output of each PV plant.

The system control center, through contact with the PV plant operator, must have a means of issuing a directive to reduce the megawatt output of the PV plant, or curtail the PV plant in the event of an emergency condition where the PV plant output is to be reduced to

respect thermal limits on nearby transmission corridors or when otherwise generation far exceeds demand.

Alternatively, the PV plant operator may intentionally disconnect blocks of PV modules in the plant to effect a reduction in the generation. In any case, this should be done in a controlled fashion and at the specified rate by the operator (e.g. certain number of MW/minute).

All PV modules in a single PV plant must not start or stop simultaneously. This can be achieved through sequencing of the start-up and shutdown controls of the PV modules in a plant.

3.7   Grid Disturbance Operation

During frequency deviations the disconnection of large MV PVPPs may create instability and in consequence recent GCs impose restrictive actions.

For example, in Germany after the "50,2Hz problem" the GC states that during frequency increase the generating plant has to reduce its active power by 10 % of the nominal power down to 0 with 10%/min rate without the disconnection from the LV or MV network. After exceeding the threshold limit the reduction of active power P has to be made with a gradient of 40 % P/Hz.

The power is allowed to increase once again if the frequency reaches once again the value of 50.05 Hz. If the frequency increases even more the PVPP is disconnected from the grid. After reconnection the active power may increase with 10%/min.

The technical requirements for a frequency increase show that the PVPP must be more and more grid interactive but also raises the problem of adjusting the already installed plants [19] [20].

4

Chapter Four

Case Study; Maslamani Plant, Tubas

4.1   Maslamani Station Description

4.1   Main Components of PV Station

4.2   Study and Analysis of Photovoltaic Station Data

4.1 Maslamani Station Description

The maslamani photovoltaic station is located in faraa camp south of tubas, and the capacity of this photovoltaic station is 3 megawatt (3MW), which integrated to the main distribution network.

Maslamani photovoltaic station consists of 9,481 solar panels and 51 inverters distributed to a group of areas as will explained in the next section. The maslamani photovoltaic station connected to the main distribution network. On the next page we show the design of the photovoltaic station on the ETAP software.

4.2 Main Components of PV Station

4.2.1 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 [21].

4.2.2 Molded Case Circuit Breaker (MCCB)

Molded case circuit breakers are a type of electrical protection device that is commonly used when load currents exceed the capabilities of miniature circuit breakers. They are also used in applications of any current rating that require adjustable trip settings, which are not available in plug-in circuit breakers and MCBs.

The main distinctions between molded-case and miniature circuit breaker are that the MCCB can have current ratings of up to 2,500 amperes, and its trip settings are normally adjustable. An additional difference is that MCCBs tend to be much larger than MCBs. As with most types of circuit breakers, an MCCB has three main functions:

- Protection against overload.
- Protection against electrical faults.
- Switching a circuit on and off

The wide range of current ratings available from molded-case circuit breakers allows them to be used in a wide variety of applications. MCCBs are available with current ratings that range from low values such as 15 amperes, to industrial ratings such as 2,500 amperes. This allows them to be used in both low-power and high-power applications [22].

4.2.3 Main Distribution Boards (MDB)

An MDB is a panel or enclosure that houses the fuses, circuit breaker and ground leakage protection unit where the electrical energy, which used to distribute electrical power to numerous individual circuit or consumer points, is taken in form the transformer or an upstream panel.

An MDB typically has a single or multiple incoming power sources and includes main circuit breaker and residual current or earth leakage protection device. A MDB is a comprised of a free standard enclosure, a bus bar system, MCCB's, metering and support equipments and required current transformer. Panels are assembled in a systematic manner such as incomer section and outgoing section.

4.2.4 Ring Main Unit (RMU)

A standard piece of switchgear in distribution systems comprising of switches for switching power cable rings and of switches in series with fuses for the protection of distribution transformers.

RMU used for H.T. side. RMU is having 3no.s of switches(Circuit Breakers or Isolators or LBS), it is used for two inputs with mechanical or electrical interlock and one outgoing to the load. Either one input with two outgoings. RMU used for redundancy feeder's purpose.

Ring main unit is used in a secondary distribution system. It is basically used for an uninterrupted power supply. Alongside, it also protects your secondary side transformer from the occasional transient currents.

Depending on your applications and loading conditions you can use a switch fuse combination or a circuit breaker to protect the transformer. This transformer connected to the switch fuse/ circuit breaker is called your T off. In a common arrangement you have Load break switches on both the sides of your T off [24].

4.2.5 Load Break Switch (LBS)

A 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.

An air switch can be modified to include a series interrupter (typically vacuum or SF6) for higher voltage and current interrupting levels.

These interrupters increase the load break capability of the disconnect switch and can be applied for switching load or fault currents of the associated equipment [25].

4.2.6 Relay REF615

REF615 is a dedicated feeder protection and control relay for protection, control, measurement and supervision of overhead lines and cable feeders in utility and industrial power distribution systems, including radial, looped and meshed distribution networks, with or without distributed power generation.

Compact and versatile solution for utility and industrial power distribution systems with integration of protection, control, monitoring and supervision in one relay [26].

Scope

- Feeder protection for overhead lines, cable feeders, and busbar systems of distribution substations.

Product Benefits

- Maximized capital by keeping assets working longer with designs that require less equipment and space.
- Enhanced safety by reducing hazards with safety-conscious designs.
- Increased reliability by maintaining vital operations with steady, high-quality power every minute of every day.
- Reduced operating costs with effective energy management and maintenance strategies.
- More flexible system upgrades without rewiring or changing components.
- Ease of integration with non-proprietary IEC 61850 communications.

Product Features

- Draw out design.
- Underground, overhead cable fault detection (CFD).
- High-impedance (HIZ) fault detection.
- Arc flash detection (AFD).
- Ring-lug terminals for all inputs and outputs.
- Large, easy-to-read LCD.

Relay REF615 with the following:

- 67N Protection directional over current.
- Loss of main protection (LOM).
- Over/Under voltage protection.
- Over/Under frequency protection.
- Phase failure.
- Phase sequence.
- Thermal Protection.
- Frequency rate of change [26].

4.3 Study and Analysis of Photovoltaic Station Data

The PV power plant is divided into two stations. The first power station, which Give a value of 1878.7kWp of the total power plant, which is approximately 62.6% of the total production value of the station.

The First PV Station (1878.7kWp)

The first power plant divided into 4 areas, Where the amount of production varies for each of the other regions:

<p align="center">**Table 4.1:** The first PV station data(1878.7kWp)</p>

Area	Number of modules in the area	WP of the modules (Wp)	Output power from the area (kWp)
4	1710 modules	320	547.2
1	1710 modules	320	547.2
2	1501 modules	320	480.32
3	950 modules	320	403

The following block diagram, show The general steps that follow the process of producing energy from the solar cells until they reach the transmission line, which is transmit the power to the distribution network.
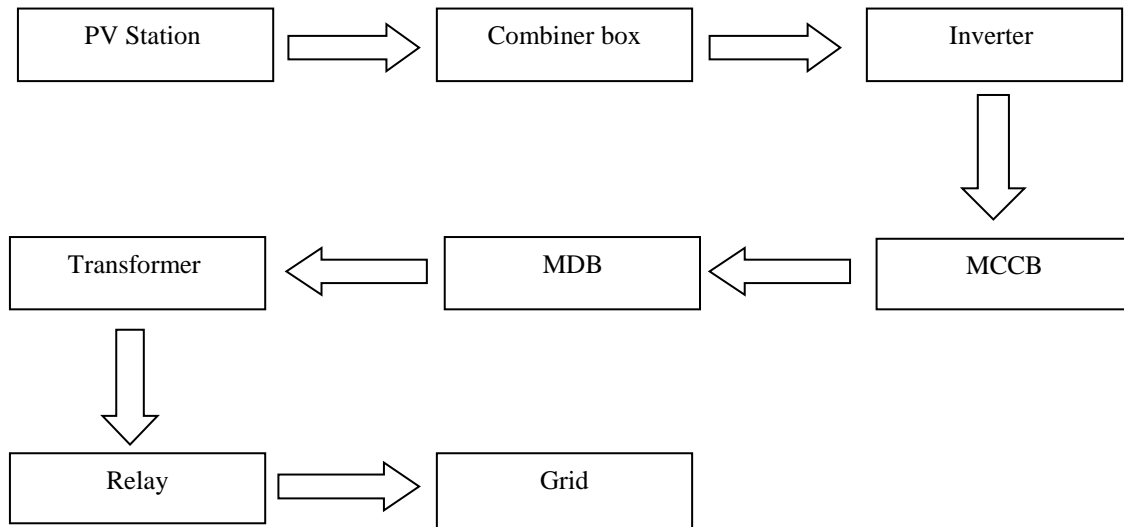
Figure 4.1: Block diagram for the first PV power plant(1878.7kWp).

The First PV Power Plant Explanation (1878.7kWp):

Area 4 connected to the combiners boxes, which have the following details:

- 9 combiner boxes used.
- Each combiner box includes 10 strings $\times$ 19 modules.

The combiner boxes then connected to the inverters:

- 9 inverters used (each combiner box connected with one inverter).
- The type of inverter is sunny tripower 60.

- Each inverter then connected to the Molded Case Circuit Breaker (MCCB):
- 9 MCCB used (each inverter connected with one MCCB).
- phase-100ampere MCCB used.
- MCCB's connected to the MDB-1, and the MDB-1 then connected with one transformer:
- Three phase transformer star-delta connected.
- 630KVA, 50Hz Transformer 0.4/33kV.

```
┌─────────────────────┐      ┌─────────────────────┐      ┌─────────────────────┐
│       Area 4        │      │    combiner box     │      │      Inverter       │
│ 1710 modules × 320Wp│ ══▶  │  9 combiner boxes   │ ══▶  │     9 inverters     │
│     (547.2kWp)      │      │(10 strings × 19 modules)│   │                     │
└─────────────────────┘      └─────────────────────┘      └─────────────────────┘
                                                                      ║
                                                                      ▼
┌─────────────────────┐      ┌─────────────────────┐      ┌─────────────────────┐
│    transformer      │      │                     │      │        MCCB         │
│ star-delta connected│ ◀══  │        MDB-1        │ ◀══  │       9 MCCB        │
│   630KVA, 50Hz      │      │                     │      │                     │
│ Transformer 0.4/33kV│      │                     │      │                     │
└─────────────────────┘      └─────────────────────┘      └─────────────────────┘
          ║
          ▼
┌─────────────────────┐
│       Relay         │
│      REF615         │
│                     │
│                     │
└─────────────────────┘
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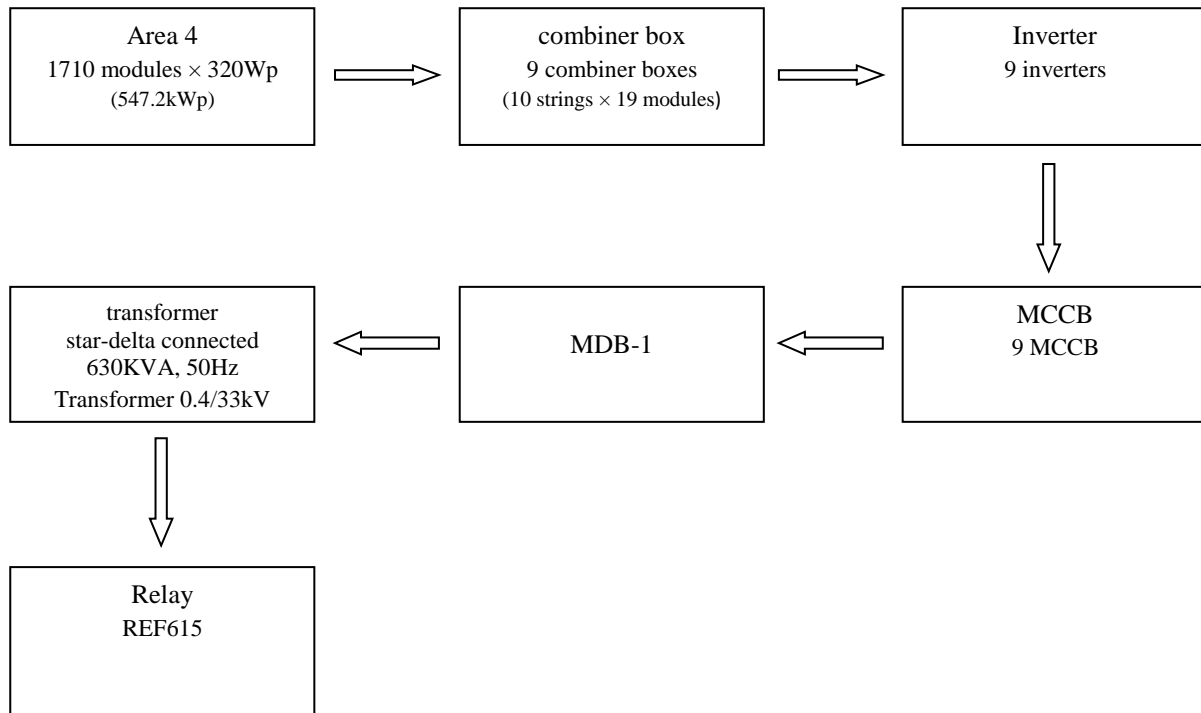
Figure 4.2: .Block diagram for the area 4 power plant(547.2kWp).

Area 1 connected to the combiner boxes, which have the following details:
- 9 combiner boxes used.
- Each combiner box includes 10 strings × 19 modules.

The combiner boxes then connected to the inverters:

- 9 inverters used (each combiner box connected with one inverter).
- The type of inverter is sunny tripower 60.

- Each inverter then connected to the Molded Case Circuit Breaker (MCCB):
- 9 MCCB used (each inverter connected with one MCCB).
- Phase-100ampere MCCB used.
- MCCB's connected to the MDB-2, and the MDB-2 then connected with one transformer:
- Three phase transformer star-delta connected.
- 630KVA, 50Hz Transformer 0.4/33kV.
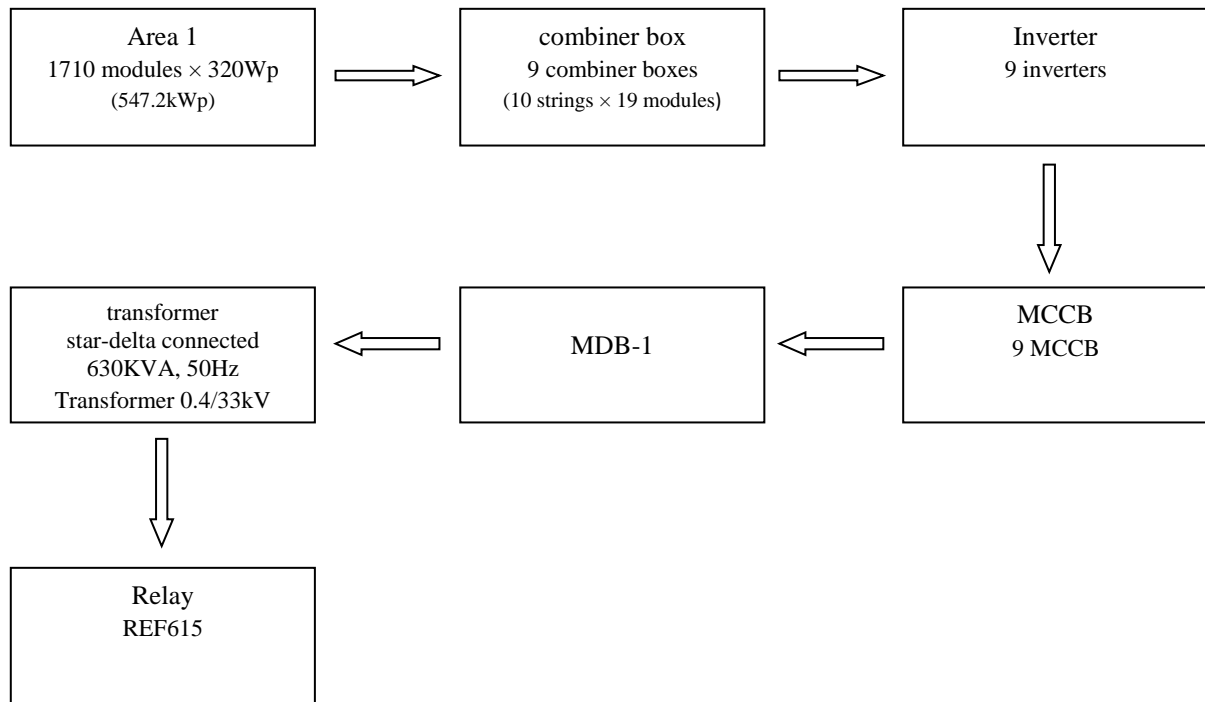
Figure 4.3: Block diagram for the area 1 power plant(547.2kWp).

Area 2 connected to the combiner boxes, which have the following details:

- 8 combiner box used.
- One of combiner boxes includes 9 strings × 19 modules and the others includes 10 strings × 19 modules .

The combiner boxes then connected to the inverters:

- 8 inverters used (each combiner box connected with one inverter).
- The type of inverter is sunny tripower 60.

- Each inverter then connected to the Molded Case Circuit Breaker (MCCB):
- 8 MCCB used.
- Phase-100 ampere MCCB used.
- MCCB's connected to the MDB-3, and the MDB-3 then connected with one transformer:
- Three phase transformer star-delta connected.
- 630kVA, 50Hz Transformer 0.4/33kV.
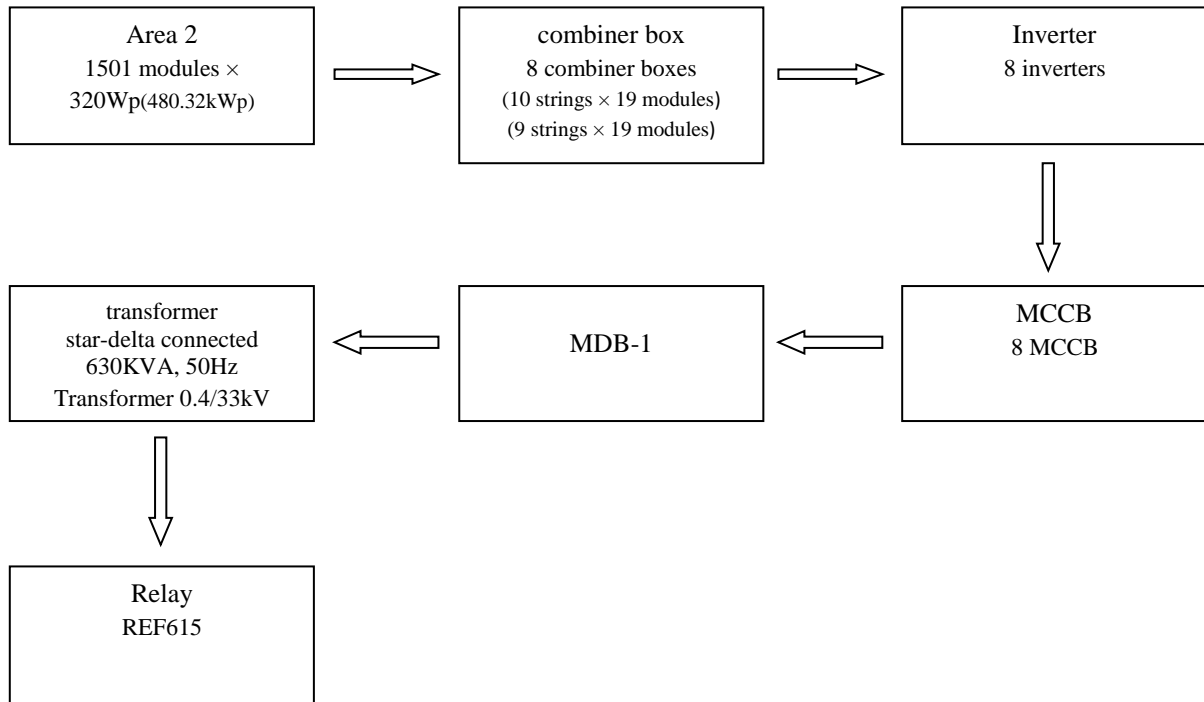
Figure 4.4: Block diagram for the area2 power plant(480.32kWp).

Area 3 connected to the combiner boxes, which have the following details:

- 5 combiner boxes used.
- Each combiner box includes 10 strings × 19 modules.

Combiner boxes then connected to the inverters:

- 5 inverters used (each combiner box connected with one inverter).
- The type of inverter is sunny tripower 60.

- Each inverter connected with Molded Case Circuit Breaker (MCCB):
- MCCB used.
- Phase-100 ampere MCCB used.
- MCCB's connected with MDB-4 then connected with one transformer:
- Three phase transformer star-delta connected.
- 400KVA, 50Hz Transformer 0.4/33kV.
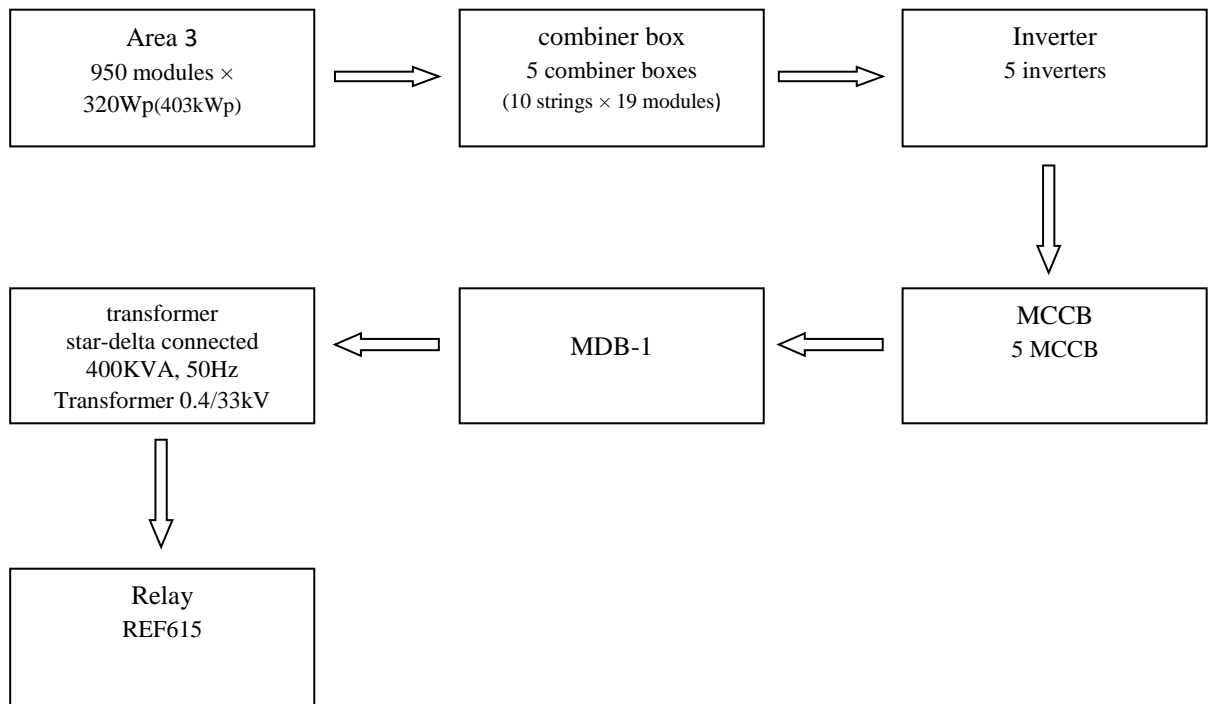
Figure 4.5: Block diagram for the area3 power plant(403kWp).

The transformers then connected to the Relay(Relay REF615), and then to the grid.

The following table show the output current and the output voltage from each area, which are calculated based on the data sheet for the PV.

Table 4.2: the output current and voltage from each area in the first PV station

Area	Output current (A)	Output voltage (V)
4	826.2	7795.89
1	826.2	8662.1
2	725.22	6929.68
3	459	4331.05

The Second PV Station (1121.28kWp):

The seconds power station, which Give a value of 1121.28kWp of the total power plant, which is approximately 37.4% of the total production value of the station. the seconds power plant divided into two areas.

The second power plant divided into 2 areas, Where the amount of production varies for each of the other regions:

Table 4.3: The second PV station data(1878.7kWp)

Area	Number of modules in the area	Wp of the Modules (Wp)	Output power from the area (kWp)
5	1910	320	608
6	1710	320	547.2

Figure 4.8 show The general steps that follow the process of producing energy from the solar cells until they reach transmission line, which is transmit the power to distribution network.
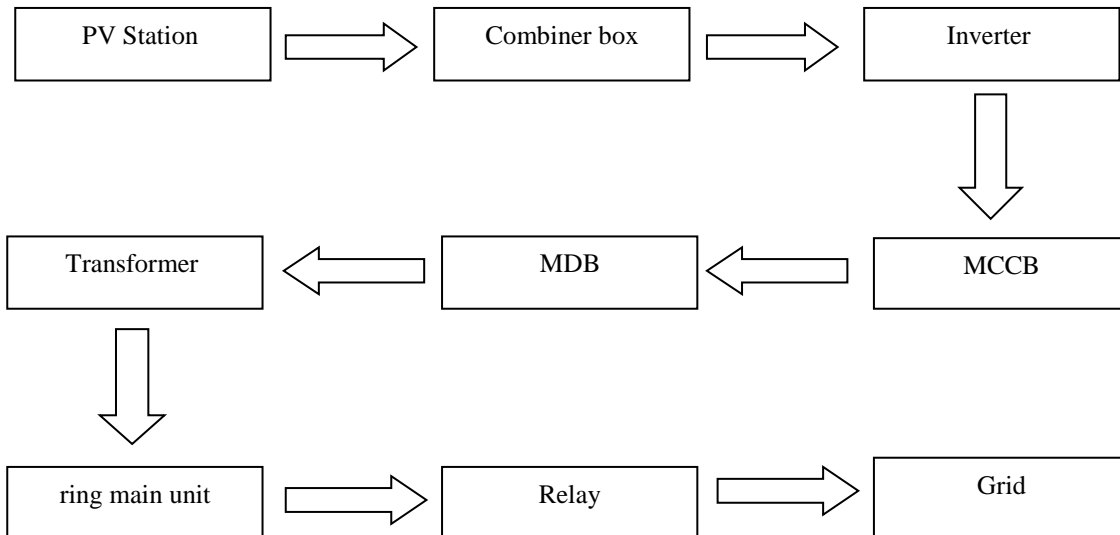
Figure 4.6: Block diagram for the first PV power plant(1121.28kWp)

The Second PV Station Explanation (1121.28kWp):

Area 5 connected to the combiner boxes, which have the following details:

- 10 combiner boxes used.
- Each combiner box includes 10 strings × 19 modules.

Then combiner boxes connected with inverters:

- 10 inverters used (each combiner box connected with one inverter).
- The type of inverters is sunny tripower 60.

- Each inverter connected to Molded Case Circuit Breaker (MCCB):

- 10 MCCB's used.

- Phase-100ampere MCCB used.

- MCCB's connected to MDB-5 then connected with one transformer:

- Three phase transformer star-delta connected.

- 630KVA, 50Hz Transformer 0.4/33kV.

```
┌─────────────────┐      ┌─────────────────────┐      ┌─────────────────┐
│     Area 5      │      │    combiner box     │      │    Inverter     │
│  1900 modules × │ ===> │  10 combiner boxes  │ ===> │   10 inverters  │
│  320Wp(608kWp)  │      │(10 strings × 19 modules)│  │                 │
└─────────────────┘      └─────────────────────┘      └─────────────────┘


┌─────────────────┐      ┌─────────────────┐      ┌─────────────────┐
│   transformer   │      │                 │      │      MCCB       │
│star-delta connected│<==│      MDB-1      │ <==  │    10 MCCB      │
│  630KVA, 50Hz   │      │                 │      │                 │
│Transformer 0.4/33kV│   └─────────────────┘      └─────────────────┘
└─────────────────┘


┌─────────────────┐
│     Relay       │
│     REF615      │
└─────────────────┘
```
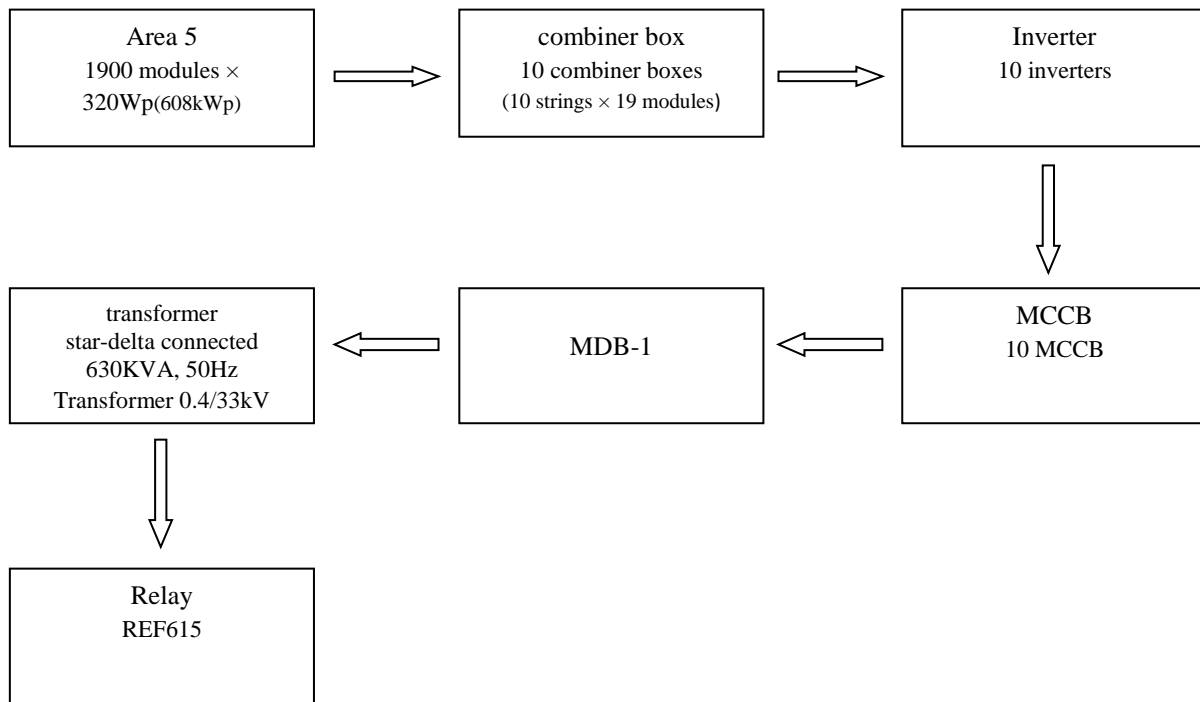
Figure 4.7: Block diagram for the area5 power plant(608kWp)

Area 6 connected to combiner boxes, which have the following details:

- 9 combiner boxes used.
- Each combiner box includes 10 strings × 19 modules.

Then combiner boxes connected to the inverters:

- 9 inverters used (each combiner box connected with one inverter).
- The type of inverter is sunny tripower 60.

- Each inverter then connected to Molded Case Circuit Breaker (MCCB):

- 9 MCCB used.

- Phase-100ampere MCCB used.

- MCCB's connected to the MDB-6 then connected with one transformer:

- Three phase transformer star-delta connected.

- 630KVA, 50Hz Transformer 0.4/33kV.
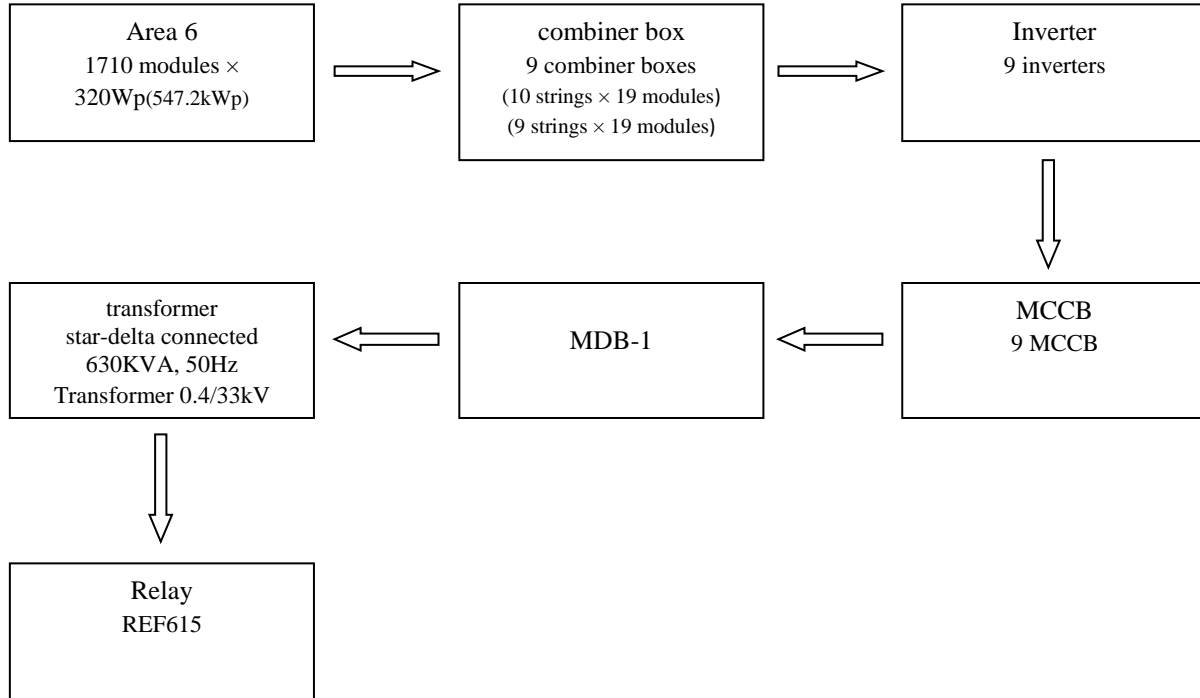
Figure 4.8: Block diagram for the area6 power plant(547.2kWp)

The transformers then connected to the Relay(Relay R/EF615), and then to the grid.

The following table show the output current and the output voltage from each area, which are calculated based on the data sheet for the PV.

Table 4.4: the output current and voltage from each area in the second PV station

area	Output current (A)	Output voltage (V)
5	918	8662.1
6	826.2	7795.89

Output Power From the Inverters (AC Power) :

$$\text{dc power}_{\text{inverter}} = \text{num. of string} \times I_{sc} \times \text{voltage of string} \times \mu_{\text{module}} \qquad (4.1)$$

$$\text{ac power}_{\text{inverter}} = \text{dc power}_{\text{inverter}} \times \mu_{\text{inverter}} \qquad (4.2)$$

$$\text{ac power}_{\text{total}} = \text{ac power}_{\text{inverter}} \times \text{num. of inverters} \qquad (4.3)$$

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Where:

I_{sc} : short circuit current

μ_{module} : efficiency of the module

For Area 4:

$P_{dc} = 10 \times 9.18 \times 866.21 \times \%83.51 = 66405.54694\text{Wp}.$

$P_{ac} = 6640554.694 \times \%98 = 65077.436\text{Wp}.$

$P_{ac}\ \text{total} = 6507743.6 \times 9 = 585696.924\text{Wp}.$

For Area 1:

$P_{dc} = 9 \times 9.18 \times 866.21 \times \%83.51 = 59764.99224\text{Wp}.$

$P_{ac} = 5976499.224 \times \%98 = 58569.6924\text{Wp}.$

$P_{ac}\ \text{total} = 5856969.24 \times 10 = 585696.924\text{Wp}.$

For Area 2 :

$P_{dc} = 10 \times 9.18 \times 866.21 \times \%83.51 = 66405.54694\text{Wp}.$

$P_{ac} = 6640554.694 \times \%98 = 65077.436\text{Wp}.$

$P_{ac}\ \text{total} = 6507743.6 \times 8 = 520619.488\text{Wp}.$

For Area 3 :

$P_{dc} = 10 \times 9.18 \times 866.21 \times \%83.51 = 66405.54694\text{Wp}.$

$P_{ac} = 6640554.694 \times \%98 = 65077.436\text{Wp}.$

$P_{ac}\ \text{total} = 6507743.6 \times 5 = 325387.18\text{Wp}.$

For Area 5:

$P_{dc} = 10 \times 9.18 \times 866.21 \times \%83.51 = 66405.54694\text{Wp}.$

$P_{ac} = 6640554.694 \times \%98 = 65077.436\text{Wp}.$

$P_{ac}\ \text{total} = 6507743.6 \times 10 = 650774.36\text{Wp}.$

For Area 6:

$P_{dc} = 10 \times 9.18 \times 866.21 \times \%83.51 = 66405.54694 Wp.$

$P_{ac} = 6640554.694 \times \%98 = 65077.436 Wp.$

P_{ac} total $= 6507743.6 \times 9 = 585696.924 Wp.$

The total ac power from the station $= \sum_{1}^{6}$ total ac power from each area $\qquad$ (4.4)

$= 585696.924 + 585696.924 + 520619.488 + 325387.18 + 650774.36 + 585696.924$

$= 3253871.8 Wp.$

Table 4.5: results of the power calculation for PV station.

area	Dc power/inverter (Wp)	Ac power/inverter (Wp)	Total Ac power (Wp)
4	66405.54694	65077.436	585696.924
1	59764.99224	58569.6924	585696.924
2	66405.54694	65077.436	520619.488
3	66405.54694	65077.436	32538718
5	66405.54694	65077.436	650774.36
6	66405.54694	65077.436	585696.924
total			3253871.8

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Chapter Five

Simulation & Results of PVsyst Software

5.1 PVsyst Design

5.2 Results and Simulation

5.1   PVsyst Design

The design of the photovoltaic system in faraa camp south of tubas have been applied on PVsyst software version 6.4.3.

In this section we make an explanation of the steps we have taken on the program to build the photovoltaic station on the software.

Initially, we have entered the coordinates of the in faraa camp site for the program (latitude, longitude, and altitude). As shown in the following figure (Figure 5.1).

Figure 5.1: geographical site parameter of the AL- Faraa camp

After entered the coordinates of the site, we entered the orientation of the PV modules (tilt angle, and azimuth angle). As shown in the following figure (Figure 5.2).
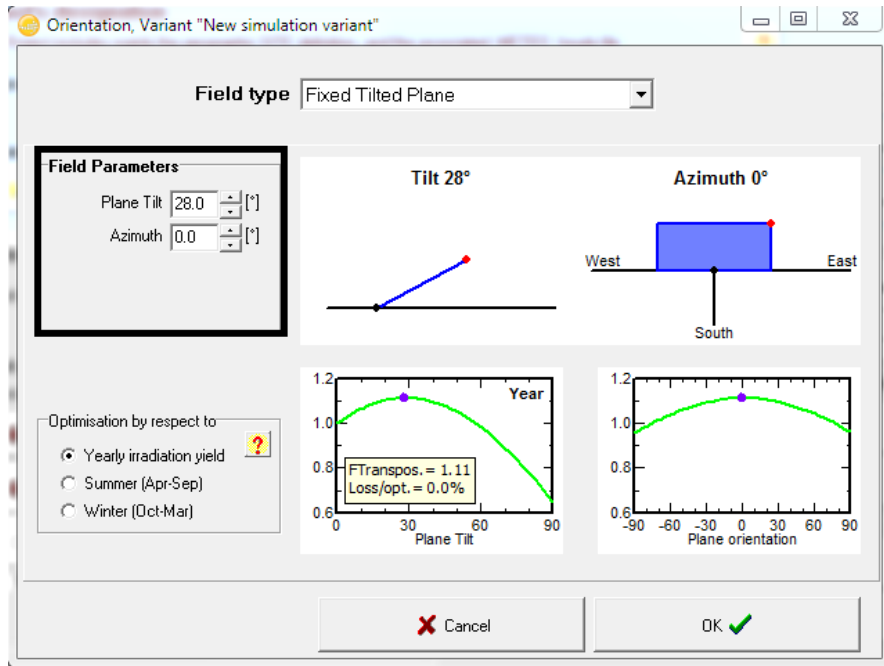
Figure 5.2: orientation of the PV modules

After enter the main parameter of the site, then we select the PV module, the definition of a PV module from PVsyst (datasheet) with IV curve @ 25°C, IV curve @ 45°C, PV curve @ 25°C, PV curve @ 45°C, efficiency vs irradiance curve, and efficiency vs temperature curve are attach as **Appendix A.**

Then the inverter that used in the project was selected, the definition of a inverter from PVsyst (datasheet) with efficiency profile vs input power curve are attach as **Appendix B.**

As we mentioned in chapter 4, the project is divided into 6 areas, and each area have it's main parameters, so in the following we show the design of each area in the project.

- Area 4[90 string, 19 series, 9 inverter]: The PVsyst confirms the lack of any problems in the original design of area 4, as shown in Figure 5.3.

To make sure that the array sizing Commensurate to the inverter sizing, we can enter to the show sizing, which through it shows the IV curve of the array, and other curve that illustrates the relationship between the array sizing (green color) and inverter sizing (mauve color).
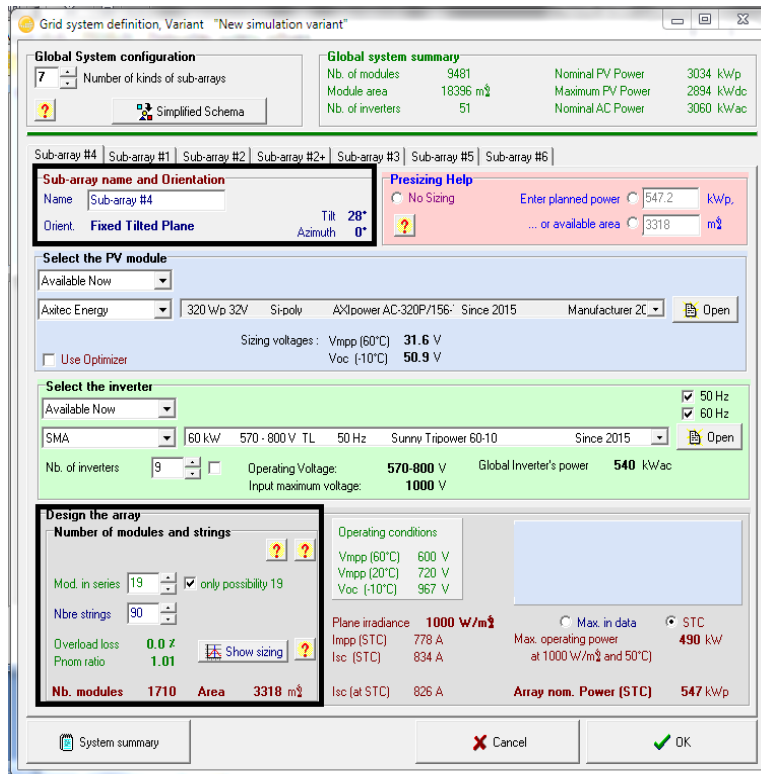
Figure 5.3: information and parameters of area 4

And by enter to the show sizing of this area, we can see that the array sizing and the inverter sizing is commensurate, as shown in the following figure (Figure 5.4).
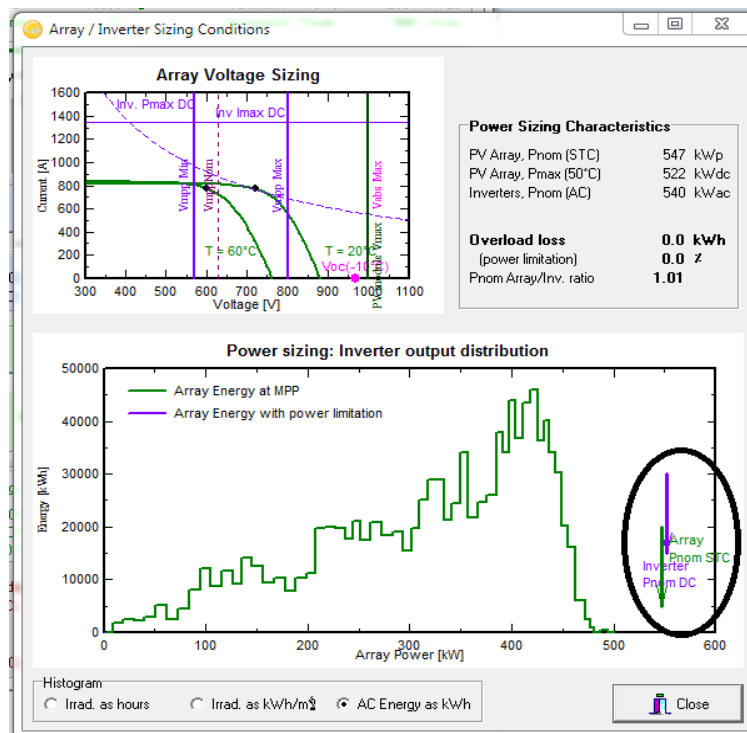
Figure 5.4: Array/Inverter sizing conditions for area 4

- Area 1[90 string, 19 series, 10 inverter]: The PVsyst shows that the inverters is slightly oversized which means that the involves installing a PV array with a rated DC power (measured @ Standard Test Conditions) is smallest than an inverter rated AC output power as shown in the following figure (Figure 5.5).
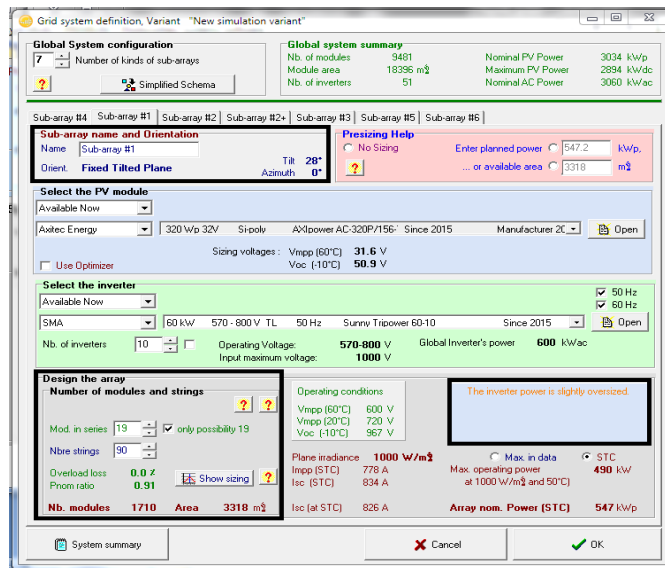
Figure 5.5: information and parameters of area 1

Note: We can reduce the number of inverters from 10 inverters to 9 inverters, and by that, we make that each inverter connected with 190 modules.

And by enter to the show sizing of this area, we can see that the array sizing and the inverter sizing is not commensurate, which the inverter sizing is larger than the array sizing, as shown in the following figure (Figure 5.6).
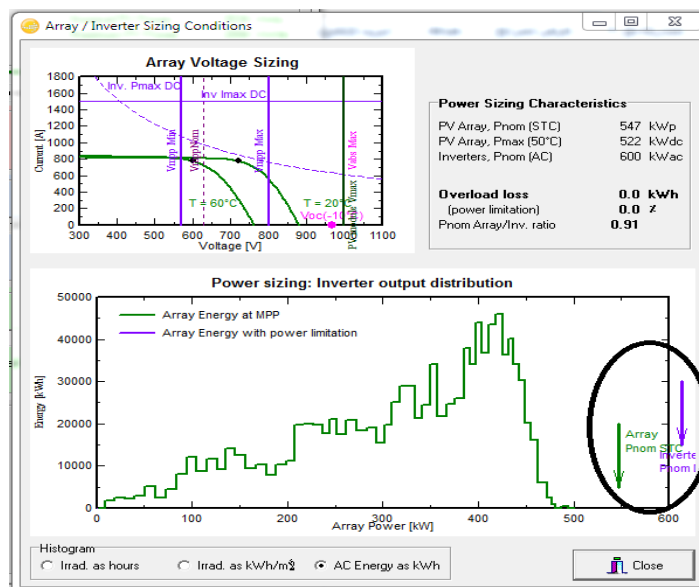
Figure 5.6: Array/Inverter sizing conditions for area 1

- Area 4 as we mentioned in chapter 4, one of the combiner boxes includes 9 string × 19 modules (first type), and the others includes 10 string × 19 modules (second type), and in the following we elucidate the design of each type on the software.

For the first type of area 2, the PVsyst shows that the inverters is slightly oversized, which means that the involves installing a PV array with a rated DC power (measured @ Standard Test Conditions) is smallest than an inverter rated AC output power, as shown in the following figure (Figure 5.7).
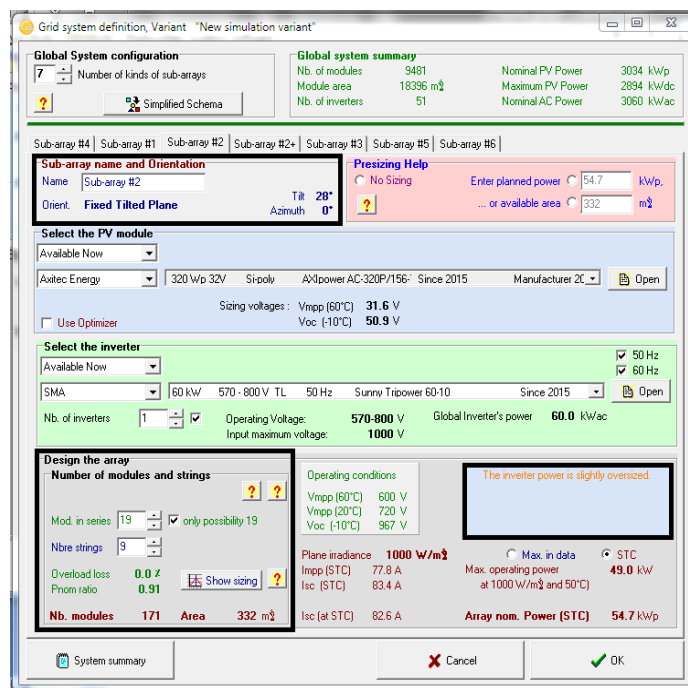
Figure 5.7: information and parameters of the first type of area 2 (9string × 19modules)

Note: We can reduce the number of inverters from 10 inverters to 9 inverters, and by that, we make that each inverter connected with 190 modules.

As we mentioned before, to be sure if the array sizing is commensurate to the inverter sizing, we entered to the show sizing of this area (first type of area 2 (9string × 19modules)), and then we can see that the array sizing and the inverter sizing is not commensurate, which means that the inverter sizing is larger than the array sizing, and this is shown in the following figure (Figure 5.8).
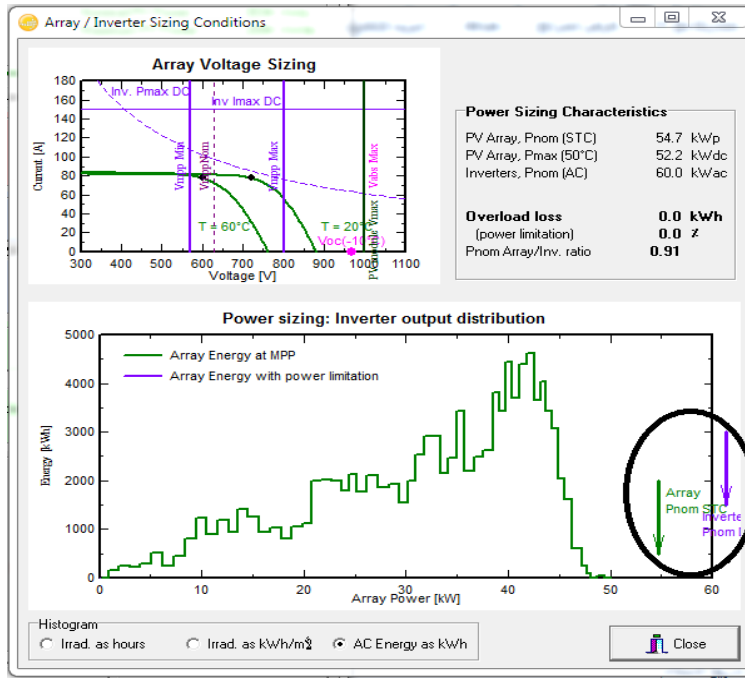
Figure 5.8: Array/Inverter sizing conditions of the first type of area 2 (9string × 19modules)

For the second type of area 2, the PVsyst confirms the lack of any problems in the design, as shown in the following figure (Figure 5.9).
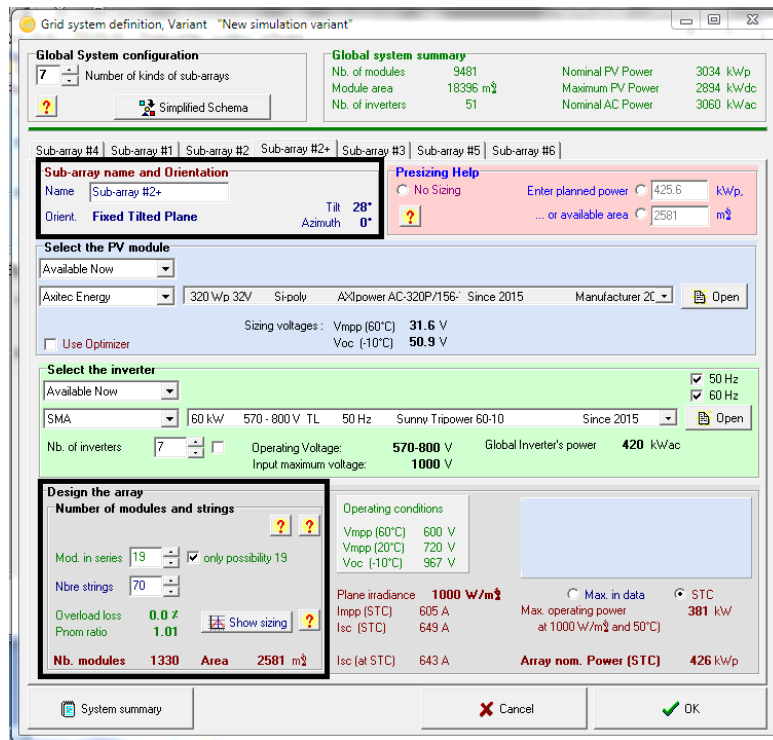
Figure 5.9: information and parameters of the second type of area 2 (10string × 19modules)

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And by enter to the show sizing, we can see that the array sizing and the inverter sizing is commensurate, as shown in the following figure (Figure 5.10).

Figure 5.10: Array/Inverter sizing conditions of the second type of area 2 (10string × 19modules)

- Area 3[50string, 19series, 5inverter]: The PVsyst confirms the lack of any problems in the design of the area 3, as shown in the following figure (Figure 5.11).

Figure 5.11: information and parameters of area 3

And to be sure that the array sizing and the inverter sizing is commensurate, we entered to the show sizing of this area, as shown in the following figure (Figure 5.12).
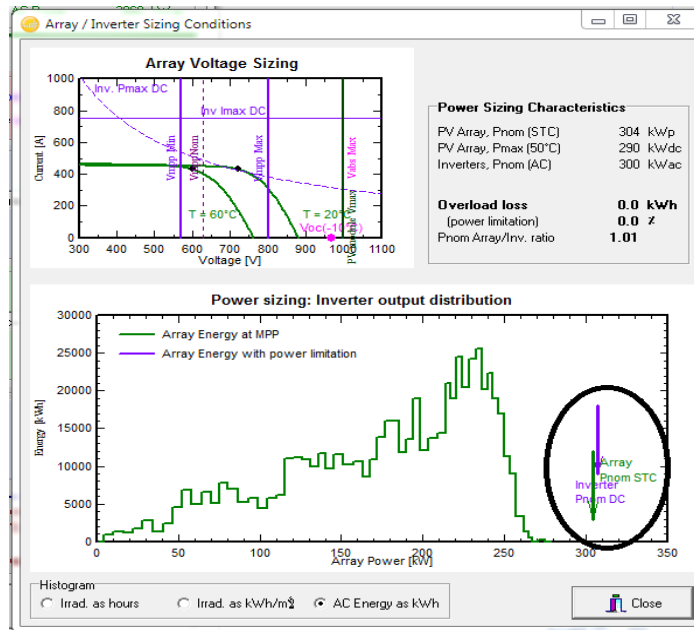
Figure 5.12: Array/Inverter sizing conditions for area 3

- Area 5[90string, 19series, 9inverter]: The PVsyst confirms the lack of any problems in the design of area 5, as shown in the following figure (Figure 5.13).
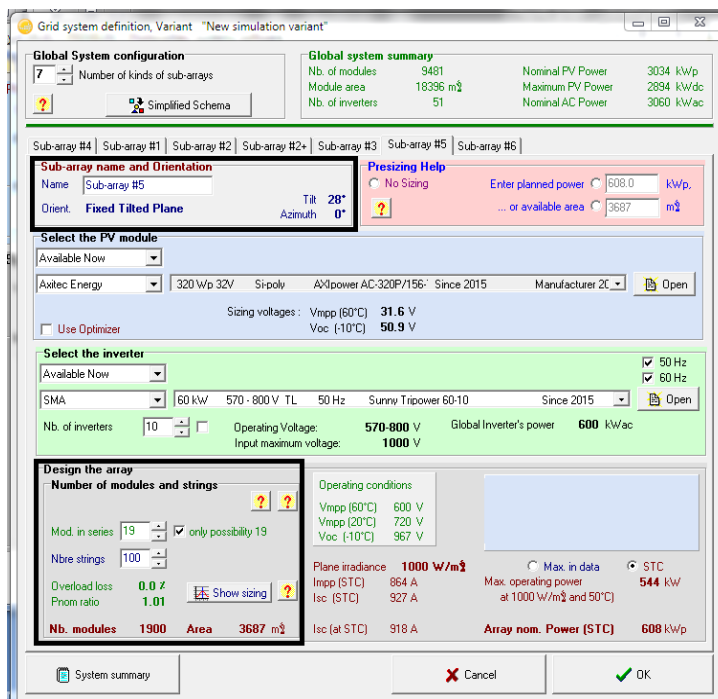
Figure 5.13: information and parameters of area 5

And to be sure that the array sizing and the inverter sizing is commensurate, we entered to the show sizing of this area, as shown in the following figure (Figure 5.14).
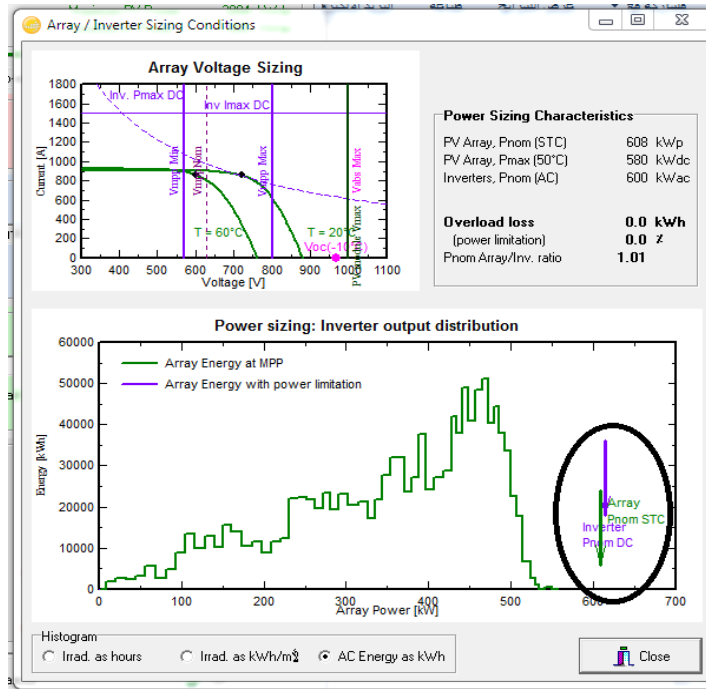
Figure 5.14: Array/Inverter sizing conditions for area 5

- Area 6[90string, 19series, 9inverter]: the PVsyst confirms the lack of any problems in the design of area 6,as shown in the following figure (Figure 5.15).
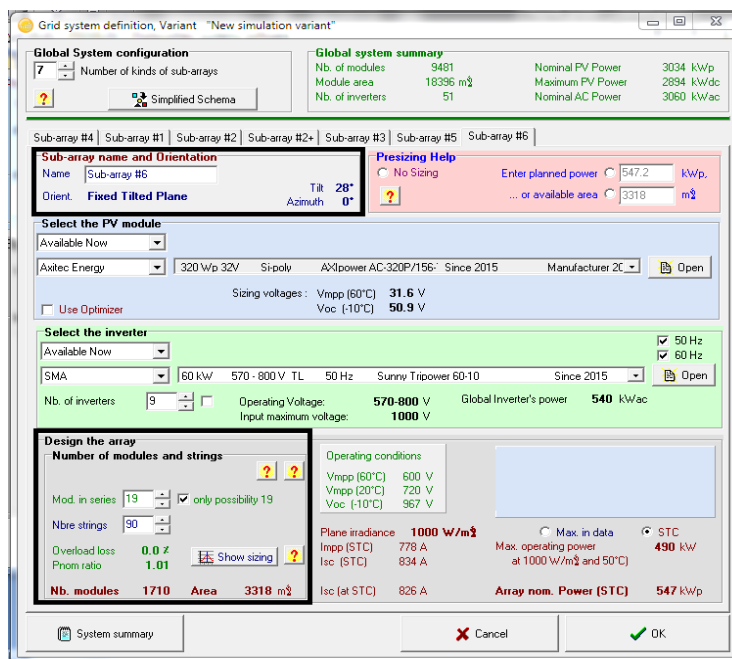
Figure 5.15 information and parameters of area 6

And to be sure that the array sizing and the inverter sizing is commensurate, we entered to the show sizing of this area, as shown in the following figure (Figure 5.16).
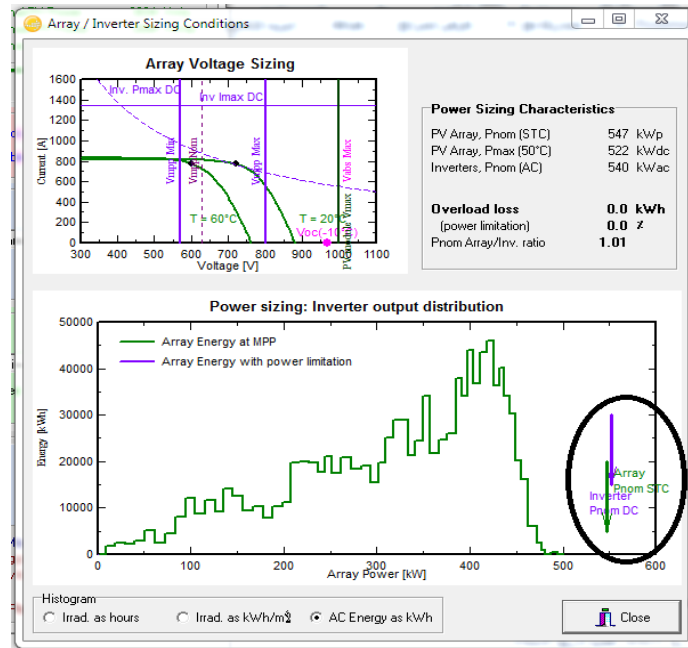
Figure 5.16: Array/Inverter sizing conditions for area 6

After finishing the list of grid system definition, then we move to the miscellaneous tools list (Inverter Temperature, Power Factor).

The inverters temperature for nominal power evaluation are set at external ambient temperature (outdoor installation) (5.17 a), and the power factor sets at 0.95 lagging(5.17 b).
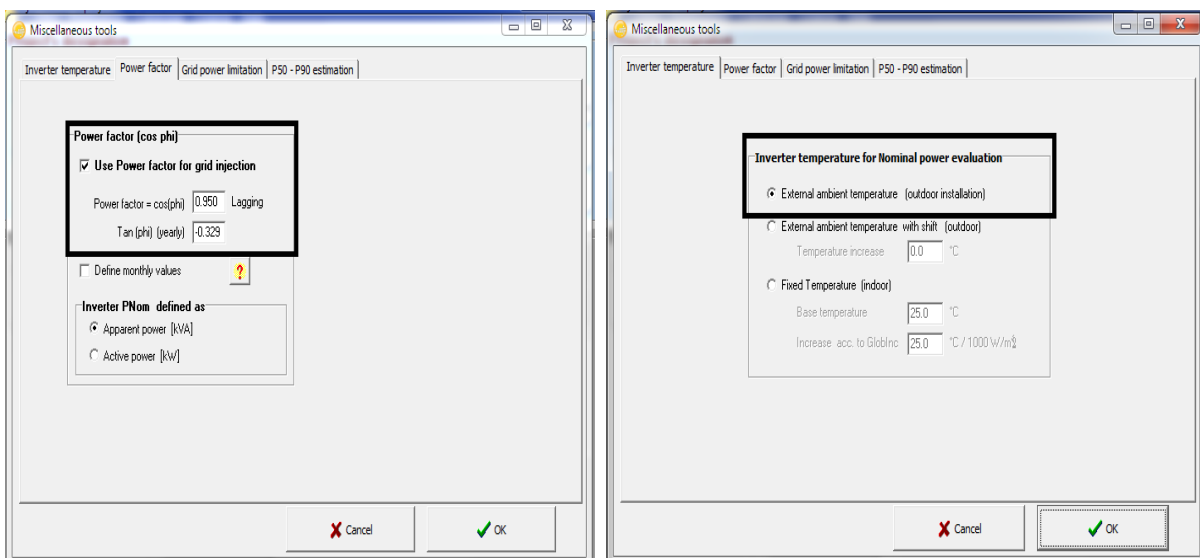
a)   b)

Figure 5.17: Miscellaneous Tools list values (Inverter Temperature, Power Factor)

5.2   Results And Simulation

After building the design of the project, we have to looking to the results of the PVsyst,. So let's take a look to The global system summary of the project.

- Number of modules = 9481 modules.
- Modules area = 18396 m^2.
- Number of inverters = 51 inverter.
- Nominal PV power = 3.034MWp.
- Maximum PV power = 2.894MWdc.
- Nominal AC power = 3.06MWac.

5.2.1 PV Array Behaviour for Each Loss Effect

Array losses for 200 W/m², 400 W/m², 600 W/m², 800W/m², 1000 W/m² irradiance with IV curve for each area with normal conditions loss effect, module quality loss effect, array mismatch, incidence angle affect, temperature effect, and wiring ohmic loss are attached as **Appendix C**.

5.2.2 Horizon(for shadings) Definition at Alfaraa

Horizon line data at Alfaraa, and horizon line solar time curve at 28° tilt angle and 0° azimuth angle are attached as **Appendix D**.

5.2.3 Grid Connected System Results

Simulation parameters for the system, main results, and loss diagram are attached as **Appendix E**.

5.2.4 Simulations Results Monthly Tables

The tables of balances and main results, meteo and incident energy, effective incident energy, optical factor, detailed system losses, detailed inverter losses, energy use and user's needs, normalized performance coefficients, and E-grid hourly average are attached as **Appendix F**.

6

Chapter Six

Simulation & Results of ETAP Software

6.1 E-TAP Description

6.2 Results and Simulation

6.1   E-TAP Design

The design of the photovoltaic system and the distribution network in Faraa camp south of Tubas have been applied on ETAP software version 12.6. The design shown in the following. Steps to use the ETAP program and make the settings for the station and the network as **Appendix G**.

6.2   Results

6.2.1 AC Power (Active & Reactive Power)

Connection the PV station to a distribution network Contributes to generating the active power with the grid's. So, the integrating the PV station will reduce the active power supply from the utilities. However, It is better that the inverters operate at unity power factor to maximize the active power generated.

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.

After integrating the PV station to the distribution grid, an increase in the reactive power consumption in the network was observed.

The following table shows the generation values in MW and MVAR from the feeding points in case of without connection the PV station with the distribution network.

Table 6.1:generation values in the system without connection the PV station

Feeding Points	MW generation	MVAR generation
Tyaseer swing grid	10.517	3.886
Al-Zawyah grid	0.826	-0.105

From the above table (Table 6.1), in case of without connection the PV station with the distribution network, the total MW generation from the system is 11.343 MW, and the total MVAR generation from the system is 3.781 MVAR.

The following table shows the generation values in MW and MVAR from the feeding points in case of connection the PV station with the distribution network.

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Table 6.2: generation values in the system with connection the PV

Feeding Points	MW generation	MVAR generation
Tyaseer swing grid	8.339	4.981
Al-Zawyah grid	2.740	-0.901
PV station	2.082	-1.203

From the above table (Table 6.2), in case of with connection the PV station with the distribution network, the total MW generation from the system is 13.161 MW, and the total MVAR generation from the system is 2.887 MVAR.

6.2.2 Power Factor

The power factor is an important factor must be taken into account when we need to integrate the PV station with the distribution network. The power factor of the PV station sets at 0.95 lagging, and the reason for choosing this value; is to achieve the best power factor on the other feeding points as possible. In the following table (Table 6.3) we show the power factor of the feeding points without connection the PV station with the distribution network.

Table 6.3: power factor of the feeding points without PV integration

Feeding point	Power factor %
Tyaseer swing grid	87.3
Al-Zawyah grid	99

After connection the PV station with the distribution network the power factor of the Tyaseer swing grid becomes 73.8%, and the power factor of the Al-Zawyah grid becomes 97.5%.

From the simulation results it was noted that as the penetration level increases in the feeder the power factor level at the grid's transformer point (Bus) decreases significantly, until

it reaches around zero level. If the penetration level of PV exceeds 90 % and reverses power flow occurs, the power factor level starts to increase again.

The power factor in the system before Interconnection process have uneven values, for example, the power factor of the buses close to the first feeding point (Tyaseer swing grid) have a power factor between (87-88.5)%, and the buses how close to the second feeding point (Al-Zawyah grid) have a power factor between (97-99.7)%, and the buses how close to the interconnection point, the power factor between (93-95)%.

The power factor of the system in general decreased after connecting the PV station to the distribution network. However, the power factor of the buses how close to the first feeding point will decrease Significantly, which becomes in the range between (73-74)%.

But with regard to buses how close to the second feeding point, the power factor decreases slightly, and have a reading between (96.5-98)%. Finally the buss close to the connection point of the PV, the power factor on some buses was affected a little, but at the same time, there are buses was greatly affected form the interconnection process. and the results are attach as **Appendix H**.

6.2.3 Dynamic Analysis

The new operating point of voltage is always greater than the voltage at MPP and the new operating point of current is always smaller than the current at MPP. This indicates that the output power of the PV array is reduced by the fault. In all fault type, the PV array was not operating at MPP.

The maximum deviation of oscillation for both the voltage and the current is largest for the LL fault followed by the DLG fault. For the three-phase fault, the maximum deviation of the oscillation is the smallest, however, the new operating point of the voltage is the largest, and the new operating point of the current is also smallest, These indicate that the output power of the PV array is the smallest, on the other hand, the output power of the PV array in the case of the SLG fault was largest.

6.2.4 Study State Analysis

The voltage at the load bus is within the acceptable range (between 0.95 and 1.05pu) under all normal system conditions because the level of PV penetration is low and the distance between the substation and PV generator is short. However, to evaluate the effects of different levels of PV penetration on voltage rise a scenario analysis has been applied in the following table (Table 6.4).

Table 6.4: Output current and voltage from the PV station in different solar radiation (G = $1000W/m^2$)

Parameter / Irradiance	Power (kW)	Voltage (kV)	Current (A)	Power factor %
G=1	2189	32.612	40.3	-86.3
G=0.75	1712	32.511	31.5	-85.9
G=0.5	1195	32.306	22	-85.7
G=0.25	0.69	32.19	0	66.7

It has been noted that the radiation rate is one of the main elements that control the work of the station and the network. With the reduction of solar radiation as shown in the table, the efficiency of the network and the expected productivity will decrease and affect the overall operation of the network.

6.2.5 Reverse Power Flow

This phenomenon unavailable in the system in normal operation Whether the PV station connects to distribution network or not. But when the system is out of control, especially if there is a fault in the grid in particular on the bus(362) that the PV connected on it, the reverse power flow occurs between the PV station and the distribution grid, and the power flow become from the network to the PV station (Figure 6.1).
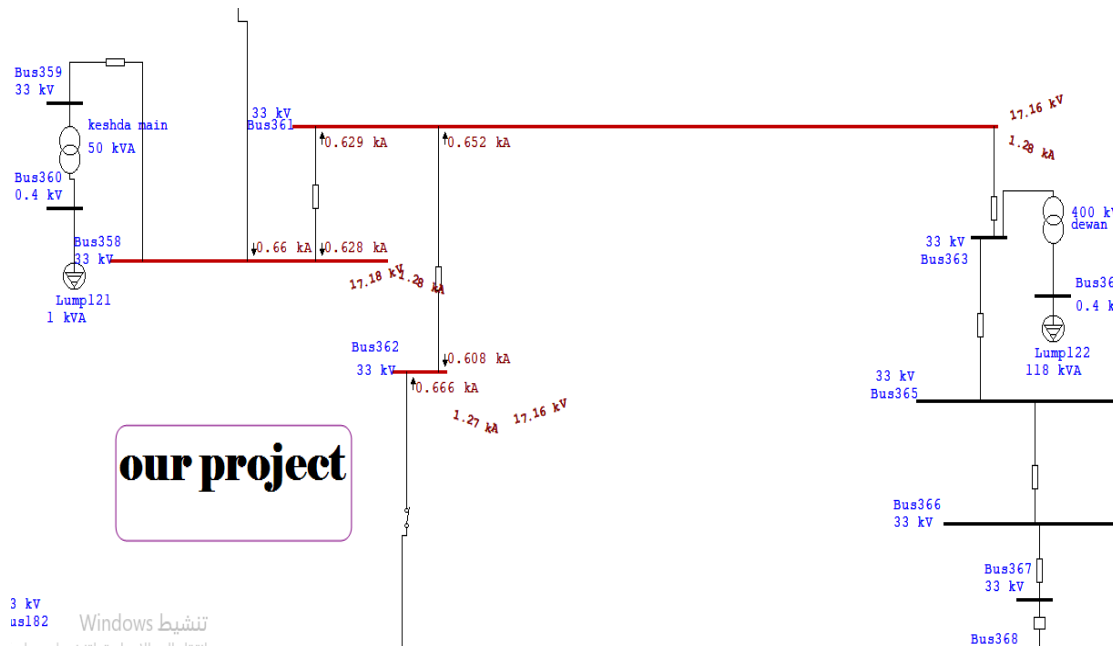
Figure 6.1: Reverse power flow in the system(between the PV station and the distribution grid)

6.2.6 Bus Voltage

Normal operating voltage or the voltage p.u is less than 0.95p.u or more than 1.05p.u are setting, the voltage on each buses increased, and the number of buses that fall in this range increased also**.** and the results are attach as **Appendix I**.

In some cases, for example in faults types, voltage sag may happened on some buses. Voltage sag is a momentary decrease in the RMS voltage, with a duration ranging from half a cycle up to one minute. It is caused by fault conditions within the plant or power system and lasts until the fault is cleared by a fuse or breaker.

On the utility side, the fault condition may be a result of lightning, storm, contamination of insulators, animals or accidents. Voltage sags can cause loss of production and revenue due to the tripping of equipment sensitive to voltage variations.

Voltage sag has a negative impact in voltage source converters used in adjustable-speed drives, grid connected photovoltaic system and industrial processes control, leading undesirable tripping on their protection devices. Voltage sags creation are generally caused by over loading, induction motors starting procedures and grid faults. The voltage sags due to grid faults can be classified in seven different types.

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The type A is the results from balanced three-phase short-circuits. The other six types are the results from unbalanced faults. For example, phase-to-ground (type B), phase-to-phase (type E) and the two-phase-to-ground (type C). The remaining types result from the propagation of these unbalanced faults through connected transformers. and the results are attach as **Appendix J.**

6.2.7 Optimum PV Placement For Voltage Stability Improvement

To choose the optimum placement of the PV connection with the distribution network, we took several places and calculated the MW loss and MVAR loss, which are presented in the following table (Table 6.5). and the results are attach as **Appendix K**.

Table 6.5: MW and MVAR loss for several scenarios of connecting the PV with distribution network

Location	Bus	MW Loss	MVAR Loss
Faraa company	361	1.162	0.522
Faraa company	510	1.153	0.517
Ras al-faraa	365	1.156	0.518
Tubas	17	1.196	0.541
Kfier	50	1.188	0.533
Zawyah	80	1.273	0.652

The following Graph shows the loss in MW and MVAR Graphically in the system when the PV connected to the different buses (Figure 6.2).
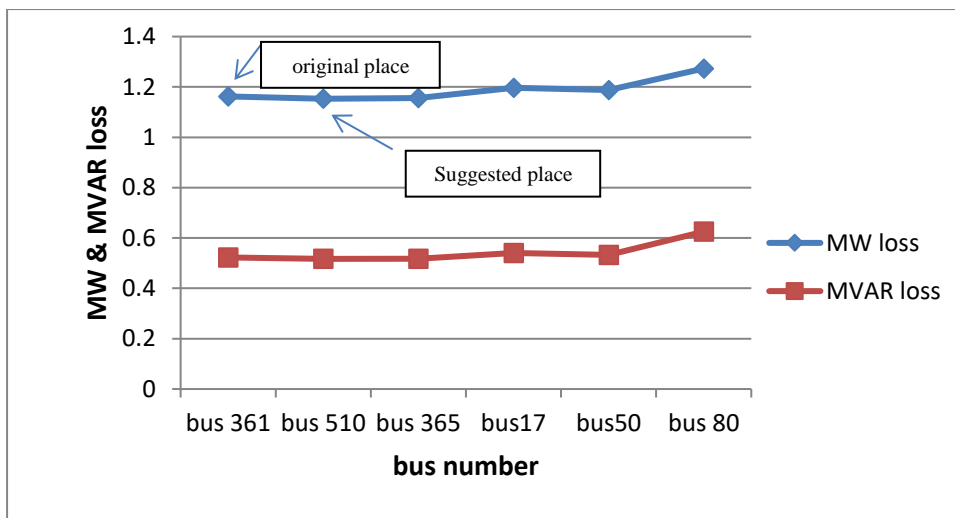
Figure 6.2: MW and MVAR loss Graph.

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The power loss is increasing sharply when the connection of the PV closed the grid's(Tyaseer swing grid, Al-Zawyah grid), also when the connection of the PV far left the distribution network(Qabateya). From the above Graph. We find that the best location to connect the PV station with the distribution network is in the Faraa company on bus 510; Which have the less losses as it compared to the other areas.

Table 6.6:loss in MW and MVAR without connected the PV with distribution network

MW loss	0.469
MVAR loss	0.064

Table 6.7:loss in MW and MVAR with connected the PV with distribution network

MW loss	1.031
MVAR loss	0.258

In the following, we presented the some calculation to get the percentage of increasing in the MW and MVAR loss in the chosen area.

$$\%loss(MW)_{Without\ PV} = \frac{MW\ loss\ without\ PV}{MW\ generation\ without\ PV}100\%$$

$$= \frac{0.469}{11.343}100\% = 4.134\%$$

$$\%loss(MVAR)_{Without\ PV} = \frac{MVAR\ loss\ without\ PV}{MVAR\ generation\ without\ PV}100\%$$

$$= \frac{0.064}{3.781}100\% = 1.69\%$$

$$\%loss(MW)_{With\ PV} = \frac{MW\ loss\ with\ PV}{MW\ generation\ with\ PV}100\%$$

$$= \frac{1.031}{13.161}100\% = 7.83\%$$

$$\%loss(MVAR)_{With\ PV} = \frac{MVAR\ loss\ with\ PV}{MVAR\ generation\ with\ PV}100\%$$

$$= \frac{0.258}{2.887}100\% = 8.94\%$$

From the above calculation we find that the MW will increase 3.696% after connected the PV with the distribution network, and the MVAR will increase 1.11%, and this percentage are the minimum increased that we can achieve**,** and the results are attach as **Appendix E.**

The following figure shows the location on ETAP that we choose to connect the PV station on it(Faraa company, bus 510).
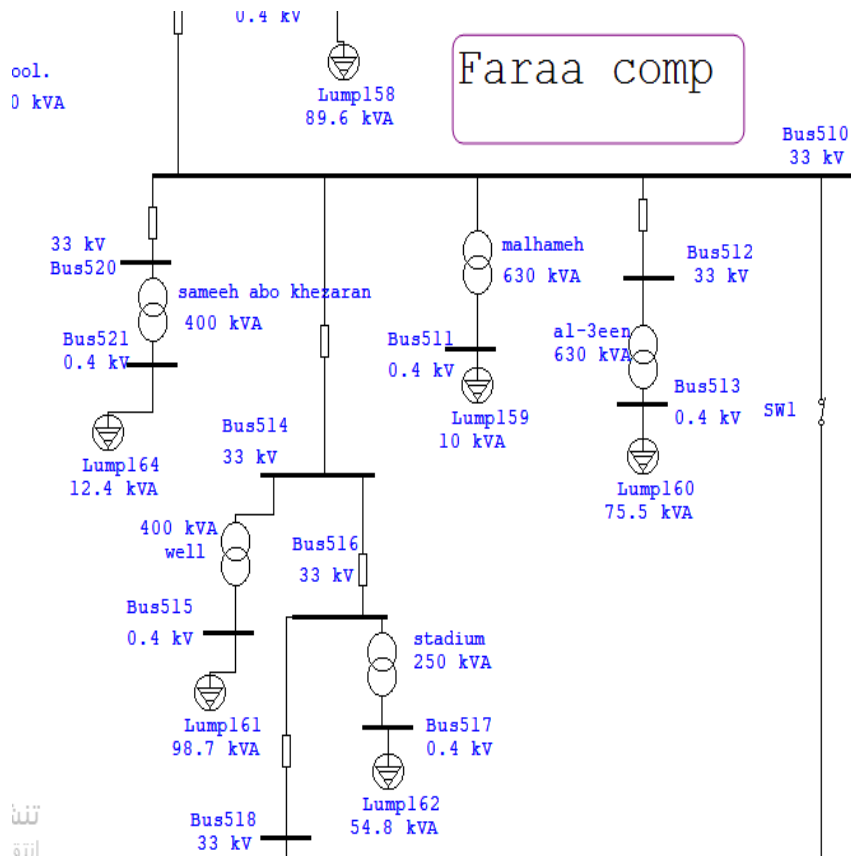
Figure 6.3: Faraa comp location on E-TAP.

6.2.8 Penetration Level

Penetration is defined as the ratio of total peak PV power to peak load apparent power on the feeder as we mentioned in chapter two. To calculate the penetration level we used the PV Penetration equation that mentioned in the same chapter (Eq. (2.4)).

The penetration level of the system can controlled by connection and disconnection the PV areas to the distribution network, Through that, we can control the percentage of penetration level on the system.

The following table, show the results of calculate the penetration level percentage in many scenarios of connection areas.

Table 6.8: Changes on the network as the penetration rate increases.

Active areas	% penetration level	Output Power (kW)	Voltage level at residential load bus (kV)	PF Of the Tyaseer grid %	Line Loss (kW)
(4)	4.6	547.2	31.316	85.5 leading	0.03
(4,1)	9.2	1094.4	31.425	84.6 leading	0.101
(4,1,2)	13.25	1574.72	31.461	83.82 leading	0.212
(4,1,2,3)	16.64	1977.72	31.486	82.91 leading	0.311
(4,1,2,3,5)	21.76	2585.72	31.511	81.511 leading	0.541
(4,1,2,3,5,6)	26.37	3132.92	31.601	80.092 leading	0.711
-	50	5939	32.151	68.7 lagging	5.11
-	75	8908.5	32.861	42.6 lagging	10.61
-	100	11878	33.611	55.11 lagging	21.511

The penetration level increase as the active areas increases also, and as the penetration level increased the output power of the PV system will increased as shown in the following diagram (figure 6.4).
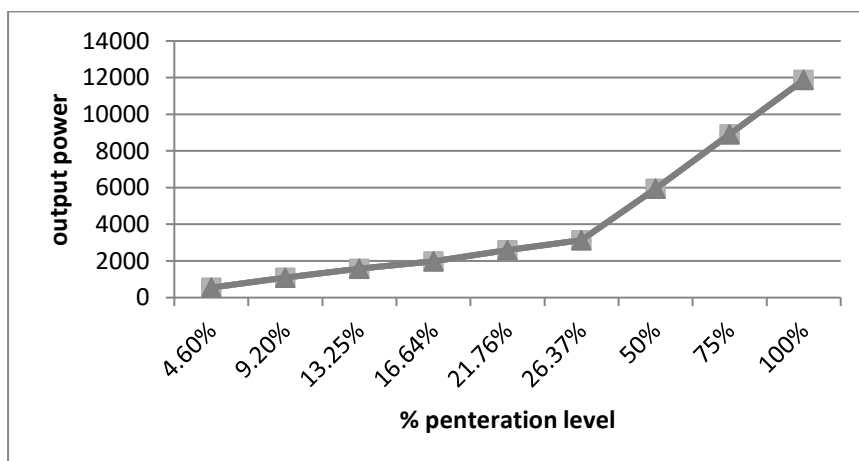
Figure 6.4: output power of the PV plant as the penetration level increased

And as the penetration level increased the Voltage level at residential load bus will increased also, and the best penetration level to avoid the undervoltage and overvoltage at residential load bus is 75%, that make the voltage at residential load bus is 32.861kW, as shown in the following diagram (Figure 6.5) .
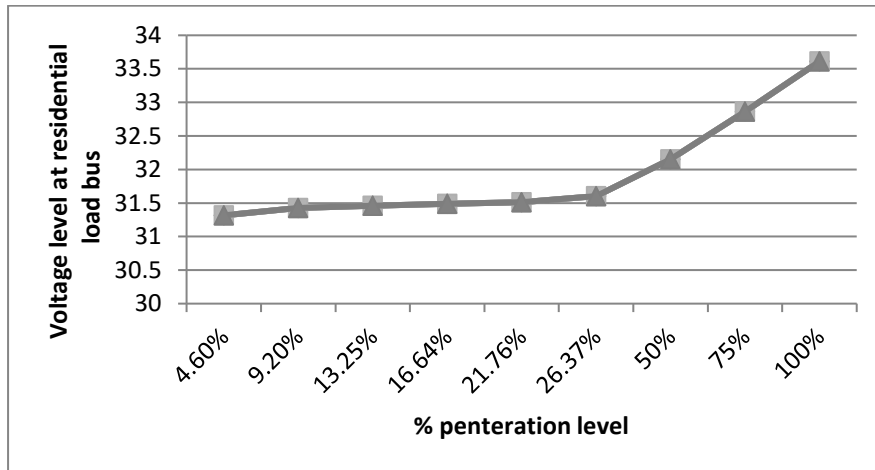
Figure 6.5: Voltage level at residential load bus as the penetration level increased

And it was noted that the power factor of the Tyaseer grid will decrease as the penetration level increased, as shown in the following figure (Figure 6.6).
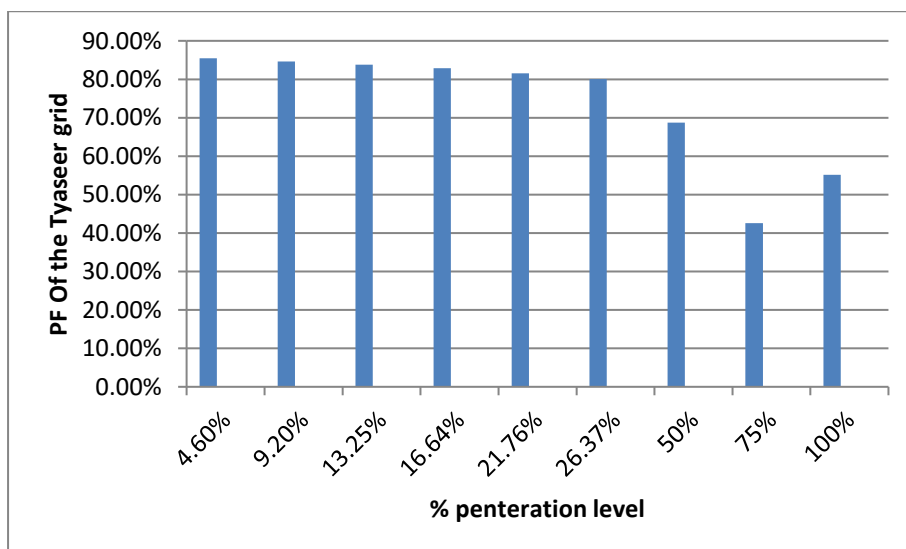
Figure 6.6: power factor of the Tyaseer grid as the penetration level increased

Finally, as the penetration level increased the line loss will increased also, as shown in the following figure (Figure 6.7)
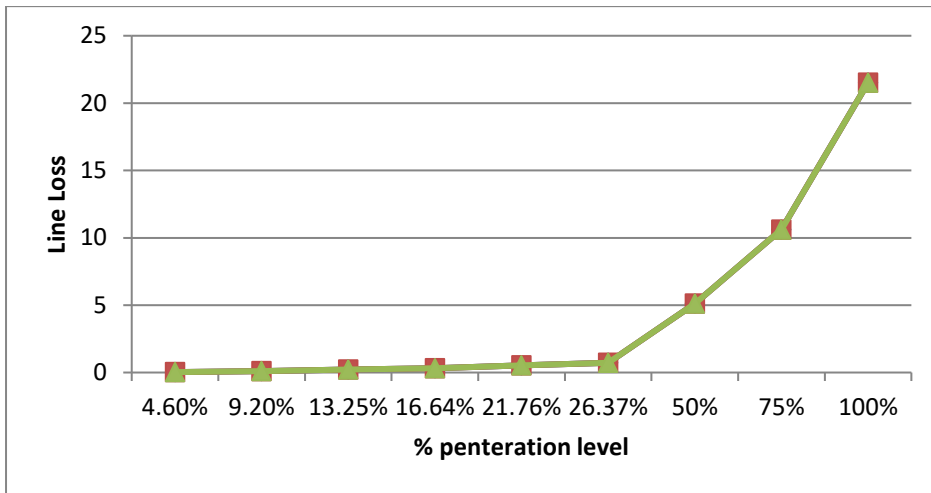
Figure 6.7: power line loss as the penetration level increased

When the a Penetration becomes 100%, a significant reverse energy flow was observed to the source that raises the voltages on the buses. The source bus appears as a reactive power source only, the heating on the network elements is less effective on the network.

Conclusion

With the increasing of active areas, many values will increase such as, penetration level, PV output power, voltage level at resident load bus and line loss. However, power factor of main grid (tyaseer) will decrease.

Photovoltaic system affects on the Ac power elements like active power, reactive power and power factor, so we suggest to change the connection placement to the best one we mentioned before, and this will improve the power loss. In addition, reverse power flow problem can be solved by using relay or tap changer transformer.

Future Work

1. To determine the optimum placement we used the trial and error method, which is not the best, and we recommend to use PSO method; because it is the best method.
2. We recommend Power Authority to prevent implement this kind of project without making an impact study to reduce the loss as much as can.

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Appendix

Appendix A

Appendix B

Appendix C

Appendix D

Appendix E

Appendix F

Appendix G

Appendix H

Appendix I

Appendix J

Appendix K

Appendix A

The definition of the PV module from PVsyst software (datasheet).

Characteristics of a PV module

Manufacturer, model :	**Axitec Energy, AXIpower AC-320P/156-72S**
Availability :	Prod. from 2015
Data source :	Manufacturer 2016

STC power (manufacturer)	Pnom	320	Wp	Technology		Si-poly	
Module size (W x L)	0.992 x 1.956		m²	Rough module area	Amodule	1.94	m²
Number of cells		1 x 72		Sensitive area (cells)	Acells	1.75	m²

Specifications for the model (manufacturer or measurement data)

Reference temperature	TRef	25	°C	Reference irradiance	GRef	1000	W/m²
Open circuit voltage	Voc	45.6	V	Short-circuit current	Isc	9.18	A
Max. power point voltage	Vmpp	37.4	V	Max. power point current	Impp	8.56	A
=> maximum power	Pmpp	320.1	W	Isc temperature coefficient	muIsc	3.7	mA/°C

One-diode model parameters

Shunt resistance	Rshunt	300	ohm	Diode saturation current	IoRef	0.056	nA
Serie resistance	Rserie	0.36	ohm	Voc temp. coefficient	MuVoc	-154	mV/°C
				Diode quality factor	Gamma	0.96	
Specified Pmax temper. coeff.	muPMaxR	-0.42	%/°C	Diode factor temper. coeff.	muGamma	0.000	1/°C

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

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

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

Max. power point voltage	Vmpp	37.1	V	Max. power point current	Impp	8.63	A
Maximum power	Pmpp	320.2	Wc	Power temper. coefficient	muPmpp	-0.41	%/°C
Efficiency(/ Module area)	Eff_mod	16.5	%	Fill factor	FF	0.765	
Efficiency(/ Cells area)	Eff_cells	18.3	%				

PV module: Axitec Energy, AXIpower AC-320P/156-72S
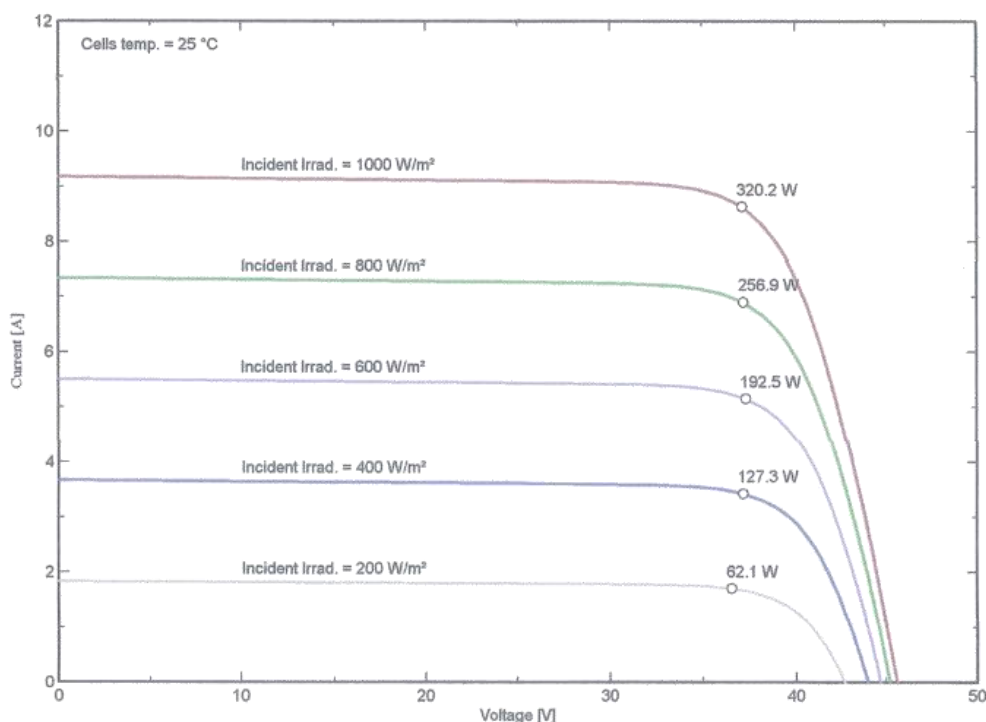
Appendix B

The definition of the inverter from PVsyst software(datasheet).

Characteristics of a grid inverter

Manufacturer, model : **SMA, Sunny Tripower 60-10**

Availability :   Prod. from 2015

Data source :   Manufacturer 2015

Input characteristics (PV array side)

Operating mode		**MPPT**			
Minimum MPP Voltage	**Vmin**	**570 V**	Nominal PV Power	Pnom DC	61 kW
Maximum MPP Voltage	**Vmax**	**800 V**	Maximum PV Power	Pmax DC	61 kW
Absolute max. PV Voltage	Vmax array	1000 V	Maximum PV Current	Imax DC	N/A A
Min. Voltage for PNom	Vmin PNom	N/A V	Power Threshold	Pthresh.	100 W
Behaviour at Vmin/Vmax		Limitation	Behaviour at Pnom		Limitation

Output characteristics (AC grid side)

Grid Voltage	Unom	400 V	**Nominal AC Power**		**Pnom AC**	**60 kWac**
Grid frequency	Freq	50 Hz	Maximum AC Power		Pmax AC	60 kWac
		Triphased	Nominal AC current		Inom AC	87 A
			Maximum AC current		Imax AC	87 A
Efficiency defined for 3 voltages		570 V	630 V	800 V		
Maximum efficiency		0.0 %	0.0 %	0.0 %		
European average efficiency		0.0 %	0.0 %	0.0 %		

Remarks and Technical features

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

Technology: TL
Protection: -25 - +60°C, IP 65: outdoor installation
Control: Graphic
Separate string combiner required!

Sizes:	Width	570 mm
	Height	740 mm
	Depth	300 mm
	Weight	75.00 kg

Efficiency profile vs Input power
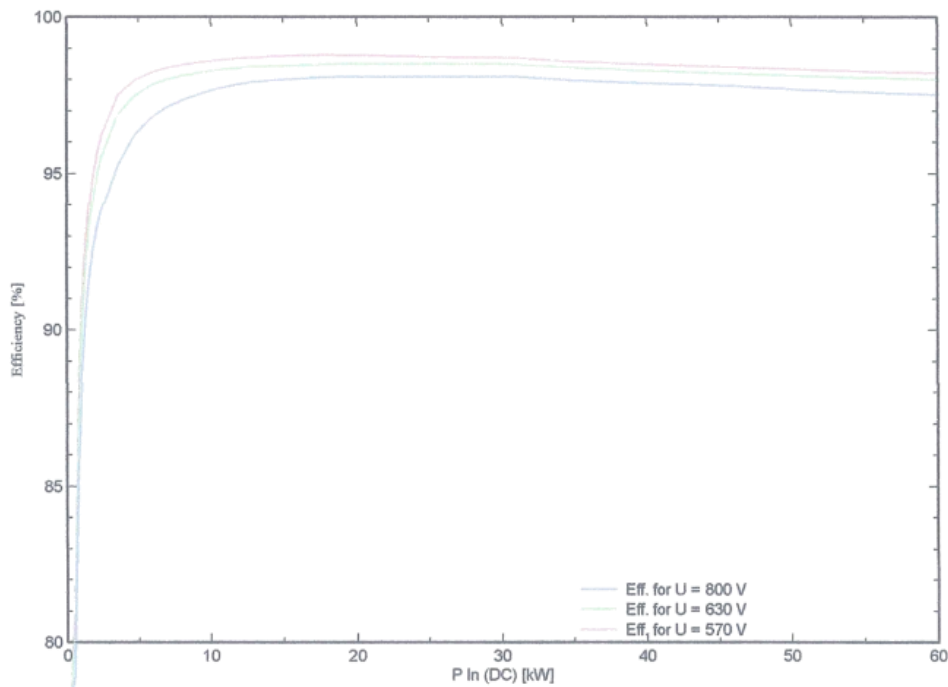
Appendix D

Horizon(for shadings) definition at Alfaraa company from PVsyst software.

Geographical Site : **Horizon line at Alfaraa**
Alfaraa

Situation

Horizon

		Country	**Israel**
	Latitude	32.3°N	Longitude	35.3°E

Situation
Time defined as   Legal Time   Time zone UT+2   Altitude   250 m

Horizon
Average Height   0.0°   Diffuse Factor   1.00
Albedo Factor   100 %   Albedo Fraction   1.00

Height [°]	0.0	0.0	0.0	0.0
Azimuth [°]	-120	-40	40	120

Horizon line Legal Time

Plane: tilt 28°, azimuth 0°

1: 22 june
2: 22 may - 23 july
3: 20 apr - 23 aug
4: 20 mar - 23 sep
5: 21 feb - 23 oct
6: 19 jan - 22 nov
7: 22 december
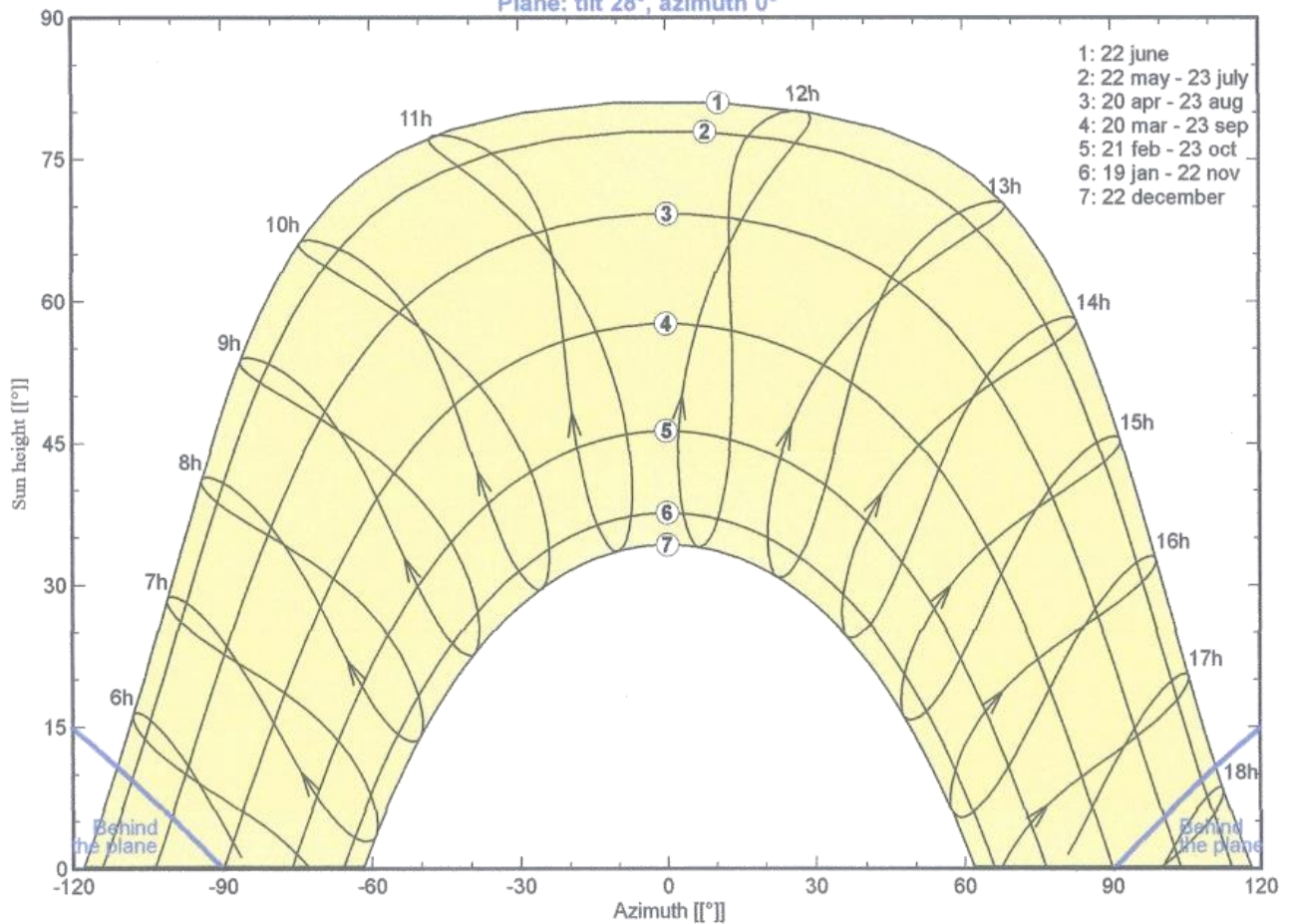
Appendix E

Grid connected system results from PVsyst software

Grid-Connected System: Simulation parameters

Project :	**Alfaraa project**		
Geographical Site	**Alfaraa**	Country	**Israel**

Situation	Latitude	32.3°N	Longitude	35.3°E
Time defined as	Legal Time	Time zone UT+2	Altitude	250 m
	Albedo	0.20		
Meteo data:	**Alfaraa**	Meteonorm 7.1 (1990-2004), Sat=100% - Synthetic		

Simulation variant :	**New simulation variant**
	Simulation date	15/01/19 11h09

Simulation parameters

Collector Plane Orientation	Tilt	28°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Arrays Characteristics (7 kinds of array defined)

PV module	Si-poly	Model	**AXIpower AC-320P/156-72S**
Custom parameters definition	Manufacturer	Axitec Energy	

Sub-array "Sub-array #4"

Number of PV modules	In series	19 modules	In parallel	90 strings
Total number of PV modules	Nb. modules	1710	Unit Nom. Power	320 Wp
Array global power	Nominal (STC)	**547 kWp**	At operating cond.	490 kWp (50°C)
Array operating characteristics (50°C)	U mpp	630 V	I mpp	778 A

Sub-array "Sub-array #1"

Number of PV modules	In series	19 modules	In parallel	90 strings
Total number of PV modules	Nb. modules	1710	Unit Nom. Power	320 Wp
Array global power	Nominal (STC)	**547 kWp**	At operating cond.	490 kWp (50°C)
Array operating characteristics (50°C)	U mpp	630 V	I mpp	778 A

Sub-array "Sub-array #2"

Number of PV modules	In series	19 modules	In parallel	9 strings
Total number of PV modules	Nb. modules	171	Unit Nom. Power	320 Wp
Array global power	Nominal (STC)	**54.7 kWp**	At operating cond.	49.0 kWp (50°C)
Array operating characteristics (50°C)	U mpp	630 V	I mpp	78 A

Sub-array "Sub-array #2+"

Number of PV modules	In series	19 modules	In parallel	70 strings
Total number of PV modules	Nb. modules	1330	Unit Nom. Power	320 Wp
Array global power	Nominal (STC)	**426 kWp**	At operating cond.	381 kWp (50°C)
Array operating characteristics (50°C)	U mpp	630 V	I mpp	605 A

Sub-array "Sub-array #3"

Number of PV modules	In series	19 modules	In parallel	50 strings
Total number of PV modules	Nb. modules	950	Unit Nom. Power	320 Wp
Array global power	Nominal (STC)	**304 kWp**	At operating cond.	272 kWp (50°C)
Array operating characteristics (50°C)	U mpp	630 V	I mpp	432 A

Sub-array "Sub-array #5"

Number of PV modules	In series	19 modules	In parallel	100 strings
Total number of PV modules	Nb. modules	1900	Unit Nom. Power	320 Wp
Array global power	Nominal (STC)	**608 kWp**	At operating cond.	544 kWp (50°C)
Array operating characteristics (50°C)	U mpp	630 V	I mpp	864 A

Grid-Connected System: Simulation parameters (continued)

Sub-array "Sub-array #6"

Number of PV modules	In series	19 modules	In parallel	90 strings
Total number of PV modules	Nb. modules	1710	Unit Nom. Power	320 Wp
Array global power	Nominal (STC)	**547 kWp**	At operating cond.	490 kWp (50°C)
Array operating characteristics (50°C)	U mpp	630 V	I mpp	778 A

Total	Arrays global power	Nominal (STC)	**3034 kWp**	Total	9481 modules
		Module area	**18396 m²**	Cell area	16615 m²

Inverter
Original PVsyst database

	Model	**Sunny Tripower 60-10**		
	Manufacturer	SMA		
Characteristics	Operating Voltage	570-800 V	Unit Nom. Power	60 kWac

Sub-array "Sub-array #4"	Nb. of inverters	9 units	Total Power	540 kWac
Sub-array "Sub-array #1"	Nb. of inverters	10 units	Total Power	600 kWac
Sub-array "Sub-array #2"	Nb. of inverters	1 units	Total Power	60 kWac
Sub-array "Sub-array #2+"	Nb. of inverters	7 units	Total Power	420 kWac
Sub-array "Sub-array #3"	Nb. of inverters	5 units	Total Power	300 kWac
Sub-array "Sub-array #5"	Nb. of inverters	10 units	Total Power	600 kWac
Sub-array "Sub-array #6"	Nb. of inverters	9 units	Total Power	540 kWac
Total	Nb. of inverters	51	Total Power	3060 kWac

PV Array loss factors

Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Array#1	14 mOhm	Loss Fraction	1.5 % at STC
	Array#2	14 mOhm	Loss Fraction	1.5 % at STC
	Array#3	136 mOhm	Loss Fraction	1.5 % at STC
	Array#4	18 mOhm	Loss Fraction	1.5 % at STC
	Array#5	25 mOhm	Loss Fraction	1.5 % at STC
	Array#6	12 mOhm	Loss Fraction	1.5 % at STC
	Array#7	14 mOhm	Loss Fraction	1.5 % at STC
	Global		Loss Fraction	1.5 % at STC
Module Quality Loss			Loss Fraction	-0.4 %
Module Mismatch Losses			Loss Fraction	1.0 % at MPP
Incidence effect, ASHRAE parametrization	IAM =	1 - bo (1/cos i - 1)	bo Param.	0.05

User's needs :   Unlimited load (grid)

Power factor	Cos(phi)	0.950 lagging	Phi	-18.2°

Grid-Connected System: Main results

Project :	**Alfaraa project**
Simulation variant :	**New simulation variant**

Main system parameters

	System type	**Grid-Connected**		
PV Field Orientation	tilt	28°	azimuth	0°
PV modules	Model	AXIpower AC-320P/156-72S		320 Wp
PV Array	Nb. of modules	9481	Pnom total	**3034 kWp**
Inverter	Model	Sunny Tripower 60-10	Pnom	60.0 kW ac
Inverter pack	Nb. of units	51.0	Pnom total	**3060 kW ac**
User's needs	Unlimited load (grid)		Cos(Phi)	0.950 lagging

Main simulation results

System Production	**Produced Energy**	**5465 MWh/year**	Specific prod.	1801 kWh/kWp/year
	Apparent energy	5753 MVAh	Perf. Ratio PR	83.3 %

Normalized productions (per installed kWp): Nominal power 3034 kWp
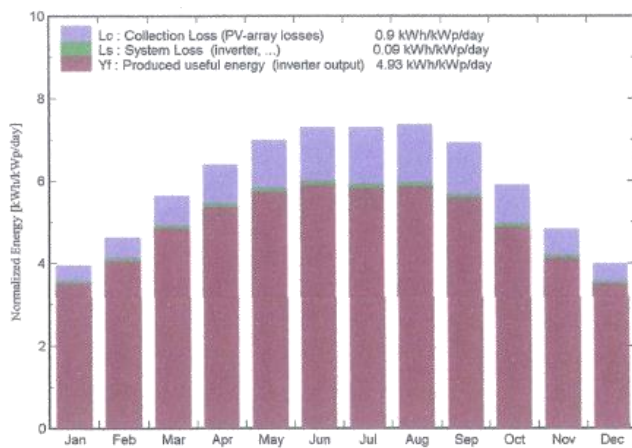
Performance Ratio PR
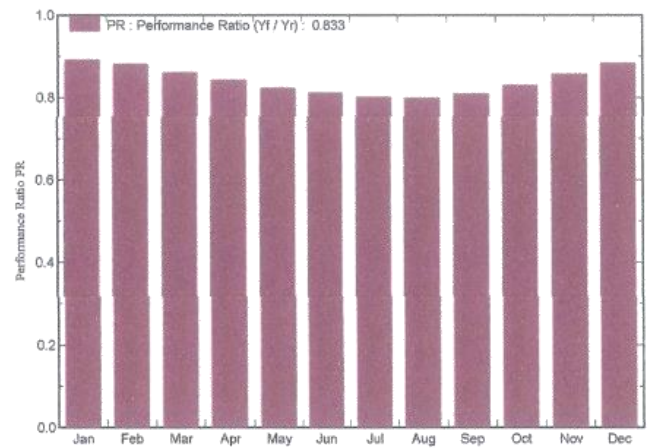
Lc : Collection Loss (PV-array losses)   0.9 kWh/kWp/day
Ls : System Loss (inverter, ...)   0.09 kWh/kWp/day
Yf : Produced useful energy (inverter output)   4.93 kWh/kWp/day

PR : Performance Ratio (Yf / Yr) : 0.833

New simulation variant

Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EApGrid	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	MWh	MWh	MVAh	%
January	87.0	12.35	122.0	118.7	335.8	329.8	347.2	14.69
February	100.1	13.22	129.2	125.6	351.1	344.9	363.0	14.51
March	150.3	16.06	174.5	169.8	463.5	455.3	479.4	14.18
April	182.1	18.99	191.1	185.8	496.6	487.9	513.7	13.88
May	226.8	22.35	216.1	209.4	548.1	538.8	567.2	13.56
June	239.0	25.07	218.4	211.5	546.2	537.0	565.4	13.37
July	242.5	27.53	225.6	218.7	556.8	547.7	576.6	13.20
August	224.7	27.75	227.8	221.5	560.5	551.3	580.3	13.15
September	182.9	25.77	207.3	202.2	516.6	508.1	534.9	13.33
October	142.1	23.33	182.6	178.1	466.6	458.8	483.0	13.66
November	101.5	18.37	144.8	141.1	382.2	375.6	395.4	14.11
December	83.4	14.39	123.3	120.0	335.5	329.6	347.0	14.53
Year	1962.4	20.47	2162.7	2102.4	5559.6	5464.9	5753.0	13.74

Legends:
GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	EApGrid	Apparent energy to the grid
GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

Grid-Connected System: Loss diagram

Project :	**Alfaraa project**
Simulation variant :	**New simulation variant**

Main system parameters	System type	Grid-Connected		
PV Field Orientation	tilt	28°	azimuth	0°
PV modules	Model	AXIpower AC-320P/156-72S		320 Wp
PV Array	Nb. of modules	9481	Pnom total	**3034 kWp**
Inverter	Model	Sunny Tripower 60-10	Pnom	60.0 kW ac
Inverter pack	Nb. of units	51.0	Pnom total	**3060 kW ac**
User's needs	Unlimited load (grid)		Cos(Phi)	0.950 lagging

Loss diagram over the whole year

1962 kWh/m²   **Horizontal global irradiation**

+10.2%   **Global incident in coll. plane**

-2.8%   IAM factor on global

2102 kWh/m² * 18396 m² coll.   **Effective irradiance on collectors**

efficiency at STC = 16.50%   PV conversion

6382 MWh   **Array nominal energy (at STC effic.)**

-0.3%   PV loss due to irradiance level

-11.1%   PV loss due to temperature

+0.4%   Module quality loss

-1.0%   Module array mismatch loss

-1.2%   Ohmic wiring loss

5560 MWh   **Array virtual energy at MPP**

-1.7%   Inverter Loss during operation (efficiency)

0.0%   Inverter Loss over nominal inv. power

0.0%   Inverter Loss due to power threshold

0.0%   Inverter Loss over nominal inv. voltage

0.0%   Inverter Loss due to voltage threshold

5465 MWh   **Available Energy at Inverter Output**

5465 MWh   **Active Energy injected into grid**

1798 MVARh   *Reactive energy from the grid: Cos(Phi) = 0.950*

5753 MVAh   **Apparent energy to the grid**

Appendix F

Simulations Results Monthly Tables from PVsyst software

New simulation variant
Balances and main results

	GlobHor	T Amb	GlobInc	GlobEff	EArray	E_Grid	EApGrid	EffSysR
	kWh/m²	°C	kWh/m²	kWh/m²	kWh	kWh	kVAh	%
January	87.0	12.35	122.0	118.7	335792	329776	347166	14.69
February	100.1	13.22	129.2	125.6	351133	344863	363048	14.51
March	150.3	16.06	174.5	169.8	463495	455341	479351	14.18
April	182.1	18.99	191.1	185.8	496632	487945	513674	13.88
May	226.8	22.35	216.1	209.4	548135	538822	567235	13.56
June	239.0	25.07	218.4	211.5	546176	537037	565356	13.37
July	242.5	27.53	225.6	218.7	556815	547686	576565	13.20
August	224.7	27.75	227.8	221.5	560473	551278	580347	13.15
September	182.9	25.77	207.3	202.2	516583	508092	534883	13.33
October	142.1	23.33	182.6	178.1	466614	458824	483018	13.66
November	101.5	18.37	144.8	141.1	382213	375630	395437	14.11
December	83.4	14.39	123.3	120.0	335503	329572	346951	14.53
Year	1962.4	20.47	2162.7	2102.4	5559565	5464867	5753030	13.74

Legends: GlobHor   Horizontal global irradiation

T Amb   Ambient Temperature

GlobInc   Global incident in coll. plane

GlobEff   Effective Global, corr. for IAM and shadings

EArray   Effective energy at the output of the array

E_Grid   Energy injected into grid

EApGrid   Apparent energy to the grid

EffSysR   Effic. Eout system / rough area

New simulation variant
Meteo and incident energy

	GlobHor	DiffHor	T Amb	WindVel	GlobInc	DifSInc	Alb Inc	DifS/GI
	kWh/m²	kWh/m²	°C	m/s	kWh/m²	kWh/m²	kWh/m²	
January	87.0	40.98	12.35	3.0	122.0	47.80	1.019	0.000
February	100.1	46.24	13.22	3.1	129.2	51.93	1.172	0.000
March	150.3	65.53	16.06	3.0	174.5	70.33	1.759	0.000
April	182.1	72.46	18.99	3.0	191.1	74.65	2.131	0.000
May	226.8	70.40	22.35	3.0	216.1	69.90	2.653	0.000
June	239.0	63.54	25.07	3.1	218.4	62.19	2.780	0.000
July	242.5	61.63	27.53	3.1	225.6	60.86	2.820	0.000
August	224.7	57.00	27.75	3.0	227.8	59.30	2.628	0.000
September	182.9	50.95	25.77	2.9	207.3	55.54	2.141	0.000
October	142.1	48.37	23.33	2.5	182.6	56.14	1.663	0.000
November	101.5	37.60	18.37	2.5	144.8	44.37	1.188	0.000
December	83.4	35.65	14.39	2.8	123.3	42.31	0.976	0.000
Year	1962.4	650.36	20.47	2.9	2162.7	695.31	22.930	0.000

Legends: GlobHor   Horizontal global irradiation

           DiffHor   Horizontal diffuse irradiation

           T Amb   Ambient Temperature

           WindVel   Wind velocity

           GlobInc   Global incident in coll. plane

           DifSInc   Sky Diffuse incident in coll. plane

           Alb Inc   Albedo incident in coll. plane

           DifS/GI   Incident Sky Diffuse / Global ratio

New simulation variant

Effective incident energy (Transpos., IAM, Shadings)

	GlobHor	GlobInc	GlobIAM	GlobEff	DiffEff
	kWh/m²	kWh/m²	kWh/m²	kWh/m²	kWh/m²
January	87.0	122.0	118.7	118.7	45.86
February	100.1	129.2	125.6	125.6	49.80
March	150.3	174.5	169.8	169.8	67.50
April	182.1	191.1	185.8	185.8	71.72
May	226.8	216.1	209.4	209.4	67.11
June	239.0	218.4	211.5	211.5	59.67
July	242.5	225.6	218.7	218.7	58.38
August	224.7	227.8	221.5	221.5	56.98
September	182.9	207.3	202.2	202.2	53.22
October	142.1	182.6	178.1	178.1	53.95
November	101.5	144.8	141.1	141.1	42.51
December	83.4	123.3	120.0	120.0	40.56
Year	1962.4	2162.7	2102.4	2102.4	667.25

Legends: GlobHor   Horizontal global irradiation

GlobInc   Global incident in coll. plane

GlobIAM   Global corrected for incidence (IAM)

GlobEff   Effective Global, corr. for IAM and shadings

DiffEff   Effective Diffuse, corr. for IAM and shadings

New simulation variant

Detailed System Losses

	ModQual	MisLoss	OhmLoss	EArrMPP	InvLoss
	kWh	kWh	kWh	kWh	kWh
January	-1363.288	3422	2971	335792	6016
February	-1426.870	3581	3430	351133	6270
March	-1885.581	4733	5053	463495	8154
April	-2022.204	5076	5864	496633	8688
May	-2233.115	5605	6772	548135	9313
June	-2225.717	5587	6893	546176	9139
July	-2269.913	5697	7218	556833	9147
August	-2286.064	5738	7553	560511	9233
September	-2106.761	5288	6891	516618	8527
October	-1900.199	4769	5566	466614	7791
November	-1554.539	3902	4075	382213	6583
December	-1362.672	3420	3108	335503	5930
Year	-22636.925	56819	65394	5559657	94790

Legends: ModQual   Module quality loss

                  MisLoss   Module array mismatch loss

                  OhmLoss   *Ohmic wiring loss*

                  EArrMPP   Array virtual energy at MPP

                  InvLoss   Global inverter losses

New simulation variant

Detailed Inverter losses

	EOutInv	EffInvR	InvLoss	IL Oper	IL Pmin	IL Pmax	IL Vmin	IL Vmax
	kWh	%	kWh	kWh	kWh	kWh	kWh	kWh
January	329776	98.2	6016	6016	0.000	0.000	0.00	0.000
February	344863	98.2	6270	6270	0.000	0.000	0.00	0.000
March	455341	98.2	8154	8154	0.000	0.000	0.00	0.000
April	487945	98.3	8688	8687	0.000	0.000	1.46	0.000
May	538822	98.3	9313	9313	0.000	0.000	0.00	0.000
June	537037	98.3	9139	9139	0.000	0.000	0.01	0.000
July	547686	98.4	9147	9129	0.000	0.000	17.40	0.000
August	551278	98.4	9233	9195	0.000	0.000	38.17	0.000
September	508092	98.4	8527	8491	0.000	0.000	35.38	0.000
October	458824	98.3	7791	7791	0.000	0.000	0.00	0.000
November	375630	98.3	6583	6583	0.000	0.000	0.00	0.000
December	329572	98.2	5930	5930	0.000	0.000	0.00	0.000
Year	5464867	98.3	94790	94698	0.000	0.000	92.43	0.000

Legends: EOutInv   Available Energy at Inverter Output

EffInvR   Inverter efficiency (operating)

InvLoss   Global inverter losses

IL Oper   Inverter Loss during operation (efficiency)

IL Pmin   Inverter Loss due to power threshold

IL Pmax   Inverter Loss over nominal inv. power

IL Vmin   Inverter Loss due to voltage threshold

IL Vmax   Inverter Loss over nominal inv. voltage

New simulation variant

Energy use and User's needs

	E_Grid
	kWh
January	329776
February	344863
March	455341
April	487945
May	538822
June	537037
July	547686
August	551278
September	508092
October	458824
November	375630
December	329572
Year	5464867

Legends: E_Grid   Energy injected into grid

New simulation variant

Normalized Performance Coefficients

	Yr	Lc	Ya	Ls	Yf	Lcr	Lsr	PR
	kWh/m².day		kWh/kWp/day		kWh/kWp/day			
January	3.94	0.367	3.57	0.064	3.51	0.093	0.016	0.891
February	4.61	0.479	4.13	0.074	4.06	0.104	0.016	0.880
March	5.63	0.702	4.93	0.087	4.84	0.125	0.015	0.860
April	6.37	0.915	5.46	0.095	5.36	0.144	0.015	0.841
May	6.97	1.142	5.83	0.099	5.73	0.164	0.014	0.822
June	7.28	1.278	6.00	0.100	5.90	0.176	0.014	0.811
July	7.28	1.358	5.92	0.097	5.82	0.187	0.013	0.800
August	7.35	1.390	5.96	0.098	5.86	0.189	0.013	0.798
September	6.91	1.233	5.68	0.093	5.58	0.179	0.014	0.808
October	5.89	0.929	4.96	0.083	4.88	0.158	0.014	0.828
November	4.83	0.626	4.20	0.072	4.13	0.130	0.015	0.855
December	3.98	0.411	3.57	0.063	3.50	0.103	0.016	0.881
Year	5.93	0.905	5.02	0.086	4.93	0.153	0.014	0.833

Legends: Yr   Reference Incident Energy in coll. plane

Lc   Normalized Array Losses

Ya   Normalized Array Production

Ls   Normalized System Losses

Yf   Normalized System Production

Lcr   Array Loss / Incident Energy Ratio

Lsr   System Loss / Incident Energy Ratio

PR   Performance Ratio

New simulation variant
Monthly Hourly sums for E_Grid [MWh]

	0H	1H	2H	3H	4H	5H	6H	7H	8H	9H	10H	11H	12H	13H	14H	15H	16H	17H	18H	19H	20H	21H	22H	23H
January	0	0	0	0	0	0	0	12	29	41	47	50	49	44	35	19	3	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	12	27	38	44	49	48	48	39	27	11	0	0	0	0	0	0	0
March	0	0	0	0	0	0	6	24	41	52	59	61	62	55	47	33	15	0	0	0	0	0	0	0
April	0	0	0	0	0	1	12	28	45	56	63	64	64	57	47	32	16	2	0	0	0	0	0	0
May	0	0	0	0	0	3	16	34	50	60	67	68	67	62	52	37	19	4	0	0	0	0	0	0
June	0	0	0	0	0	3	16	33	49	59	66	68	66	61	51	38	21	6	0	0	0	0	0	0
July	0	0	0	0	0	3	14	33	49	61	67	69	67	62	53	39	22	7	0	0	0	0	0	0
August	0	0	0	0	0	1	14	33	49	61	69	71	69	64	54	40	21	4	0	0	0	0	0	0
September	0	0	0	0	0	0	13	32	47	59	66	67	66	60	49	33	15	1	0	0	0	0	0	0
October	0	0	0	0	0	0	11	28	45	56	62	65	63	57	42	25	8	0	0	0	0	0	0	0
November	0	0	0	0	0	0	1	21	39	49	55	55	54	48	35	18	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	15	30	42	49	51	49	44	34	16	0	0	0	0	0	0	0	0
Year	0	0	0	0	0	11	103	307	501	634	713	738	725	663	538	357	150	28	0	0	0	0	0	0

Appendix G

Steps to use the ETAP program and make the settings for the PV station and the network.

Grid

The distribution network in our project feeds Basically by two grids which are:

1. Tyaseer swing grid (20MVA).
2. Al-Zawyah grid (5MVA).
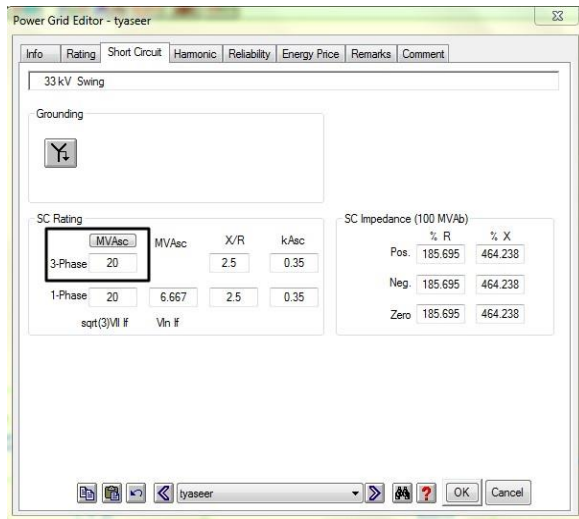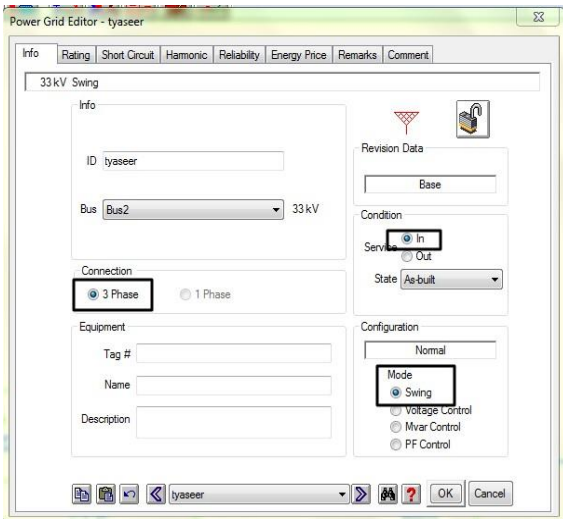
Tyaseer swing grid (20MVA).
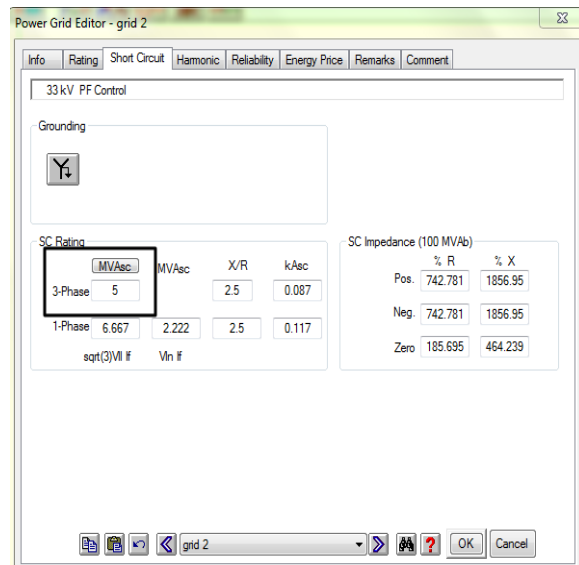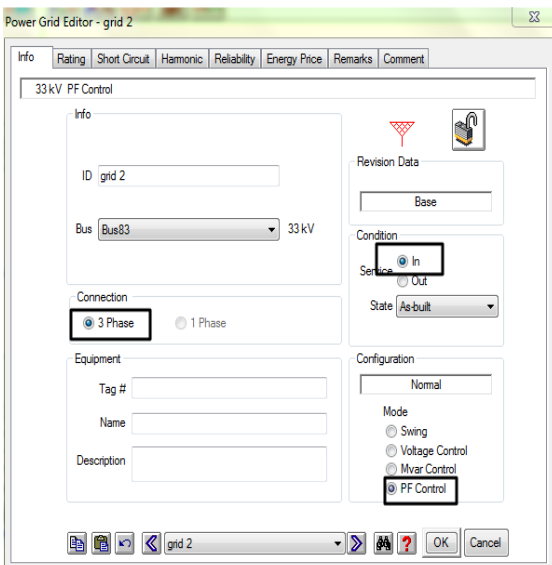
Al-Zawyah grid (5MVA).

Transmission lines

A transmission lines is a pair of electrical conductors carrying an electrical signal from one place to another. Coaxial cable and twisted pair cable are examples. The two conductors have inductance per unit length, which we can calculate from their size and shape.

In our project the transmission lines transmit power between busses, and transmit power from the PV station and grids to the loads. After filing the needed data from datasheet in to the library of the program, it choose a calculated value for impedance per conductor per length unit, and then we add the length for each
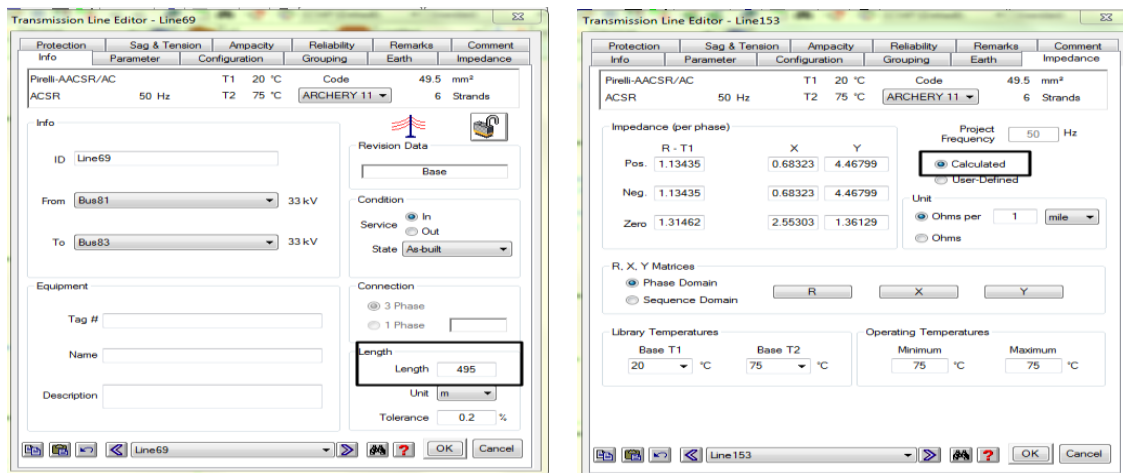
transmission.

Transmission lines data in E-TAP

After filing the required data for transmission lines, we run E-TAP to get the current flow at each transmission line, and set the allowable loading equal 80% from the real loading.
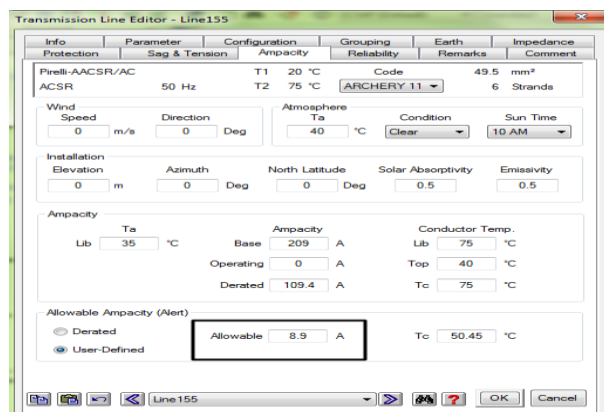
Cabels

An underground cable is a cable that buried below the ground. They distribute electrical power or telecommunications. Such cables are an alternative to overhead cables, which are several meters above the ground. Downtown areas with many tall buildings   usually have few or no cables above ground, This is mainly for aesthetic purposes because underground cables can't be seen. They are also less dangerous to people because they are out of the way. They cost more to install, but last longer.

In our project the cable transmit power between some busses, and transmit power in the PV station and grids to the loads. After filing the needed data from datasheet in to the library of the program, we add the length for each cable.

cable data in E-tap

Transformers

There are three kinds of transformers:

- Step-down Transformers 33/0.4kV- Exiting(in the distribution network).

- Auto transformer 33/33kV(in the distribution network).

- Step-up Transformers 0.4/33kV-proposed(in the PV station).

After We fill the parameters of transformers from the datasheet, we put a typical impedance.
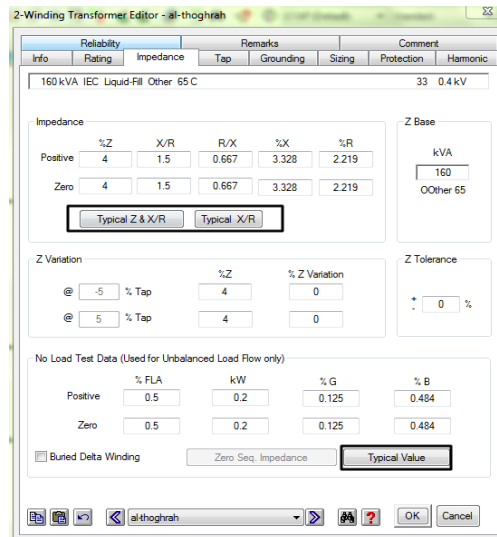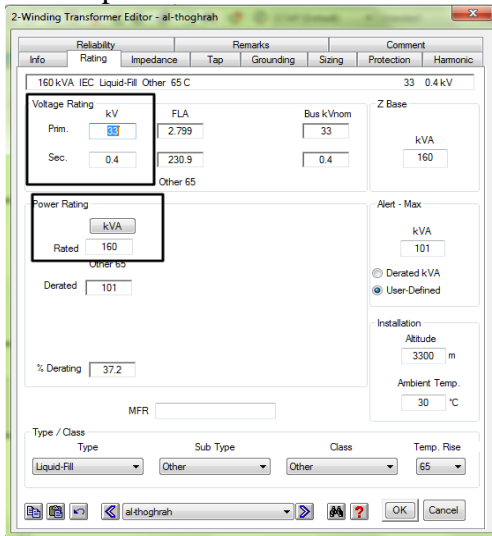
Transformers data in E-tap

Photovoltaic system & inverter

The following figures shows how we fill the data for PV area.
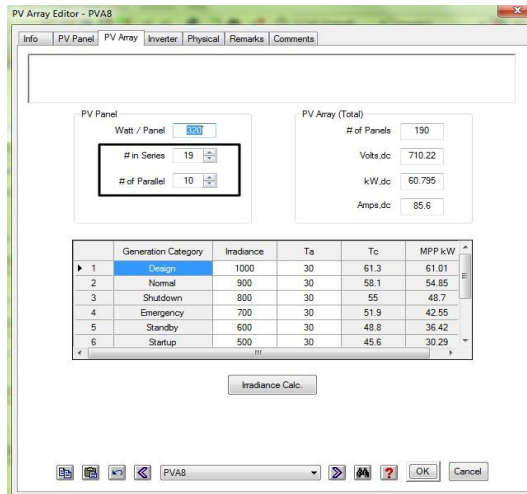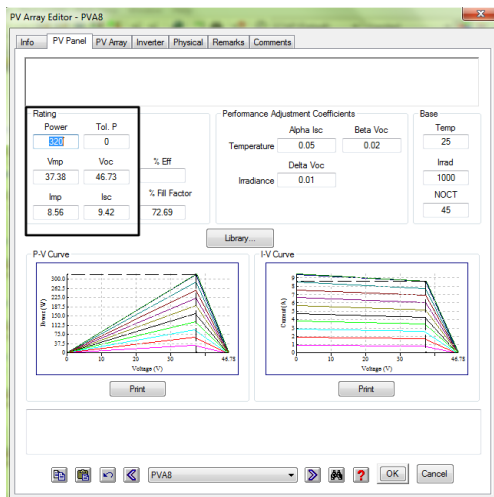
PV data in E-TAP
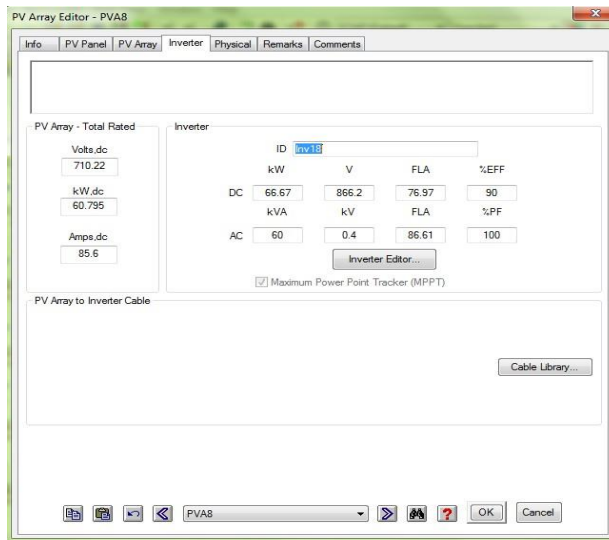
inverter data in E-TAP

Load

The following figures shows how we fill the data for each load.
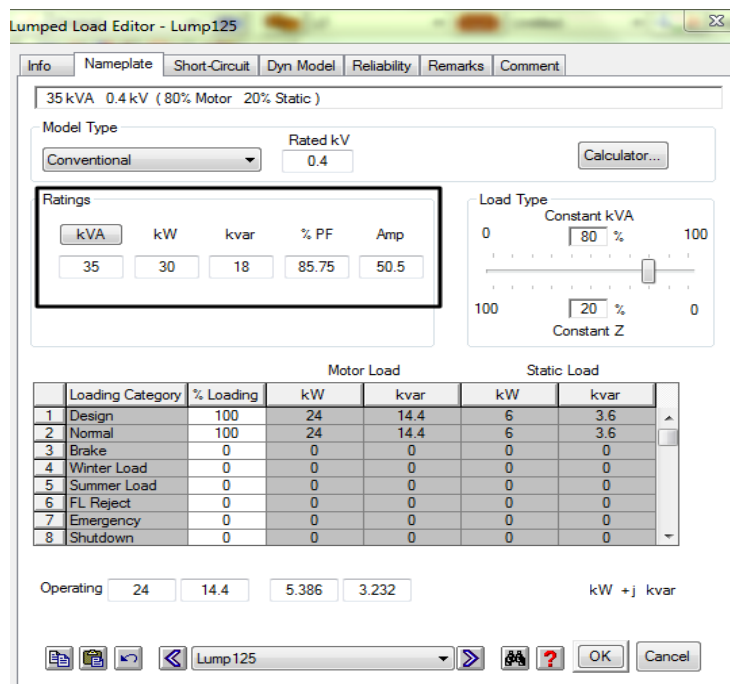
load data in E-TAP

Appendix H

Results of Power factor on the buses from the ETAP software

Bus Loading Summary Report

| Bus | | | Directly Connected Load | | | | | | | | Total Bus Load | | | |
| | | | Constant kVA | | Constant Z | | Constant I | | Generic | | | | | Percent |
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus2	33.000		0	0	0	0	0	0	0	0	5.951	73.8	104.1	
Bus3	33.000		0	0	0	0	0	0	0	0	5.951	73.8	104.1	
Bus4	33.000		0	0	0	0	0	0	0	0	0.035	87.8	0.6	
Bus5	33.000		0	0	0	0	0	0	0	0	0.035	87.8	0.6	
Bus6	33.000		0	0	0	0	0	0	0	0	0.038	81.8	0.7	
Bus7	33.000		0	0	0	0	0	0	0	0	5.909	73.8	103.6	
Bus8	33.000		0	0	0	0	0	0	0	0	5.747	72.9	101.4	
Bus9	33.000		0	0	0	0	0	0	0	0	5.720	72.8	101.0	
Bus10	33.000		0	0	0	0	0	0	0	0	5.720	72.8	101.0	
Bus11	33.000		0	0	0	0	0	0	0	0	5.715	72.8	101.0	
Bus12	33.000		0	0	0	0	0	0	0	0	5.620	73.9	101.0	
Bus13	33.000		0	0	0	0	0	0	0	0	5.605	73.8	101.0	
Bus14	33.000		0	0	0	0	0	0	0	0	5.510	73.3	99.6	
Bus15	33.000		0	0	0	0	0	0	0	0	5.420	72.7	98.2	
Bus16	33.000		0	0	0	0	0	0	0	0	5.414	72.7	98.2	
Bus17	33.000		0	0	0	0	0	0	0	0	5.393	72.5	97.9	
Bus18	33.000		0	0	0	0	0	0	0	0	0.927	77.3	16.8	
Bus19	33.000		0	0	0	0	0	0	0	0	0.821	74.1	14.9	
Bus20	33.000		0	0	0	0	0	0	0	0	0.283	96.9	5.1	
Bus21	33.000		0	0	0	0	0	0	0	0	0.191	96.7	3.5	
Bus22	33.000		0	0	0	0	0	0	0	0	0.092	97.4	1.7	
Bus23	33.000		0	0	0	0	0	0	0	0	0.092	97.4	1.7	
Bus24	33.000		0	0	0	0	0	0	0	0	0.092	97.2	1.7	
Bus25	33.000		0	0	0	0	0	0	0	0	0.092	96.9	1.7	
Bus26	33.000		0	0	0	0	0	0	0	0	0.587	57.0	10.7	
Bus27	33.000		0	0	0	0	0	0	0	0	0.587	57.0	10.7	
Bus28	33.000		0	0	0	0	0	0	0	0	0.587	56.9	10.7	
Bus29	33.000		0	0	0	0	0	0	0	0	0.139	93.7	2.5	
Bus30	33.000		0	0	0	0	0	0	0	0	0.444	37.1	8.1	
Bus31	33.000		0	0	0	0	0	0	0	0	0.039	99.8	0.7	
Bus32	33.000		0	0	0	0	0	0	0	0	0.039	99.8	0.7	
Bus33	33.000		0	0	0	0	0	0	0	0	0.039	99.8	0.7	
Bus34	33.000		0	0	0	0	0	0	0	0	0.030	100.0	0.5	
Bus35	33.000		0	0	0	0	0	0	0	0	0.398	28.1	7.2	
Bus36	33.000		0	0	0	0	0	0	0	0	0.027	95.9	0.5	
Bus37	33.000		0	0	0	0	0	0	0	0	0.402	35.2	7.3	

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Config.:   Normal

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus38	33.000		0	0	0	0	0	0	0	0	0.454	61.9	8.3	
Bus39	33.000		0	0	0	0	0	0	0	0	0.155	89.9	2.8	
Bus40	33.000		0	0	0	0	0	0	0	0	0.154	89.8	2.8	
Bus41	33.000		0	0	0	0	0	0	0	0	0.466	72.9	8.5	
Bus42	33.000		0	0	0	0	0	0	0	0	0.585	86.0	10.6	
Bus43	33.000		0	0	0	0	0	0	0	0	0.025	95.7	0.5	
Bus44	33.000		0	0	0	0	0	0	0	0	0.007	95.9	0.1	
Bus45	33.000		0	0	0	0	0	0	0	0	0.687	92.6	12.5	
Bus46	33.000		0	0	0	0	0	0	0	0	0.690	95.5	12.5	
Bus47	33.000		0	0	0	0	0	0	0	0	0.688	95.7	12.5	
Bus48	33.000		0	0	0	0	0	0	0	0	0.688	95.7	12.5	
Bus49	33.000		0	0	0	0	0	0	0	0	0.688	95.7	12.5	
Bus50	33.000		0	0	0	0	0	0	0	0	0.690	95.6	12.5	
Bus51	33.000		0	0	0	0	0	0	0	0	0.002	0.0	0.0	
Bus52	33.000		0	0	0	0	0	0	0	0	0.002	0.0	0.0	
Bus53	33.000		0	0	0	0	0	0	0	0	0.002	0.0	0.0	
Bus54	33.000		0	0	0	0	0	0	0	0	0.002	0.0	0.0	
Bus55	33.000		0	0	0	0	0	0	0	0	0.698	95.7	12.7	
Bus56	33.000		0	0	0	0	0	0	0	0	0.708	95.9	12.8	
Bus57	33.000		0	0	0	0	0	0	0	0	0.709	96.1	12.9	
Bus58	33.000		0	0	0	0	0	0	0	0	2.352	97.6	42.6	
Bus59	33.000		0	0	0	0	0	0	0	0	2.436	98.3	44.1	
Bus60	33.000		0	0	0	0	0	0	0	0	0.103	95.7	1.9	
Bus61	33.000		0	0	0	0	0	0	0	0	2.571	98.1	46.6	
Bus62	33.000		0	0	0	0	0	0	0	0	2.714	98.2	49.2	
Bus63	33.000		0	0	0	0	0	0	0	0	0.146	98.0	2.6	
Bus64	33.000		0	0	0	0	0	0	0	0	0.065	98.2	1.2	
Bus65	33.000		0	0	0	0	0	0	0	0	0.065	98.1	1.2	
Bus66	33.000		0	0	0	0	0	0	0	0	0.068	93.8	1.2	
Bus67	33.000		0	0	0	0	0	0	0	0	2.786	98.2	50.4	
Bus68	33.000		0	0	0	0	0	0	0	0	2.836	98.1	51.0	
Bus69	33.000		0	0	0	0	0	0	0	0	2.928	98.1	52.6	
Bus70	33.000		0	0	0	0	0	0	0	0	3.205	97.5	57.5	
Bus71	33.000		0	0	0	0	0	0	0	0	0.289	86.5	5.2	
Bus72	33.000		0	0	0	0	0	0	0	0	0.248	83.6	4.4	
Bus73	33.000		0	0	0	0	0	0	0	0	3.278	97.4	58.8	
Bus74	33.000		0	0	0	0	0	0	0	0	3.484	97.2	61.9	
Bus75	33.000		0	0	0	0	0	0	0	0	0.087	92.5	1.5	

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Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus76	33.000		0	0	0	0	0	0	0	0	3.514	97.1	62.4	
Bus77	33.000		0	0	0	0	0	0	0	0	0.029	77.9	0.5	
Bus78	33.000		0	0	0	0	0	0	0	0	3.540	97.1	62.5	
Bus79	33.000		0	0	0	0	0	0	0	0	0.008	96.9	0.1	
Bus80	33.000		0	0	0	0	0	0	0	0	3.954	97.2	69.8	
Bus81	33.000		0	0	0	0	0	0	0	0	3.995	97.1	70.0	
Bus82	33.000		0	0	0	0	0	0	0	0	0.018	77.9	0.3	
Bus83	33.000		0	0	0	0	0	0	0	0	4.061	97.1	71.1	
Bus84	33.000		0	0	0	0	0	0	0	0	0.025	96.9	0.4	
Bus87	33.000		0	0	0	0	0	0	0	0	0.410	97.3	7.2	
Bus88	33.000		0	0	0	0	0	0	0	0	0.061	97.1	1.1	
Bus89	33.000		0	0	0	0	0	0	0	0	0.020	92.8	0.4	
Bus90	33.000		0	0	0	0	0	0	0	0	0.349	97.2	6.2	
Bus91	33.000		0	0	0	0	0	0	0	0	0.013	97.0	0.2	
Bus92	33.000		0	0	0	0	0	0	0	0	0.242	96.7	4.3	
Bus93	33.000		0	0	0	0	0	0	0	0	0.205	97.2	3.6	
Bus94	33.000		0	0	0	0	0	0	0	0	0.171	95.2	3.0	
Bus95	33.000		0	0	0	0	0	0	0	0	0.075	90.7	1.3	
Bus96	33.000		0	0	0	0	0	0	0	0	1.693	95.3	30.7	
Bus97	33.000		0	0	0	0	0	0	0	0	1.693	95.3	30.7	
Bus98	33.000		0	0	0	0	0	0	0	0	1.693	95.3	30.7	
Bus99	33.000		0	0	0	0	0	0	0	0	0.287	93.0	5.2	
Bus100	33.000		0	0	0	0	0	0	0	0	0.212	93.2	3.8	
Bus101	33.000		0	0	0	0	0	0	0	0	0.196	93.1	3.6	
Bus102	33.000		0	0	0	0	0	0	0	0	0.196	93.1	3.6	
Bus103	33.000		0	0	0	0	0	0	0	0	0.198	92.3	3.6	
Bus104	33.000		0	0	0	0	0	0	0	0	0.198	92.0	3.6	
Bus105	33.000		0	0	0	0	0	0	0	0	0.151	91.9	2.7	
Bus106	33.000		0	0	0	0	0	0	0	0	0.105	91.2	1.9	
Bus109	33.000		0	0	0	0	0	0	0	0	0.106	91.0	1.9	
Bus110	33.000		0	0	0	0	0	0	0	0	0.052	91.8	1.0	
Bus111	33.000		0	0	0	0	0	0	0	0	0	0.0	0.0	
Bus112	33.000		0	0	0	0	0	0	0	0	1.406	95.7	25.5	
Bus113	33.000		0	0	0	0	0	0	0	0	1.406	95.7	25.5	
Bus114	33.000		0	0	0	0	0	0	0	0	1.404	95.5	25.5	
Bus115	33.000		0	0	0	0	0	0	0	0	0.076	100.0	1.4	
Bus116	33.000		0	0	0	0	0	0	0	0	1.331	95.0	24.2	
Bus118	33.000		0	0	0	0	0	0	0	0	0.317	96.1	5.8	

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Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus119	33.000		0	0	0	0	0	0	0	0	0.202	94.3	3.7	
Bus120	33.000		0	0	0	0	0	0	0	0	0.139	96.0	2.5	
Bus122	33.000		0	0	0	0	0	0	0	0	0.139	95.9	2.5	
Bus123	33.000		0	0	0	0	0	0	0	0	0.717	96.5	13.1	
Bus124	33.000		0	0	0	0	0	0	0	0	0.402	96.5	7.3	
Bus125	33.000		0	0	0	0	0	0	0	0	0.400	96.4	7.3	
Bus126	33.000		0	0	0	0	0	0	0	0	0.355	96.0	6.5	
Bus127	33.000		0	0	0	0	0	0	0	0	0.061	94.5	1.1	
Bus135	33.000		0	0	0	0	0	0	0	0	0.062	93.9	1.1	
Bus137	33.000		0	0	0	0	0	0	0	0	0.216	95.8	3.9	
Bus138	33.000		0	0	0	0	0	0	0	0	0.194	96.7	3.5	
Bus139	33.000		0	0	0	0	0	0	0	0	0.169	96.1	3.1	
Bus140	33.000		0	0	0	0	0	0	0	0	0.088	95.9	1.6	
Bus141	33.000		0	0	0	0	0	0	0	0	0.012	92.9	0.2	
Bus142	33.000		0	0	0	0	0	0	0	0	0.616	92.9	11.2	
Bus143	33.000		0	0	0	0	0	0	0	0	0.059	92.9	1.1	
Bus144	33.000		0	0	0	0	0	0	0	0	0.557	92.9	10.1	
Bus145	33.000		0	0	0	0	0	0	0	0	0.464	91.9	8.4	
Bus146	33.000		0	0	0	0	0	0	0	0	0.344	91.3	6.3	
Bus147	33.000		0	0	0	0	0	0	0	0	0.142	98.9	2.6	
Bus148	33.000		0	0	0	0	0	0	0	0	0.087	97.9	1.6	
Bus149	33.000		0	0	0	0	0	0	0	0	0.163	60.7	3.0	
Bus150	33.000		0	0	0	0	0	0	0	0	0.057	97.9	1.0	
Bus151	33.000		0	0	0	0	0	0	0	0	0.126	34.0	2.3	
Bus152	33.000		0	0	0	0	0	0	0	0	0.121	92.5	2.2	
Bus153	33.000		0	0	0	0	0	0	0	0	0.030	98.9	0.6	
Bus154	33.000		0	0	0	0	0	0	0	0	0.094	87.3	1.7	
Bus155	33.000		0	0	0	0	0	0	0	0	0.093	86.9	1.7	
Bus156	33.000		0	0	0	0	0	0	0	0	0.071	85.3	1.3	
Bus157	33.000		0	0	0	0	0	0	0	0	0.001	92.0	0.0	
Bus158	33.000		0	0	0	0	0	0	0	0	4.470	71.5	81.1	
Bus159	33.000		0	0	0	0	0	0	0	0	0.132	94.6	2.4	
Bus160	33.000		0	0	0	0	0	0	0	0	4.350	70.6	79.0	
Bus161	33.000		0	0	0	0	0	0	0	0	4.330	70.3	78.7	
Bus162	33.000		0	0	0	0	0	0	0	0	4.166	68.9	75.7	
Bus163	33.000		0	0	0	0	0	0	0	0	4.166	68.9	75.7	
Bus164	33.000		0	0	0	0	0	0	0	0	4.159	68.9	75.7	
Bus165	33.000		0	0	0	0	0	0	0	0	4.004	66.9	72.9	

| Bus | | | Directly Connected Load | | | | | | | | | | Total Bus Load | | | |
| | | | Constant kVA | | Constant Z | | Constant I | | Generic | | | | | | | Percent |
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus167	33.000		0	0	0	0	0	0	0	0	4.001	66.8	72.9	
Bus168	33.000		0	0	0	0	0	0	0	0	0.146	89.4	2.7	
Bus169	33.000		0	0	0	0	0	0	0	0	3.864	65.8	70.5	
Bus170	33.000		0	0	0	0	0	0	0	0	3.864	65.8	70.5	
Bus171	33.000		0	0	0	0	0	0	0	0	3.861	65.7	70.5	
Bus173	33.000		0	0	0	0	0	0	0	0	1.104	95.9	20.1	
Bus174	33.000		0	0	0	0	0	0	0	0	0.039	98.0	0.7	
Bus175	33.000		0	0	0	0	0	0	0	0	0.039	96.5	0.7	
Bus176	33.000		0	0	0	0	0	0	0	0	0.035	95.5	0.6	
Bus177	33.000		0	0	0	0	0	0	0	0	0.036	94.8	0.7	
Bus178	33.000		0	0	0	0	0	0	0	0	1.066	95.7	19.5	
Bus179	33.000		0	0	0	0	0	0	0	0	0.992	96.0	18.1	
Bus180	33.000		0	0	0	0	0	0	0	0	0.035	96.9	0.6	
Bus181	33.000		0	0	0	0	0	0	0	0	0.958	95.8	17.5	
Bus182	33.000		0	0	0	0	0	0	0	0	0.908	95.7	16.6	
Bus183	33.000		0	0	0	0	0	0	0	0	0.101	94.7	1.8	
Bus184	33.000		0	0	0	0	0	0	0	0	0.807	95.9	14.8	
Bus185	33.000		0	0	0	0	0	0	0	0	0.751	95.6	13.8	
Bus186	33.000		0	0	0	0	0	0	0	0	0.078	95.7	1.4	
Bus187	33.000		0	0	0	0	0	0	0	0	0.050	94.6	0.9	
Bus188	33.000		0	0	0	0	0	0	0	0	0.624	95.6	11.4	
Bus189	33.000		0	0	0	0	0	0	0	0	0.418	94.8	7.7	
Bus190	33.000		0	0	0	0	0	0	0	0	0.269	94.9	4.9	
Bus191	33.000		0	0	0	0	0	0	0	0	0.230	94.4	4.2	
Bus192	33.000		0	0	0	0	0	0	0	0	0.157	93.4	2.9	
Bus193	33.000		0	0	0	0	0	0	0	0	0.040	95.9	0.7	
Bus194	33.000		0	0	0	0	0	0	0	0	0.126	97.0	2.3	
Bus195	33.000		0	0	0	0	0	0	0	0	0.126	97.0	2.3	
Bus196	33.000		0	0	0	0	0	0	0	0	0.127	96.6	2.3	
Bus197	33.000		0	0	0	0	0	0	0	0	0.112	95.1	2.1	
Bus198	33.000		0	0	0	0	0	0	0	0	0.017	96.0	0.3	
Bus199	33.000		0	0	0	0	0	0	0	0	0.008	97.0	0.2	
Bus201	33.000		0	0	0	0	0	0	0	0	0.097	93.1	1.8	
Bus202	33.000		0	0	0	0	0	0	0	0	0.086	92.9	1.6	
Bus203	33.000		0	0	0	0	0	0	0	0	0.013	87.0	0.2	
Bus229	0.400		0.183	0.037	0	0	0	0	0	0	0.187	98.0	283.6	
Bus230	0.400		0.031	0.021	0	0	0	0	0	0	0.037	82.0	54.5	
Bus231	0.400		0.128	0.042	0	0	0	0	0	0	0.134	95.0	197.8	

| | | | | Directly Connected Load | | | | | | | | Total Bus Load | | | |
| | **Bus** | | | Constant kVA | | Constant Z | | Constant I | | Generic | | | | | Percent |
ID	kV	Rated Amp		MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus233	0.400			0.024	0.009	0	0	0	0	0	0	0.025	94.0	37.0	
Bus234	0.400			0.084	0.021	0	0	0	0	0	0	0.087	97.0	131.8	
Bus235	0.400			0.086	0.025	0	0	0	0	0	0	0.090	96.0	135.3	
Bus237	0.400			0.021	0.003	0	0	0	0	0	0	0.021	99.0	31.7	
Bus238	0.400			0.123	0.040	0	0	0	0	0	0	0.130	95.0	197.8	
Bus239	0.400			0.172	0.056	0	0	0	0	0	0	0.181	95.0	275.5	
Bus240	0.400			0.019	0.006	0	0	0	0	0	0	0.020	95.0	29.9	
Bus246	0.400			0.107	0.035	0	0	0	0	0	0	0.113	95.0	171.4	
Bus247	0.400			0.182	0.046	0	0	0	0	0	0	0.188	97.0	285.6	
Bus248	0.400			0.089	0.022	0	0	0	0	0	0	0.092	97.0	138.4	
Bus249	0.400			0.123	0.041	0	0	0	0	0	0	0.130	95.0	198.3	
Bus250	0.400			0.129	0.047	0	0	0	0	0	0	0.137	94.0	208.1	
Bus251	0.400			0.124	0.031	0	0	0	0	0	0	0.128	97.0	194.5	
Bus252	0.400			0.009	0.002	0	0	0	0	0	0	0.009	97.0	13.9	
Bus253	0.400			0.030	0	0	0	0	0	0	0	0.030	100.0	45.1	
Bus254	0.400			0.026	0.008	0	0	0	0	0	0	0.027	96.0	40.5	
Bus255	0.400			0.030	0.020	0	0	0	0	0	0	0.036	83.0	54.2	
Bus256	0.400			0.138	0.067	0	0	0	0	0	0	0.153	90.0	231.4	
Bus257	0.400			0.001	0	0	0	0	0	0	0	0.001	98.0	1.5	
Bus258	0.400			0.058	0.023	0	0	0	0	0	0	0.062	93.0	93.8	
Bus259	0.400			0.138	0.035	0	0	0	0	0	0	0.143	97.0	216.2	
Bus260	0.400			0.017	0.007	0	0	0	0	0	0	0.018	92.0	27.6	
Bus261	0.400			0.007	0.002	0	0	0	0	0	0	0.007	96.0	10.9	
Bus262	0.400			0.132	0.056	0	0	0	0	0	0	0.143	92.0	217.3	
Bus263	0.400			0.022	0.007	0	0	0	0	0	0	0.023	95.0	34.7	
Bus264	0.400			0.009	0.004	0	0	0	0	0	0	0.010	91.0	14.8	
Bus268	0.400			0.011	0.008	0	0	0	0	0	0	0.014	80.0	20.4	
Bus269	0.400			0.001	0.115	0	0.001	0	0	0	0	0.116	1.0	175.1	
Bus270	0.400			0.098	0.028	0	0	0	0	0	0	0.102	96.0	154.0	
Bus271	0.400			0.126	0.050	0	0	0	0	0	0	0.135	93.0	204.5	
Bus272	0.400			0.068	0.010	0	0	0	0	0	0	0.069	99.0	102.9	
Bus273	0.400			0.035	0.018	0	0	0	0	0	0	0.039	89.0	57.9	
Bus274	0.400			0.084	0.021	0	0	0	0	0	0	0.087	97.0	129.2	
Bus275	0.400			0.043	0.012	0	0	0	0	0	0	0.044	96.0	66.7	
Bus276	0.400			0.205	0.132	0	0	0	0	0	0	0.244	84.0	366.8	
Bus277	0.400			0.084	0.041	0	0	0	0	0	0	0.094	90.0	138.3	
Bus278	0.400			0.079	0.031	0	0	0	0	0	0	0.085	93.0	127.7	
Bus279	0.400			0.023	0.018	0	0	0	0	0	0	0.029	78.0	43.0	

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Config.:   Normal

Bus				Directly Connected Load								Total Bus Load			
				Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp		MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus280	0.400			0.055	0.022	0	0	0	0	0	0	0.059	93.0	88.9	
Bus281	0.400			0.091	0.023	0	0	0	0	0	0	0.094	97.0	141.3	
Bus282	0.400			0.075	0.011	0	0	0	0	0	0	0.076	99.0	114.7	
Bus283	0.400			0.084	0.017	0	0	0	0	0	0	0.086	98.0	130.0	
Bus284	0.400			0.056	0.011	0	0	0	0	0	0	0.057	98.0	85.8	
Bus285	0.400			0.021	0.059	0	0	0	0	0	0	0.063	34.0	94.9	
Bus286	0.400			0.021	0.059	0	0	0	0	0	0	0.063	34.0	94.9	
Bus287	0.400			0.008	0.002	0	0	0	0	0	0	0.008	97.0	12.1	
Bus288	0.400			0.040	0.010	0	0	0	0	0	0	0.041	97.0	61.3	
Bus289	0.400			0.019	0.007	0	0	0	0	0	0	0.020	93.0	29.7	
Bus290	0.400			0.013	0.003	0	0	0	0	0	0	0.013	97.0	19.4	
Bus291	0.400			0.035	0.015	0	0	0	0	0	0	0.038	92.0	55.6	
Bus292	0.400			0.036	0	0	0	0	0	0	0	0.036	100.0	52.9	
Bus293	0.400			0.092	0.023	0	0	0	0	0	0	0.095	97.0	139.1	
Bus294	0.400			0.094	0.024	0	0	0	0	0	0	0.097	97.0	142.5	
Bus295	0.400			0.067	0.031	0	0	0	0	0	0	0.074	91.0	108.8	
Bus296	0.400			0.014	0.011	0	0	0	0	0	0	0.018	78.0	25.9	
Bus297	0.400			0.034	0.008	0	0	0	0	0	0	0.035	97.0	50.6	
Bus298	0.400			0.024	0.006	0	0	0	0	0	0	0.025	97.0	35.8	
Bus299	0.400			0.068	0.027	0	0	0	0	0	0	0.073	93.0	108.5	
Bus300	0.400			0.078	0.028	0	0	0	0	0	0	0.083	94.0	125.2	
Bus301	0.400			0.064	0.023	0	0	0	0	0	0	0.068	94.0	102.1	
Bus302	0.400			0.074	0	0	0	0	0	0	0	0.074	100.0	113.6	
Bus303	0.400			0.069	0.030	0	0	0	0	0	0	0.075	92.0	113.3	
Bus304	0.400			0.015	0.012	0	0	0	0	0	0	0.019	78.0	28.8	
Bus305	0.400			0.043	0.018	0	0	0	0	0	0	0.047	92.0	71.0	
Bus306	0.400			0.055	0.011	0	0	0	0	0	0	0.056	98.0	84.9	
Bus307	0.400			0.030	0.004	0	0	0	0	0	0	0.030	99.0	45.5	
Bus308	0.400			0.001	0	0	0	0	0	0	0	0.001	92.0	1.6	
Bus309	0.400			0.020	0.009	0	0	0	0	0	0	0.022	91.0	33.0	
Bus310	0.400			0.059	0.037	0	0	0	0	0	0	0.070	85.0	105.6	
Bus311	0.400			0.001	0	0	0	0	0	0	0	0.001	92.0	1.6	
Bus312	0.400			0.002	0	0	0	0	0	0	0	0.002	100.0	2.9	
Bus313	0.400			0.069	0.014	0	0	0	0	0	0	0.071	98.0	107.0	
Bus314	0.400			0.045	0.009	0	0	0	0	0	0	0.046	98.0	69.1	
Bus315	0.400			0.044	0.006	0	0	0	0	0	0	0.044	99.0	66.8	
Bus316	0.400			0	0	0	0	0	0	0	0	0	0.0	0.0	
Bus317	0.400			0.075	0.025	0	0	0	0	0	0	0.079	95.0	120.2	

| Bus | | | | Directly Connected Load | | | | | | | | Total Bus Load | | | |
| | | | | Constant kVA | | Constant Z | | Constant I | | Generic | | | | | Percent |
ID	kV	Rated Amp		MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus319	0.400			0.058	0.021	0	0	0	0	0	0	0.061	94.0	92.8	
Bus320	0.400			0.019	0.015	0	0	0	0	0	0	0.024	78.0	36.6	
Bus321	0.400			0.078	0.023	0	0	0	0	0	0	0.081	96.0	123.3	
Bus322	0.400			0.025	0.006	0	0	0	0	0	0	0.026	97.0	39.0	
Bus323	0.400			0.073	0.024	0	0	0	0	0	0	0.077	95.0	116.4	
Bus324	0.400			0.011	0.004	0	0	0	0	0	0	0.012	93.0	17.7	
Bus325	0.400			0.058	0.028	0	0	0	0	0	0	0.064	90.0	96.5	
Bus327	0.400			0.075	0.011	0	0	0	0	0	0	0.076	99.0	114.3	
Bus328	0.400			0.058	0.028	0	0	0	0	0	0	0.064	90.0	96.5	
Bus329	0.400			0.048	0.024	0	0	0	0	0	0	0.054	89.0	81.0	
Bus330	0.400			0.048	0.020	0	0	0	0	0	0	0.052	92.0	78.5	
Bus331	0.400			0.043	0.018	0	0	0	0	0	0	0.047	92.0	70.1	
Bus332	0.400			0.128	0.062	0	0	0	0	0	0	0.143	90.0	219.4	
Bus333	0.400			0.032	0.010	0	0	0	0	0	0	0.034	95.0	50.9	
Bus334	0.400			0.066	0.032	0	0	0	0	0	0	0.074	90.0	112.1	
Bus335	0.400			0.004	0.001	0	0	0	0	0	0	0.004	97.0	6.2	
Bus336	0.400			0.034	0.011	0	0	0	0	0	0	0.035	95.0	53.8	
Bus337	0.400			0.034	0.008	0	0	0	0	0	0	0.035	97.0	52.6	
Bus338	0.400			0.048	0.014	0	0	0	0	0	0	0.050	96.0	75.3	
Bus339	0.400			0.094	0.031	0	0	0	0	0	0	0.099	95.0	152.2	
Bus340	0.400			0.055	0.011	0	0	0	0	0	0	0.056	98.0	85.3	
Bus341	0.400			0.074	0.022	0	0	0	0	0	0	0.077	96.0	118.2	
Bus342	0.400			0.047	0.015	0	0	0	0	0	0	0.049	95.0	75.4	
Bus343	0.400			0.076	0.019	0	0	0	0	0	0	0.078	97.0	120.4	
Bus344	0.400			0.139	0.046	0	0	0	0	0	0	0.146	95.0	226.1	
Bus345	0.400			0.069	0.020	0	0	0	0	0	0	0.072	96.0	111.0	
Bus346	0.400			0.038	0.011	0	0	0	0	0	0	0.040	96.0	60.1	
Bus347	0.400			0.144	0.052	0	0	0	0	0	0	0.154	94.0	237.8	
Bus348	0.400			0.016	0.005	0	0	0	0	0	0	0.017	95.0	25.4	
Bus349	0.400			0.008	0.003	0	0	0	0	0	0	0.009	93.0	12.9	
Bus350	0.400			0.008	0.002	0	0	0	0	0	0	0.008	97.0	12.5	
Bus351	0.400			0.079	0.031	0	0	0	0	0	0	0.085	93.0	129.8	
Bus352	0.400			0.011	0.006	0	0	0	0	0	0	0.013	87.0	19.0	
Bus353	33.000			0	0	0	0	0	0	0	0	2.961	48.7	54.1	
Bus354	33.000			0	0	0	0	0	0	0	0	2.961	48.7	54.1	
Bus355	33.000			0	0	0	0	0	0	0	0	2.958	48.6	54.2	
Bus356	33.000			0	0	0	0	0	0	0	0	0.070	89.8	1.3	
Bus357	0.400			0.063	0.030	0	0	0	0	0	0	0.070	90.0	106.1	

| Bus | | | | Directly Connected Load | | | | | | | | | Total Bus Load | | | |
| | | | | Constant kVA | | Constant Z | | Constant I | | Generic | | | | | | Percent |
ID	kV	Rated Amp		MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus358	33.000			0	0	0	0	0	0	0	0	2.900	47.3	53.1	
Bus359	33.000			0	0	0	0	0	0	0	0	0.003	88.9	0.1	
Bus360	0.400			0.003	0.002	0	0	0	0	0	0	0.003	89.0	5.1	
Bus361	33.000			0	0	0	0	0	0	0	0	4.290	80.4	78.6	
Bus362	33.000			0	0	0	0	0	0	0	0	2.403	86.6	44.0	
Bus363	33.000			0	0	0	0	0	0	0	0	3.698	93.1	67.9	
Bus364	0.400			0.099	0.064	0	0	0	0	0	0	0.118	84.0	180.4	
Bus365	33.000			0	0	0	0	0	0	0	0	3.577	93.3	65.8	
Bus366	33.000			0	0	0	0	0	0	0	0	1.127	88.8	20.7	
Bus367	33.000			0	0	0	0	0	0	0	0	0.843	88.4	15.5	
Bus368	33.000			0	0	0	0	0	0	0	0	0.843	88.4	15.5	
Bus369	33.000			0	0	0	0	0	0	0	0	0.843	88.4	15.5	
Bus370	33.000			0	0	0	0	0	0	0	0	0.768	87.9	14.1	
Bus371	33.000			0	0	0	0	0	0	0	0	0.318	85.5	5.8	
Bus372	0.400			0.268	0.159	0	0	0	0	0	0	0.311	86.0	482.4	
Bus373	33.000			0	0	0	0	0	0	0	0	0.152	88.7	2.8	
Bus374	33.000			0	0	0	0	0	0	0	0	0.153	88.1	2.8	
Bus375	0.400			0.104	0.056	0	0	0	0	0	0	0.119	88.0	181.3	
Bus376	33.000			0	0	0	0	0	0	0	0	0.035	84.9	0.6	
Bus377	0.400			0.030	0.018	0	0	0	0	0	0	0.035	85.0	53.4	
Bus378	0.400			0.198	0.107	0	0	0	0	0	0	0.225	88.0	350.1	
Bus379	0.400			0.067	0.022	0	0	0	0	0	0	0.070	95.0	107.0	
Bus383	0.400			0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus384	0.400			0	0	0	0	0	0	0	0	0.513	94.8	651.7	
Bus388	0.400			0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus389	0.400			0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus390	0.400			0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus391	0.400			0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus392	0.400			0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus393	0.400			0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus394	0.400			0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus395	0.400			0	0	0	0	0	0	0	0	0.432	87.7	651.6	
Bus396	33.000			0	0	0	0	0	0	0	0	2.404	86.6	44.1	
Bus408	0.400			0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus409	0.400			0	0	0	0	0	0	0	0	0.514	94.8	652.3	
Bus410	0.400			0	0	0	0	0	0	0	0	0.049	100.0	62.9	
Bus411	0.400			0	0	0	0	0	0	0	0	0.451	94.8	581.0	
Bus413	0.400			0	0	0	0	0	0	0	0	0.055	100.0	69.9	

| Bus | | | Directly Connected Load | | | | | | | | | Total Bus Load | | | |
| | | | Constant kVA | | Constant Z | | Constant I | | Generic | | | | | | Percent |
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus414	0.400		0	0	0	0	0	0	0	0	0.055	100.0	69.9	
Bus415	0.400		0	0	0	0	0	0	0	0	0.055	100.0	69.9	
Bus416	0.400		0	0	0	0	0	0	0	0	0.055	100.0	69.9	
Bus417	0.400		0	0	0	0	0	0	0	0	0.055	100.0	69.9	
Bus423	0.400		0	0	0	0	0	0	0	0	0.055	100.0	73.1	
Bus424	0.400		0	0	0	0	0	0	0	0	0.055	100.0	73.1	
Bus425	0.400		0	0	0	0	0	0	0	0	0.055	100.0	73.1	
Bus426	0.400		0	0	0	0	0	0	0	0	0.055	100.0	73.1	
Bus427	0.400		0	0	0	0	0	0	0	0	0.055	100.0	73.1	
Bus428	0.400		0	0	0	0	0	0	0	0	0.285	94.8	384.6	
Bus429	0.400		0	0	0	0	0	0	0	0	0.432	87.7	652.3	
Bus430	0.400		0	0	0	0	0	0	0	0	0.385	88.6	581.0	
Bus431	0.400		0	0	0	0	0	0	0	0	0.255	90.9	384.6	
Bus432	0.400		0	0	0	0	0	0	0	0	0.474	86.8	714.6	
Bus433	0.400		0	0	0	0	0	0	0	0	0.432	87.7	651.6	
Bus434	33.000		0	0	0	0	0	0	0	0	0.076	91.9	1.4	
Bus435	0.400		0.070	0.030	0	0	0	0	0	0	0.076	92.0	115.5	
Bus436	33.000		0	0	0	0	0	0	0	0	0.285	89.8	5.2	
Bus437	0.400		0.071	0.042	0	0	0	0	0	0	0.083	86.0	126.3	
Bus438	33.000		0	0	0	0	0	0	0	0	0.203	90.9	3.7	
Bus439	33.000		0	0	0	0	0	0	0	0	0.114	84.8	2.1	
Bus440	0.400		0.096	0.059	0	0	0	0	0	0	0.113	85.0	172.2	
Bus441	0.400		0.021	0.006	0	0	0	0	0	0	0.022	96.0	33.2	
Bus442	33.000		0	0	0	0	0	0	0	0	0.070	94.9	1.3	
Bus443	0.400		0.067	0.022	0	0	0	0	0	0	0.070	95.0	106.9	
Bus444	33.000		0	0	0	0	0	0	0	0	2.459	95.0	45.2	
Bus446	33.000		0	0	0	0	0	0	0	0	0.138	84.1	2.5	
Bus448	33.000		0	0	0	0	0	0	0	0	0.139	83.8	2.6	
Bus449	0.400		0.116	0.075	0	0	0	0	0	0	0.138	84.0	210.7	
Bus450	33.000		0	0	0	0	0	0	0	0	2.325	95.5	42.8	
Bus451	33.000		0	0	0	0	0	0	0	0	0.040	86.8	0.7	
Bus452	0.400		0.035	0.020	0	0	0	0	0	0	0.040	87.0	61.1	
Bus453	33.000		0	0	0	0	0	0	0	0	2.284	95.6	42.1	
Bus454	33.000		0	0	0	0	0	0	0	0	1.193	94.1	22.0	
Bus455	33.000		0	0	0	0	0	0	0	0	0.234	93.0	4.3	
Bus456	0.400		0.079	0.034	0	0	0	0	0	0	0.086	92.0	132.0	
Bus457	33.000		0	0	0	0	0	0	0	0	0.061	94.9	1.1	
Bus458	0.400		0.079	0.034	0	0	0	0	0	0	0.086	92.0	132.0	

Project:

Location:

Contract:

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Config.:   Normal

			Directly Connected Load									Total Bus Load			
Bus			Constant kVA		Constant Z		Constant I		Generic						Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus459	0.400		0.058	0.019	0	0	0	0	0	0	0.061	95.0	92.8	
Bus460	33.000		0	0	0	0	0	0	0	0	0.960	94.3	17.7	
Bus461	33.000		0	0	0	0	0	0	0	0	0.797	94.9	14.7	
Bus462	33.000		0	0	0	0	0	0	0	0	0.213	96.0	3.9	
Bus463	0.400		0.036	0.013	0	0	0	0	0	0	0.038	94.0	58.0	
Bus464	33.000		0	0	0	0	0	0	0	0	0.175	96.2	3.2	
Bus465	0.400		0.099	0.029	0	0	0	0	0	0	0.104	96.0	159.0	
Bus466	33.000		0	0	0	0	0	0	0	0	0.071	96.4	1.3	
Bus467	0.400		0.030	0.011	0	0	0	0	0	0	0.032	94.0	48.2	
Bus468	33.000		0	0	0	0	0	0	0	0	0.040	96.9	0.7	
Bus469	0.400		0.039	0.010	0	0	0	0	0	0	0.040	97.0	60.9	
Bus470	33.000		0	0	0	0	0	0	0	0	0.585	94.4	10.8	
Bus471	0.400		0.155	0.061	0	0	0	0	0	0	0.166	93.0	255.8	
Bus472	33.000		0	0	0	0	0	0	0	0	0.418	94.8	7.7	
Bus473	0.400		0.090	0.026	0	0	0	0	0	0	0.094	96.0	144.8	
Bus474	33.000		0	0	0	0	0	0	0	0	0.324	94.2	6.0	
Bus475	0.400		0.036	0.009	0	0	0	0	0	0	0.037	97.0	56.6	
Bus476	33.000		0	0	0	0	0	0	0	0	0.287	93.8	5.3	
Bus477	33.000		0	0	0	0	0	0	0	0	0.287	93.8	5.3	
Bus478	33.000		0	0	0	0	0	0	0	0	0.288	93.5	5.3	
Bus479	33.000		0	0	0	0	0	0	0	0	0.077	92.8	1.4	
Bus480	0.400		0.072	0.028	0	0	0	0	0	0	0.077	93.0	118.0	
Bus481	33.000		0	0	0	0	0	0	0	0	0.079	96.9	1.5	
Bus482	0.400		0.076	0.019	0	0	0	0	0	0	0.078	97.0	119.8	
Bus485	33.000		0	0	0	0	0	0	0	0	0.133	90.9	2.5	
Bus486	33.000		0	0	0	0	0	0	0	0	0.111	89.7	2.1	
Bus487	0.400		0.099	0.048	0	0	0	0	0	0	0.110	90.0	169.5	
Bus488	33.000		0	0	0	0	0	0	0	0	0.023	92.9	0.4	
Bus489	0.400		0.021	0.008	0	0	0	0	0	0	0.022	93.0	34.3	
Bus490	33.000		0	0	0	0	0	0	0	0	0.074	91.7	1.4	
Bus491	0.400		0.068	0.029	0	0	0	0	0	0	0.074	92.0	113.1	
Bus492	33.000		0	0	0	0	0	0	0	0	0.091	87.7	1.7	
Bus493	33.000		0	0	0	0	0	0	0	0	0.013	83.9	0.2	
Bus494	0.400		0.011	0.007	0	0	0	0	0	0	0.013	84.0	19.9	
Bus495	33.000		0	0	0	0	0	0	0	0	0.079	87.5	1.5	
Bus496	33.000		0	0	0	0	0	0	0	0	0.072	84.8	1.3	
Bus497	33.000		0	0	0	0	0	0	0	0	0.009	93.0	0.2	
Bus498	0.400		0.061	0.038	0	0	0	0	0	0	0.071	85.0	109.3	

			Directly Connected Load								Total Bus Load			
Bus			Constant kVA		Constant Z		Constant I		Generic						Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus499	0.400		0.008	0.003	0	0	0	0	0	0	0.009	93.0	13.0	
Bus500	33.000		0	0	0	0	0	0	0	0	1.093	96.9	20.1	
Bus501	33.000		0	0	0	0	0	0	0	0	0.258	96.2	4.8	
Bus502	0.400		0.242	0.061	0	0	0	0	0	0	0.249	97.0	392.4	
Bus503	33.000		0	0	0	0	0	0	0	0	0.157	97.9	2.9	
Bus504	33.000		0	0	0	0	0	0	0	0	0.139	97.6	2.6	
Bus505	33.000		0	0	0	0	0	0	0	0	0.018	99.0	0.3	
Bus506	0.400		0.134	0.027	0	0	0	0	0	0	0.137	98.0	211.9	
Bus507	0.400		0.018	0.003	0	0	0	0	0	0	0.018	99.0	27.4	
Bus508	33.000		0	0	0	0	0	0	0	0	0.678	96.8	12.5	
Bus509	0.400		0.088	0.018	0	0	0	0	0	0	0.090	98.0	136.8	
Bus510	33.000		0	0	0	0	0	0	0	0	0.588	96.6	10.8	
Bus511	0.400		0.008	0.006	0	0	0	0	0	0	0.010	80.0	15.2	
Bus512	33.000		0	0	0	0	0	0	0	0	0.076	97.9	1.4	
Bus513	0.400		0.074	0.015	0	0	0	0	0	0	0.076	98.0	115.2	
Bus514	33.000		0	0	0	0	0	0	0	0	0.491	96.5	9.0	
Bus515	0.400		0.082	0.055	0	0	0	0	0	0	0.099	83.0	151.7	
Bus516	33.000		0	0	0	0	0	0	0	0	0.398	98.3	7.3	
Bus517	0.400		0.053	0.015	0	0	0	0	0	0	0.055	96.0	84.0	
Bus518	33.000		0	0	0	0	0	0	0	0	0.343	98.6	6.3	
Bus519	0.400		0.331	0.047	0	0	0	0	0	0	0.334	99.0	521.7	
Bus520	33.000		0	0	0	0	0	0	0	0	0.012	97.0	0.2	
Bus521	0.400		0.012	0.003	0	0	0	0	0	0	0.012	97.0	18.8	
Bus524	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus525	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus526	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus527	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus528	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus529	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus530	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus531	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus533	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus536	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus537	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus538	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus539	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus540	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus541	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	Loading
Bus542	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus543	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus544	0.400		0	0	0	0	0	0	0	0	0.055	100.0	67.9	
Bus545	0.400		0	0	0	0	0	0	0	0	0.571	94.8	714.6	
Bus546	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus547	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus548	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus549	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus550	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus551	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus552	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus553	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus554	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus556	0.400		0	0	0	0	0	0	0	0	0.513	94.8	651.7	
Bus558	0.400		0	0	0	0	0	0	0	0	0.055	100.0	69.9	
Bus560	0.400		0	0	0	0	0	0	0	0	0.055	100.0	68.8	
Bus562	0.400		0	0	0	0	0	0	0	0	0.049	100.0	62.0	
Bus564	0.400		0	0	0	0	0	0	0	0	0.055	100.0	69.9	

* Indicates operating load of a bus exceeds the bus critical limit (100.0% of the Continuous Ampere rating).

\# Indicates operating load of a bus exceeds the bus marginal limit (95.0% of the Continuous Ampere rating).

Appendix I

Results of the buses Voltage from the ETAP software

Alert Summary Report

% Alert Settings

	Critical	Marginal
Loading		
Bus	100.0	95.0
Cable	100.0	95.0
Reactor	100.0	95.0
Line	100.0	95.0
Transformer	100.0	95.0
Panel	100.0	95.0
Protective Device	100.0	95.0
Generator	100.0	95.0
Inverter/Charger	100.0	95.0
Bus Voltage		
OverVoltage	105.0	102.0
UnderVoltage	95.0	98.0
Generator Excitation		
OverExcited (Q Max.)	100.0	95.0
UnderExcited (Q Min.)	100.0	

Marginal Alerts Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
alrfaid	Transformer	Overload	0.157	MVA	0.150	95.3	3-Phase
Bus100	Bus	Under Voltage	33.000	kV	31.836	96.5	3-Phase
Bus101	Bus	Under Voltage	33.000	kV	31.821	96.4	3-Phase
Bus102	Bus	Under Voltage	33.000	kV	31.821	96.4	3-Phase
Bus103	Bus	Under Voltage	33.000	kV	31.821	96.4	3-Phase
Bus104	Bus	Under Voltage	33.000	kV	31.817	96.4	3-Phase
Bus105	Bus	Under Voltage	33.000	kV	31.815	96.4	3-Phase
Bus106	Bus	Under Voltage	33.000	kV	31.813	96.4	3-Phase
Bus109	Bus	Under Voltage	33.000	kV	31.812	96.4	3-Phase
Bus110	Bus	Under Voltage	33.000	kV	31.811	96.4	3-Phase
Bus111	Bus	Under Voltage	33.000	kV	31.821	96.4	3-Phase
Bus112	Bus	Under Voltage	33.000	kV	31.835	96.5	3-Phase
Bus113	Bus	Under Voltage	33.000	kV	31.835	96.5	3-Phase
Bus114	Bus	Under Voltage	33.000	kV	31.734	96.2	3-Phase
Bus115	Bus	Under Voltage	33.000	kV	31.734	96.2	3-Phase
Bus116	Bus	Under Voltage	33.000	kV	31.721	96.1	3-Phase
Bus118	Bus	Under Voltage	33.000	kV	31.713	96.1	3-Phase
Bus119	Bus	Under Voltage	33.000	kV	31.712	96.1	3-Phase
Bus12	Bus	Under Voltage	33.000	kV	32.117	97.3	3-Phase
Bus120	Bus	Under Voltage	33.000	kV	31.712	96.1	3-Phase
Bus122	Bus	Under Voltage	33.000	kV	31.712	96.1	3-Phase
Bus123	Bus	Under Voltage	33.000	kV	31.714	96.1	3-Phase
Bus124	Bus	Under Voltage	33.000	kV	31.695	96.0	3-Phase
Bus125	Bus	Under Voltage	33.000	kV	31.687	96.0	3-Phase
Bus126	Bus	Under Voltage	33.000	kV	31.678	96.0	3-Phase
Bus127	Bus	Under Voltage	33.000	kV	31.675	96.0	3-Phase
Bus13	Bus	Under Voltage	33.000	kV	32.028	97.1	3-Phase
Bus135	Bus	Under Voltage	33.000	kV	31.674	96.0	3-Phase
Bus137	Bus	Under Voltage	33.000	kV	31.672	96.0	3-Phase
Bus138	Bus	Under Voltage	33.000	kV	31.667	96.0	3-Phase
Bus139	Bus	Under Voltage	33.000	kV	31.660	95.9	3-Phase
Bus14	Bus	Under Voltage	33.000	kV	31.923	96.7	3-Phase
Bus140	Bus	Under Voltage	33.000	kV	31.659	95.9	3-Phase
Bus141	Bus	Under Voltage	33.000	kV	31.659	95.9	3-Phase
Bus142	Bus	Under Voltage	33.000	kV	31.718	96.1	3-Phase
Bus143	Bus	Under Voltage	33.000	kV	31.718	96.1	3-Phase

Marginal Alerts Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus144	Bus	Under Voltage	33.000	kV	31.713	96.1	3-Phase
Bus145	Bus	Under Voltage	33.000	kV	31.712	96.1	3-Phase
Bus146	Bus	Under Voltage	33.000	kV	31.707	96.1	3-Phase
Bus147	Bus	Under Voltage	33.000	kV	31.707	96.1	3-Phase
Bus148	Bus	Under Voltage	33.000	kV	31.707	96.1	3-Phase
Bus149	Bus	Under Voltage	33.000	kV	31.706	96.1	3-Phase
Bus15	Bus	Under Voltage	33.000	kV	31.866	96.6	3-Phase
Bus150	Bus	Under Voltage	33.000	kV	31.706	96.1	3-Phase
Bus151	Bus	Under Voltage	33.000	kV	31.706	96.1	3-Phase
Bus152	Bus	Under Voltage	33.000	kV	31.710	96.1	3-Phase
Bus153	Bus	Under Voltage	33.000	kV	31.710	96.1	3-Phase
Bus154	Bus	Under Voltage	33.000	kV	31.707	96.1	3-Phase
Bus155	Bus	Under Voltage	33.000	kV	31.706	96.1	3-Phase
Bus156	Bus	Under Voltage	33.000	kV	31.706	96.1	3-Phase
Bus157	Bus	Under Voltage	33.000	kV	31.706	96.1	3-Phase
Bus158	Bus	Under Voltage	33.000	kV	31.810	96.4	3-Phase
Bus159	Bus	Under Voltage	33.000	kV	31.809	96.4	3-Phase
Bus16	Bus	Under Voltage	33.000	kV	31.830	96.5	3-Phase
Bus160	Bus	Under Voltage	33.000	kV	31.801	96.4	3-Phase
Bus161	Bus	Under Voltage	33.000	kV	31.777	96.3	3-Phase
Bus162	Bus	Under Voltage	33.000	kV	31.769	96.3	3-Phase
Bus163	Bus	Under Voltage	33.000	kV	31.769	96.3	3-Phase
Bus164	Bus	Under Voltage	33.000	kV	31.714	96.1	3-Phase
Bus165	Bus	Under Voltage	33.000	kV	31.705	96.1	3-Phase
Bus167	Bus	Under Voltage	33.000	kV	31.678	96.0	3-Phase
Bus168	Bus	Under Voltage	33.000	kV	31.677	96.0	3-Phase
Bus169	Bus	Under Voltage	33.000	kV	31.659	95.9	3-Phase
Bus17	Bus	Under Voltage	33.000	kV	31.813	96.4	3-Phase
Bus170	Bus	Under Voltage	33.000	kV	31.659	95.9	3-Phase
Bus171	Bus	Under Voltage	33.000	kV	31.632	95.9	3-Phase
Bus173	Bus	Under Voltage	33.000	kV	31.624	95.8	3-Phase
Bus174	Bus	Under Voltage	33.000	kV	31.623	95.8	3-Phase
Bus175	Bus	Under Voltage	33.000	kV	31.622	95.8	3-Phase
Bus176	Bus	Under Voltage	33.000	kV	31.622	95.8	3-Phase
Bus177	Bus	Under Voltage	33.000	kV	31.621	95.8	3-Phase
Bus178	Bus	Under Voltage	33.000	kV	31.618	95.8	3-Phase

Marginal Alerts Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus179	Bus	Under Voltage	33.000	kV	31.599	95.8	3-Phase
Bus18	Bus	Under Voltage	33.000	kV	31.804	96.4	3-Phase
Bus180	Bus	Under Voltage	33.000	kV	31.599	95.8	3-Phase
Bus181	Bus	Under Voltage	33.000	kV	31.560	95.6	3-Phase
Bus182	Bus	Under Voltage	33.000	kV	31.534	95.6	3-Phase
Bus183	Bus	Under Voltage	33.000	kV	31.533	95.6	3-Phase
Bus184	Bus	Under Voltage	33.000	kV	31.530	95.5	3-Phase
Bus185	Bus	Under Voltage	33.000	kV	31.523	95.5	3-Phase
Bus186	Bus	Under Voltage	33.000	kV	31.522	95.5	3-Phase
Bus187	Bus	Under Voltage	33.000	kV	31.522	95.5	3-Phase
Bus188	Bus	Under Voltage	33.000	kV	31.510	95.5	3-Phase
Bus189	Bus	Under Voltage	33.000	kV	31.504	95.5	3-Phase
Bus19	Bus	Under Voltage	33.000	kV	31.800	96.4	3-Phase
Bus190	Bus	Under Voltage	33.000	kV	31.504	95.5	3-Phase
Bus191	Bus	Under Voltage	33.000	kV	31.501	95.5	3-Phase
Bus192	Bus	Under Voltage	33.000	kV	31.498	95.4	3-Phase
Bus193	Bus	Under Voltage	33.000	kV	31.503	95.5	3-Phase
Bus194	Bus	Under Voltage	33.000	kV	31.510	95.5	3-Phase
Bus195	Bus	Under Voltage	33.000	kV	31.510	95.5	3-Phase
Bus196	Bus	Under Voltage	33.000	kV	31.507	95.5	3-Phase
Bus197	Bus	Under Voltage	33.000	kV	31.503	95.5	3-Phase
Bus198	Bus	Under Voltage	33.000	kV	31.502	95.5	3-Phase
Bus199	Bus	Under Voltage	33.000	kV	31.502	95.5	3-Phase
Bus20	Bus	Under Voltage	33.000	kV	31.799	96.4	3-Phase
Bus201	Bus	Under Voltage	33.000	kV	31.502	95.5	3-Phase
Bus202	Bus	Under Voltage	33.000	kV	31.501	95.5	3-Phase
Bus203	Bus	Under Voltage	33.000	kV	31.501	95.5	3-Phase
Bus21	Bus	Under Voltage	33.000	kV	31.798	96.4	3-Phase
Bus22	Bus	Under Voltage	33.000	kV	31.799	96.4	3-Phase
Bus229	Bus	Under Voltage	0.400	kV	0.381	95.2	3-Phase
Bus23	Bus	Under Voltage	33.000	kV	31.799	96.4	3-Phase
Bus234	Bus	Under Voltage	0.400	kV	0.381	95.4	3-Phase
Bus235	Bus	Under Voltage	0.400	kV	0.384	96.0	3-Phase
Bus237	Bus	Under Voltage	0.400	kV	0.385	96.1	3-Phase
Bus24	Bus	Under Voltage	33.000	kV	31.798	96.4	3-Phase
Bus240	Bus	Under Voltage	0.400	kV	0.385	96.2	3-Phase

Project: **ETAP**   Page: 5

Location: 12.6.0H   Date: 01-09-2019

Contract: SN:

Engineer: Revision: Base

                           Study Case: LF

Filename: project   Config.:   Normal

Marginal Alerts Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus248	Bus	Under Voltage	0.400	kV	0.384	95.9	3-Phase
Bus25	Bus	Under Voltage	33.000	kV	31.797	96.4	3-Phase
Bus250	Bus	Under Voltage	0.400	kV	0.381	95.2	3-Phase
Bus252	Bus	Under Voltage	0.400	kV	0.384	96.1	3-Phase
Bus253	Bus	Under Voltage	0.400	kV	0.384	96.1	3-Phase
Bus254	Bus	Under Voltage	0.400	kV	0.384	96.0	3-Phase
Bus255	Bus	Under Voltage	0.400	kV	0.384	96.0	3-Phase
Bus256	Bus	Under Voltage	0.400	kV	0.382	95.4	3-Phase
Bus257	Bus	Under Voltage	0.400	kV	0.385	96.3	3-Phase
Bus258	Bus	Under Voltage	0.400	kV	0.382	95.5	3-Phase
Bus259	Bus	Under Voltage	0.400	kV	0.381	95.2	3-Phase
Bus26	Bus	Under Voltage	33.000	kV	31.798	96.4	3-Phase
Bus260	Bus	Under Voltage	0.400	kV	0.384	96.1	3-Phase
Bus261	Bus	Under Voltage	0.400	kV	0.384	96.1	3-Phase
Bus262	Bus	Under Voltage	0.400	kV	0.380	95.1	3-Phase
Bus263	Bus	Under Voltage	0.400	kV	0.385	96.1	3-Phase
Bus264	Bus	Under Voltage	0.400	kV	0.384	96.1	3-Phase
Bus268	Bus	Under Voltage	0.400	kV	0.385	96.3	3-Phase
Bus269	Bus	Under Voltage	0.400	kV	0.383	95.9	3-Phase
Bus27	Bus	Under Voltage	33.000	kV	31.798	96.4	3-Phase
Bus270	Bus	Under Voltage	0.400	kV	0.381	95.3	3-Phase
Bus271	Bus	Under Voltage	0.400	kV	0.382	95.4	3-Phase
Bus272	Bus	Under Voltage	0.400	kV	0.385	96.2	3-Phase
Bus273	Bus	Under Voltage	0.400	kV	0.388	97.0	3-Phase
Bus274	Bus	Under Voltage	0.400	kV	0.387	96.7	3-Phase
Bus275	Bus	Under Voltage	0.400	kV	0.384	96.0	3-Phase
Bus276	Bus	Under Voltage	0.400	kV	0.384	96.0	3-Phase
Bus277	Bus	Under Voltage	0.400	kV	0.390	97.6	3-Phase
Bus278	Bus	Under Voltage	0.400	kV	0.386	96.6	3-Phase
Bus28	Bus	Under Voltage	33.000	kV	31.796	96.4	3-Phase
Bus280	Bus	Under Voltage	0.400	kV	0.382	95.6	3-Phase
Bus281	Bus	Under Voltage	0.400	kV	0.383	95.6	3-Phase
Bus282	Bus	Under Voltage	0.400	kV	0.381	95.2	3-Phase
Bus283	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus284	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus285	Bus	Under Voltage	0.400	kV	0.383	95.8	3-Phase

Marginal Alerts Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus286	Bus	Under Voltage	0.400	kV	0.383	95.8	3-Phase
Bus288	Bus	Under Voltage	0.400	kV	0.386	96.6	3-Phase
Bus29	Bus	Under Voltage	33.000	kV	31.795	96.3	3-Phase
Bus291	Bus	Under Voltage	0.400	kV	0.391	97.8	3-Phase
Bus299	Bus	Under Voltage	0.400	kV	0.387	96.9	3-Phase
Bus30	Bus	Under Voltage	33.000	kV	31.792	96.3	3-Phase
Bus300	Bus	Under Voltage	0.400	kV	0.384	95.9	3-Phase
Bus301	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus303	Bus	Under Voltage	0.400	kV	0.384	96.1	3-Phase
Bus304	Bus	Under Voltage	0.400	kV	0.385	96.2	3-Phase
Bus306	Bus	Under Voltage	0.400	kV	0.382	95.4	3-Phase
Bus307	Bus	Under Voltage	0.400	kV	0.382	95.6	3-Phase
Bus308	Bus	Under Voltage	0.400	kV	0.384	96.1	3-Phase
Bus309	Bus	Under Voltage	0.400	kV	0.384	96.0	3-Phase
Bus31	Bus	Under Voltage	33.000	kV	31.792	96.3	3-Phase
Bus310	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus311	Bus	Under Voltage	0.400	kV	0.384	96.1	3-Phase
Bus312	Bus	Under Voltage	0.400	kV	0.384	96.0	3-Phase
Bus313	Bus	Under Voltage	0.400	kV	0.382	95.6	3-Phase
Bus314	Bus	Under Voltage	0.400	kV	0.381	95.2	3-Phase
Bus315	Bus	Under Voltage	0.400	kV	0.384	95.9	3-Phase
Bus316	Bus	Under Voltage	0.400	kV	0.386	96.4	3-Phase
Bus317	Bus	Under Voltage	0.400	kV	0.381	95.3	3-Phase
Bus319	Bus	Under Voltage	0.400	kV	0.382	95.5	3-Phase
Bus32	Bus	Under Voltage	33.000	kV	31.792	96.3	3-Phase
Bus320	Bus	Under Voltage	0.400	kV	0.381	95.4	3-Phase
Bus322	Bus	Under Voltage	0.400	kV	0.381	95.2	3-Phase
Bus324	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus325	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus327	Bus	Under Voltage	0.400	kV	0.382	95.6	3-Phase
Bus328	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus329	Bus	Under Voltage	0.400	kV	0.382	95.6	3-Phase
Bus33	Bus	Under Voltage	33.000	kV	31.791	96.3	3-Phase
Bus330	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus331	Bus	Under Voltage	0.400	kV	0.384	96.0	3-Phase
Bus333	Bus	Under Voltage	0.400	kV	0.381	95.2	3-Phase

Project:

Location:

Contract:

Engineer:

Filename: project

ETAP

12.6.0H

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Config.:   Normal

Marginal Alerts Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus334	Bus	Under Voltage	0.400	kV	0.380	95.1	3-Phase
Bus335	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus336	Bus	Under Voltage	0.400	kV	0.380	95.1	3-Phase
Bus337	Bus	Under Voltage	0.400	kV	0.381	95.3	3-Phase
Bus338	Bus	Under Voltage	0.400	kV	0.382	95.4	3-Phase
Bus34	Bus	Under Voltage	33.000	kV	31.790	96.3	3-Phase
Bus348	Bus	Under Voltage	0.400	kV	0.381	95.1	3-Phase
Bus349	Bus	Under Voltage	0.400	kV	0.381	95.3	3-Phase
Bus35	Bus	Under Voltage	33.000	kV	31.789	96.3	3-Phase
Bus350	Bus	Under Voltage	0.400	kV	0.381	95.3	3-Phase
Bus352	Bus	Under Voltage	0.400	kV	0.382	95.4	3-Phase
Bus353	Bus	Under Voltage	33.000	kV	31.587	95.7	3-Phase
Bus354	Bus	Under Voltage	33.000	kV	31.587	95.7	3-Phase
Bus355	Bus	Under Voltage	33.000	kV	31.527	95.5	3-Phase
Bus356	Bus	Under Voltage	33.000	kV	31.526	95.5	3-Phase
Bus358	Bus	Under Voltage	33.000	kV	31.512	95.5	3-Phase
Bus359	Bus	Under Voltage	33.000	kV	31.512	95.5	3-Phase
Bus36	Bus	Under Voltage	33.000	kV	31.789	96.3	3-Phase
Bus360	Bus	Under Voltage	0.400	kV	0.381	95.2	3-Phase
Bus361	Bus	Under Voltage	33.000	kV	31.490	95.4	3-Phase
Bus362	Bus	Under Voltage	33.000	kV	31.498	95.4	3-Phase
Bus363	Bus	Under Voltage	33.000	kV	31.448	95.3	3-Phase
Bus365	Bus	Under Voltage	33.000	kV	31.411	95.2	3-Phase
Bus366	Bus	Under Voltage	33.000	kV	31.405	95.2	3-Phase
Bus367	Bus	Under Voltage	33.000	kV	31.393	95.1	3-Phase
Bus368	Bus	Under Voltage	33.000	kV	31.393	95.1	3-Phase
Bus369	Bus	Under Voltage	33.000	kV	31.388	95.1	3-Phase
Bus37	Bus	Under Voltage	33.000	kV	31.789	96.3	3-Phase
Bus370	Bus	Under Voltage	33.000	kV	31.382	95.1	3-Phase
Bus371	Bus	Under Voltage	33.000	kV	31.371	95.1	3-Phase
Bus373	Bus	Under Voltage	33.000	kV	31.382	95.1	3-Phase
Bus374	Bus	Under Voltage	33.000	kV	31.378	95.1	3-Phase
Bus376	Bus	Under Voltage	33.000	kV	31.377	95.1	3-Phase
Bus38	Bus	Under Voltage	33.000	kV	31.789	96.3	3-Phase
Bus39	Bus	Under Voltage	33.000	kV	31.788	96.3	3-Phase
Bus395	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase

Marginal Alerts Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus396	Bus	Under Voltage	33.000	kV	31.507	95.5	3-Phase
Bus40	Bus	Under Voltage	33.000	kV	31.788	96.3	3-Phase
Bus41	Bus	Under Voltage	33.000	kV	31.790	96.3	3-Phase
Bus42	Bus	Under Voltage	33.000	kV	31.796	96.4	3-Phase
Bus429	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus43	Bus	Under Voltage	33.000	kV	31.795	96.3	3-Phase
Bus430	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus431	Bus	Under Voltage	0.400	kV	0.383	95.9	3-Phase
Bus432	Bus	Under Voltage	0.400	kV	0.383	95.6	3-Phase
Bus433	Bus	Under Voltage	0.400	kV	0.383	95.7	3-Phase
Bus434	Bus	Under Voltage	33.000	kV	31.387	95.1	3-Phase
Bus436	Bus	Under Voltage	33.000	kV	31.404	95.2	3-Phase
Bus438	Bus	Under Voltage	33.000	kV	31.400	95.2	3-Phase
Bus439	Bus	Under Voltage	33.000	kV	31.399	95.1	3-Phase
Bus44	Bus	Under Voltage	33.000	kV	31.795	96.3	3-Phase
Bus442	Bus	Under Voltage	33.000	kV	31.397	95.1	3-Phase
Bus444	Bus	Under Voltage	33.000	kV	31.391	95.1	3-Phase
Bus446	Bus	Under Voltage	33.000	kV	31.390	95.1	3-Phase
Bus448	Bus	Under Voltage	33.000	kV	31.388	95.1	3-Phase
Bus45	Bus	Under Voltage	33.000	kV	31.800	96.4	3-Phase
Bus450	Bus	Under Voltage	33.000	kV	31.382	95.1	3-Phase
Bus451	Bus	Under Voltage	33.000	kV	31.382	95.1	3-Phase
Bus46	Bus	Under Voltage	33.000	kV	31.823	96.4	3-Phase
Bus47	Bus	Under Voltage	33.000	kV	31.827	96.4	3-Phase
Bus48	Bus	Under Voltage	33.000	kV	31.829	96.5	3-Phase
Bus49	Bus	Under Voltage	33.000	kV	31.829	96.5	3-Phase
Bus50	Bus	Under Voltage	33.000	kV	31.831	96.5	3-Phase
Bus51	Bus	Under Voltage	33.000	kV	31.831	96.5	3-Phase
Bus52	Bus	Under Voltage	33.000	kV	31.831	96.5	3-Phase
Bus53	Bus	Under Voltage	33.000	kV	31.831	96.5	3-Phase
Bus54	Bus	Under Voltage	33.000	kV	31.831	96.5	3-Phase
Bus55	Bus	Under Voltage	33.000	kV	31.834	96.5	3-Phase
Bus56	Bus	Under Voltage	33.000	kV	31.834	96.5	3-Phase
Bus57	Bus	Under Voltage	33.000	kV	31.851	96.5	3-Phase
Bus58	Bus	Under Voltage	33.000	kV	31.857	96.5	3-Phase
Bus59	Bus	Under Voltage	33.000	kV	31.866	96.6	3-Phase

Marginal Alerts Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus60	Bus	Under Voltage	33.000	kV	31.866	96.6	3-Phase
Bus61	Bus	Under Voltage	33.000	kV	31.877	96.6	3-Phase
Bus62	Bus	Under Voltage	33.000	kV	31.884	96.6	3-Phase
Bus63	Bus	Under Voltage	33.000	kV	31.884	96.6	3-Phase
Bus64	Bus	Under Voltage	33.000	kV	31.884	96.6	3-Phase
Bus65	Bus	Under Voltage	33.000	kV	31.884	96.6	3-Phase
Bus66	Bus	Under Voltage	33.000	kV	31.883	96.6	3-Phase
Bus67	Bus	Under Voltage	33.000	kV	31.919	96.7	3-Phase
Bus68	Bus	Under Voltage	33.000	kV	32.080	97.2	3-Phase
Bus69	Bus	Under Voltage	33.000	kV	32.140	97.4	3-Phase
Bus70	Bus	Under Voltage	33.000	kV	32.170	97.5	3-Phase
Bus71	Bus	Under Voltage	33.000	kV	32.165	97.5	3-Phase
Bus72	Bus	Under Voltage	33.000	kV	32.155	97.4	3-Phase
Bus73	Bus	Under Voltage	33.000	kV	32.173	97.5	3-Phase
Bus96	Bus	Under Voltage	33.000	kV	31.845	96.5	3-Phase
Bus97	Bus	Under Voltage	33.000	kV	31.845	96.5	3-Phase
Bus98	Bus	Under Voltage	33.000	kV	31.840	96.5	3-Phase
Bus99	Bus	Under Voltage	33.000	kV	31.839	96.5	3-Phase
Line138	Line	Overload	70.500	Amp	70.465	100.0	3-Phase
Line139	Line	Overload	70.500	Amp	70.475	100.0	3-Phase
Line175	Line	Overload	54.200	Amp	54.126	99.9	3-Phase
Line176	Line	Overload	54.200	Amp	54.162	99.9	3-Phase
Line178	Line	Overload	53.300	Amp	53.129	99.7	3-Phase
Line180	Line	Overload	53.200	Amp	53.101	99.8	3-Phase
Line50	Line	Overload	49.000	Amp	46.558	95.0	3-Phase
Line53	Line	Overload	51.100	Amp	49.150	96.2	3-Phase
Line54	Line	Overload	52.100	Amp	50.392	96.7	3-Phase
Line55	Line	Overload	52.600	Amp	51.046	97.0	3-Phase
Line56	Line	Overload	53.800	Amp	52.603	97.8	3-Phase
T3	Transformer	Overload	0.396	MVA	0.385	97.3	3-Phase

Appendix J

Results of the fault test from ETAP software

SHORT- CIRCUIT REPORT

Fault at bus: **Bus11**

Prefault voltage = 33.000 kV   = 100.00 % of nominal bus kV (33.000 kV)

                                   = 100.00 % of base kV (33.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus	To Bus	% V	kA	% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
ID	ID	From Bus	Symm. rms	Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Bus11	Total	0.00	1.043	0.00	128.76	124.96	0.599	0.599	7.49E+001	1.50E+002	2.03E+002	5.02E+002
Bus10	Bus11	0.36	0.354	0.51	128.52	124.71	0.335	0.599	1.93E+002	4.55E+002	2.03E+002	5.02E+002
Bus12	Bus11	15.77	0.690	74.52	79.23	100.00	0.264	0.000	1.20E+002	2.23E+002		

\# Indicates fault current contribution is from three-winding transformers

* Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Project:		**ETAP**		Page:	2
Location:		12.6.0H		Date:	12-09-2018
Contract:				SN:	
Engineer:				Revision:	Base
		Study Case: SC			
Filename:	project			Config.:	Normal

Fault at bus: **Bus13**

Prefault voltage = 33.000 kV

= 100.00 % of nominal bus kV (33.000 kV)

= 100.00 % of base kV (33.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
				Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Bus13	Total	0.00	1.141	0.00	92.32	84.02	1.523	1.523	7.49E+001	1.34E+002	8.89E+000	3.82E+001
Bus12	Bus13	0.91	0.327	2.91	92.06	83.61	0.701	1.232	2.00E+002	4.97E+002	6.92E+000	4.80E+001
Bus14	Bus13	2.70	0.811	2.89	91.55	84.92	0.823	0.314	1.15E+002	1.82E+002	1.03E+002	1.60E+002
Bus234	Bus13	9.14	0.006	51.68	53.59	100.00	0.006	0.000	1.10E+004	2.50E+004		

\#   Indicates fault current contribution is from three-winding transformers

*   Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

	ETAP	Page:	3
Project:	12.6.0H		
Location:		Date:	12-09-2018
Contract:		SN:	
Engineer:		Revision:	Base
Filename: project	Study Case: SC	Config.:	Normal

Fault at bus: **Bus15**

Prefault voltage = 33.000 kV   = 100.00 % of nominal bus kV (33.000 kV)

                                              = 100.00 % of base kV (33.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus	To Bus	% V	kA	% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
ID	ID	From Bus	Symm. rms	Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Bus15	Total	0.00	1.167	0.00	91.76	86.20	1.513	1.513	7.18E+001	1.32E+002	1.58E+001	4.50E+001
Bus14	Bus15	0.62	0.336	1.81	91.55	85.91	0.660	1.110	2.00E+002	4.81E+002	1.61E+001	6.30E+001
Bus16	Bus15	0.95	0.834	1.07	91.50	86.48	0.858	0.419	1.08E+002	1.80E+002	9.34E+001	1.45E+002

\#   Indicates fault current contribution is from three-winding transformers

*   Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Fault at bus: **Bus81**

Prefault voltage = 33.000 kV

= 100.00 % of nominal bus kV (33.000 kV)

= 100.00 % of base kV (33.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
				Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Bus81	Total	0.00	0.742	0.00	111.87	100.91	0.657	0.657	1.54E+002	1.78E+002	1.66E+002	2.85E+002
Bus80	Bus81	6.34	0.650	6.95	110.00	100.70	0.566	0.548	1.80E+002	2.00E+002	1.95E+002	3.45E+002
Bus82	Bus81	0.00	0.001	0.00	111.87	100.91	0.001	0.000	4.86E+004	1.14E+005		
Bus83	Bus81	0.23	0.092	0.29	111.75	100.88	0.090	0.110	1.04E+003	1.59E+003	1.10E+003	1.65E+003

\#   Indicates fault current contribution is from three-winding transformers

*   Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Fault at bus: **Bus87**

Prefault voltage = 33.000 kV   = 100.00 % of nominal bus kV (33.000 kV)

                                    = 100.00 % of base kV (33.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
				Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Bus87	Total	0.00	0.776	0.00	111.18	101.04	0.691	0.691	1.44E+002	1.73E+002	1.56E+002	2.70E+002
Bus80	Bus87	0.87	0.746	1.00	110.89	100.99	0.673	0.691	1.52E+002	1.78E+002	1.56E+002	2.70E+002
Bus88	Bus87	0.00	0.004	0.00	111.18	101.04	0.003	0.000	1.59E+004	3.59E+004		
Bus90	Bus87	0.06	0.027	0.04	111.18	101.05	0.016	0.000	2.56E+003	5.93E+003		

\#   Indicates fault current contribution is from three-winding transformers

*   Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Fault at bus: **Bus361**

Prefault voltage = 33.000 kV   = 100.00 % of nominal bus kV (33.000 kV)

= 100.00 % of base kV (33.000 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault					Positive & Zero Sequence Impedances Looking into "From Bus"			
From Bus	To Bus	% V	kA	% Voltage at From Bus			kA Symm. rms		% Impedance on 100 MVA base			
ID	ID	From Bus	Symm. rms	Va	Vb	Vc	Ia	3I0	R1	X1	R0	X0
Bus361	Total	0.00	1.106	0.00	90.88	89.14	1.388	1.388	8.18E+001	1.35E+002	2.96E+001	5.44E+001
Bus358	Bus361	1.23	0.798	1.65	90.61	89.28	0.891	0.674	1.12E+002	1.89E+002	5.04E+001	1.17E+002
Bus362	Bus361	0.05	0.054	0.51	90.74	89.04	0.273	0.719	3.22E+003	4.75E+002	6.61E+001	9.96E+001
Bus363	Bus361	0.52	0.276	0.44	90.79	89.32	0.231	0.000	2.59E+002	5.79E+002		

\#   Indicates fault current contribution is from three-winding transformers

*   Indicates a zero sequence fault current contribution (3I0) from a grounded Delta- Y transformer

Appendix K

results of the loss in the system from ETAP software

Branch Losses Summary Report

CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line2	4.394	4.013	-4.394	-4.013	0.8	0.3	100.0	100.0	0.01
Line3	0.031	0.017	-0.031	-0.017	0.0	-0.2	100.0	100.0	0.00
Line5	4.363	3.997	-4.359	-3.989	4.1	7.1	100.0	99.8	0.17
Line4	0.031	0.017	-0.031	-0.022	0.0	-4.9	100.0	100.0	0.01
aqapeh main	0.031	0.022	-0.031	-0.021	0.2	0.3	100.0	99.1	0.88
Line6	4.229	3.945	-4.192	-3.931	37.3	14.2	99.8	99.1	0.69
tayseer main	0.129	0.044	-0.128	-0.042	1.7	2.5	99.8	98.1	1.73
Line7	4.168	3.922	-4.165	-3.921	3.1	1.2	99.1	99.1	0.06
midical harps	0.024	0.009	-0.024	-0.009	0.1	0.1	99.1	98.6	0.52
Line8	4.165	3.921	-4.160	-3.919	5.3	2.0	99.1	99.0	0.10
T4	4.160	3.919	-4.153	-3.786	6.7	133.2	99.0	97.3	1.65
Line9	4.153	3.786	-4.139	-3.780	14.5	5.6	97.3	97.1	0.27
Line10	4.053	3.757	-4.036	-3.751	16.9	6.5	97.1	96.7	0.32
al-thoghrah	0.086	0.023	-0.084	-0.021	1.2	1.7	97.1	95.4	1.70
Line11	3.949	3.725	-3.940	-3.721	9.2	3.5	96.7	96.6	0.17
toop factory	0.087	0.026	-0.086	-0.025	0.5	0.7	96.7	96.0	0.72
Line12	3.940	3.721	-3.934	-3.719	5.7	2.1	96.6	96.5	0.11
Line13	3.915	3.713	-3.913	-3.712	2.7	1.0	96.5	96.4	0.05
sameeh.	0.019	0.006	-0.019	-0.006	0.0	0.1	96.5	96.2	0.26
Line14	0.717	0.587	-0.717	-0.587	0.3	-0.9	96.4	96.4	0.03
Line129	3.196	3.125	-3.196	-3.125	0.3	0.2	96.4	96.4	0.01
Line15	0.608	0.550	-0.608	-0.551	0.1	-0.4	96.4	96.4	0.01
karag	0.108	0.037	-0.107	-0.035	1.3	1.9	96.4	94.9	1.50
Line16	0.274	0.069	-0.274	-0.069	0.0	-0.5	96.4	96.4	0.00
Line21	0.334	0.482	-0.334	-0.482	0.0	-0.3	96.4	96.4	0.01
Line17	0.184	0.049	-0.184	-0.049	0.0	-0.4	96.4	96.4	0.00
Line18	0.090	0.021	-0.090	-0.021	0.0	-0.2	96.4	96.4	0.00
mahta	0.184	0.049	-0.182	-0.046	2.2	3.3	96.4	94.9	1.47
Line19	0.090	0.021	-0.090	-0.022	0.0	-0.6	96.4	96.4	0.00
Line20	0.090	0.022	-0.090	-0.023	0.0	-1.2	96.4	96.4	0.00
masriya	0.090	0.023	-0.089	-0.022	0.3	0.5	96.4	95.9	0.45
Line22	0.334	0.482	-0.334	-0.483	0.0	-0.4	96.4	96.4	0.01
Cable1	0.130	0.031	-0.130	-0.049	0.0	-17.3	96.4	96.3	0.00
Line23	0.079	0.408	-0.079	-0.410	0.1	-1.3	96.4	96.3	0.01
al-helal	0.125	0.043	-0.123	-0.041	1.7	2.5	96.4	94.6	1.74

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CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	
al-hawooz 1	0.130	0.049	-0.129	-0.047	1.2	1.7	96.3	95.2	1.16
Line24	0.039	-0.003	-0.039	0.002	0.0	-0.3	96.3	96.3	0.00
Line27	-0.086	0.379	0.086	-0.382	0.1	-2.9	96.3	96.3	0.01
al-daqnya	0.125	0.033	-0.124	-0.031	1.6	2.4	96.3	94.7	1.61
Line25	0.039	-0.002	-0.039	0.000	0.0	-2.6	96.3	96.3	0.00
Line26	0.030	-0.002	-0.030	0.000	0.0	-2.3	96.3	96.3	0.00
span	0.009	0.002	-0.009	-0.002	0.0	0.0	96.3	96.1	0.28
stone cutter	0.030	0.000	-0.030	0.000	0.1	0.1	96.3	96.1	0.28
Line28	0.026	0.006	-0.026	-0.008	0.0	-1.8	96.3	96.3	0.00
Line29	-0.112	0.376	0.112	-0.377	0.0	-0.5	96.3	96.3	0.00
safya north	0.026	0.008	-0.026	-0.008	0.1	0.1	96.3	96.0	0.34
Line30	-0.142	0.356	0.142	-0.357	0.0	-0.3	96.3	96.3	0.00
al-aqapeh	0.030	0.020	-0.030	-0.020	0.1	0.1	96.3	96.0	0.35
Cable2	0.140	0.039	-0.140	-0.068	0.0	-29.4	96.3	96.3	0.00
Line32	-0.281	0.318	0.281	-0.319	0.0	-0.7	96.3	96.3	0.00
Line31	0.139	0.068	-0.139	-0.068	0.0	-0.2	96.3	96.3	0.00
tupas hospital 1	0.001	0.000	-0.001	0.000	0.0	0.0	96.3	96.3	0.00
tubas hospital 2	0.139	0.068	-0.138	-0.067	0.9	1.4	96.3	95.4	0.88
Line33	-0.339	0.295	0.340	-0.298	0.2	-3.1	96.3	96.4	0.02
gas station	0.058	0.023	-0.058	-0.023	0.4	0.6	96.3	95.5	0.86
Line34	0.024	0.004	-0.024	-0.006	0.0	-2.4	96.4	96.3	0.00
Line36	-0.503	0.258	0.503	-0.259	0.1	-1.3	96.4	96.4	0.01
eastren aqapa	0.140	0.037	-0.138	-0.035	1.2	1.9	96.4	95.2	1.11
Line35	0.007	-0.001	-0.007	-0.002	0.0	-3.0	96.3	96.3	0.00
dawajen	0.017	0.007	-0.017	-0.007	0.0	0.0	96.3	96.1	0.26
salhab	0.007	0.002	-0.007	-0.002	0.0	0.0	96.3	96.1	0.23
Line37	-0.636	0.201	0.637	-0.205	0.6	-4.1	96.4	96.4	0.07
westwern aqapa	0.133	0.058	-0.132	-0.056	1.3	1.9	96.4	95.1	1.26
Line38	-0.659	0.198	0.659	-0.199	0.1	-0.6	96.4	96.4	0.01
hawooz aqapa	0.022	0.007	-0.022	-0.007	0.1	0.1	96.4	96.1	0.30
Line39	-0.659	0.199	0.659	-0.199	0.1	-0.4	96.4	96.5	0.01
Line40	-0.659	0.199	0.659	-0.199	0.1	-0.4	96.5	96.5	0.01
Line41	0.000	-0.004	0.000	0.002	0.0	-1.5	96.5	96.5	0.00
Line44	-0.659	0.203	0.659	-0.203	0.1	-0.4	96.5	96.5	0.01
Line42	0.000	-0.002	0.000	0.002	0.0	-0.5	96.5	96.5	0.00
Line43	0.000	-0.002	0.000	0.000	0.0	-1.6	96.5	96.5	0.00
Line45	-0.668	0.199	0.668	-0.202	0.0	-2.2	96.5	96.5	0.00

CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	
al kafeer main	0.009	0.004	-0.009	-0.004	0.0	0.0	96.5	96.1	0.35
Line46	-0.679	0.193	0.680	-0.196	0.5	-2.8	96.5	96.5	0.05
mahajeer 1	0.011	0.008	-0.011	-0.008	0.0	0.0	96.5	96.3	0.21
Line47	-0.681	0.079	0.681	-0.080	0.1	-0.9	96.5	96.5	0.02
eastren zababde	0.002	0.117	-0.001	-0.116	0.5	0.8	96.5	95.9	0.65
Line48	-2.295	-0.434	2.295	0.434	0.6	-0.1	96.5	96.6	0.03
Line81	1.613	0.514	-1.613	-0.515	0.6	-0.4	96.5	96.5	0.04
Cable3	0.099	0.014	-0.099	-0.030	0.0	-15.8	96.6	96.6	0.00
Line49	-2.394	-0.449	2.395	0.448	0.7	-0.1	96.6	96.6	0.03
shcool zababdeh	0.099	0.030	-0.098	-0.028	1.0	1.5	96.6	95.3	1.31
Line50	-2.521	-0.500	2.522	0.500	0.6	0.0	96.6	96.6	0.02
middle zababdeh	0.127	0.051	-0.126	-0.050	1.1	1.7	96.6	95.4	1.17
Line51	0.143	0.017	-0.143	-0.017	0.0	-0.2	96.6	96.6	0.00
Line53	-2.665	-0.517	2.667	0.517	2.8	0.1	96.6	96.7	0.11
Cable4	0.064	-0.012	-0.064	-0.012	0.0	-24.2	96.6	96.6	0.00
westren zababdeh	0.079	0.029	-0.078	-0.028	0.4	0.6	96.6	95.9	0.70
Line52	0.064	0.012	-0.064	-0.013	0.0	-0.4	96.6	96.6	0.00
Cable5	0.064	0.013	-0.064	-0.024	0.0	-11.0	96.6	96.6	0.00
sefferya zababdeh	0.064	0.024	-0.064	-0.023	0.4	0.7	96.6	95.7	0.91
Line54	-2.736	-0.527	2.749	0.528	13.0	0.8	96.7	97.2	0.49
arciticular college	0.068	0.010	-0.068	-0.010	0.3	0.4	96.7	96.2	0.48
Line55	-2.783	-0.546	2.788	0.546	4.9	0.3	97.2	97.4	0.18
manasheer meselya	0.035	0.018	-0.035	-0.018	0.1	0.1	97.2	97.0	0.22
Line56	-2.873	-0.568	2.875	0.568	2.6	0.2	97.4	97.5	0.09
eastren maslya	0.084	0.022	-0.084	-0.021	0.4	0.7	97.4	96.7	0.66
Line57	0.250	0.143	-0.250	-0.145	0.0	-1.7	97.5	97.5	0.02
Line59	-3.126	-0.711	3.126	0.711	0.2	0.0	97.5	97.5	0.01
Line58	0.207	0.132	-0.207	-0.136	0.1	-3.8	97.5	97.4	0.03
masalya	0.043	0.013	-0.043	-0.012	0.5	0.7	97.5	96.0	1.42
weels	0.207	0.136	-0.205	-0.132	2.3	3.4	97.4	96.0	1.48
Line60	-3.194	-0.738	3.222	0.743	28.4	4.8	97.5	98.4	0.92
westren maslya	0.068	0.027	-0.068	-0.027	0.3	0.5	97.5	96.9	0.62
Line61	0.081	0.032	-0.081	-0.033	0.0	-1.4	98.4	98.4	0.00
Line62	-3.387	-0.816	3.391	0.817	3.1	0.6	98.4	98.5	0.10
jarpa main	0.085	0.042	-0.084	-0.041	0.5	0.8	98.4	97.6	0.83
east jarpa	0.081	0.033	-0.079	-0.031	1.1	1.6	98.4	96.6	1.83
Line63	0.023	0.018	-0.023	-0.018	0.0	-0.3	98.5	98.5	0.00

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CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line64	-3.413	-0.835	3.431	0.839	17.8	3.6	98.5	99.1	0.54
plastic factory	0.023	0.018	-0.023	-0.018	0.1	0.1	98.5	98.1	0.45
Line65	0.008	0.001	-0.008	-0.002	0.0	-0.6	99.1	99.1	0.00
Line66	-3.439	-0.840	3.443	0.841	3.7	0.7	99.1	99.2	0.11
wadi al efsha	0.008	0.002	-0.008	-0.002	0.0	0.0	99.1	98.6	0.50
Line67	-3.842	-0.936	3.866	0.942	24.3	6.2	99.2	99.8	0.66
Line71	0.399	0.095	-0.399	-0.095	0.0	-0.7	99.2	99.2	0.01
Line68	0.014	0.010	-0.014	-0.011	0.0	-1.2	99.8	99.8	0.00
Line69	-3.880	-0.952	3.887	0.953	6.3	1.6	99.8	100.0	0.17
eastren zawya	0.014	0.011	-0.014	-0.011	0.0	0.1	99.8	99.4	0.43
Line70	0.024	0.005	-0.024	-0.006	0.0	-1.0	100.0	100.0	0.00
3en zaya	0.034	0.009	-0.034	-0.008	0.3	0.4	100.0	99.0	1.04
westren zayah 2	0.024	0.006	-0.024	-0.006	0.1	0.1	100.0	99.7	0.29
Line72	0.059	0.014	-0.059	-0.015	0.0	-0.3	99.2	99.2	0.00
Line74	0.339	0.081	-0.339	-0.083	0.0	-1.3	99.2	99.1	0.01
Line73	0.019	0.003	-0.019	-0.008	0.0	-4.2	99.2	99.2	0.00
abo omar	0.041	0.011	-0.040	-0.010	0.8	1.2	99.2	96.6	2.54
wadi d3oqa	0.019	0.008	-0.019	-0.007	0.1	0.1	99.2	98.5	0.68
Line75	0.013	0.000	-0.013	-0.003	0.0	-3.4	99.1	99.1	0.00
Line76	0.234	0.059	-0.234	-0.061	0.0	-2.3	99.1	99.1	0.02
shcool maraqa	0.093	0.024	-0.092	-0.023	0.5	0.8	99.1	98.4	0.72
water pumb	0.013	0.003	-0.013	-0.003	0.0	0.0	99.1	99.0	0.10
Line77	0.199	0.046	-0.199	-0.048	0.0	-2.0	99.1	99.1	0.01
masria	0.035	0.015	-0.035	-0.015	0.3	0.5	99.1	97.8	1.29
Line78	0.163	0.047	-0.162	-0.052	0.0	-5.0	99.1	99.1	0.03
hafreya	0.036	0.000	-0.036	0.000	0.3	0.4	99.1	98.3	0.82
Line79	0.068	0.028	-0.068	-0.031	0.0	-3.4	99.1	99.1	0.01
beer al- basha	0.095	0.024	-0.094	-0.024	0.5	0.8	99.1	98.4	0.73
eastren beer basha	0.068	0.031	-0.067	-0.031	0.5	0.8	99.1	98.1	1.03
Line83	1.613	0.515	-1.612	-0.515	0.2	-0.2	96.5	96.5	0.01
Line84	0.267	0.105	-0.267	-0.105	0.0	-0.3	96.5	96.5	0.00
Line94	1.345	0.410	-1.345	-0.410	0.2	-0.2	96.5	96.5	0.01
Line85	0.198	0.075	-0.198	-0.077	0.0	-1.2	96.5	96.5	0.01
AUU intersiction ZA	0.070	0.030	-0.069	-0.030	0.2	0.3	96.5	96.1	0.42
Line86	0.183	0.065	-0.183	-0.072	0.1	-7.0	96.5	96.4	0.04
manasheer ZA	0.015	0.012	-0.015	-0.012	0.0	0.1	96.5	96.2	0.30
Line87	0.183	0.072	-0.183	-0.072	0.0	-0.3	96.4	96.4	0.00

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CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line88	0.183	0.076	-0.183	-0.078	0.0	-1.8	96.4	96.4	0.01
Line93	0.000	-0.004	0.000	0.000	0.0	-4.1	96.4	96.4	0.00
Line89	0.139	0.059	-0.139	-0.060	0.0	-1.0	96.4	96.4	0.00
rahwa.	0.043	0.019	-0.043	-0.018	0.5	0.8	96.4	94.8	1.65
Line90	0.096	0.041	-0.096	-0.043	0.0	-2.2	96.4	96.4	0.01
rahwa	0.043	0.018	-0.043	-0.018	0.1	0.2	96.4	96.0	0.41
Line91	0.096	0.043	-0.096	-0.044	0.0	-0.6	96.4	96.4	0.00
Line92	0.048	0.019	-0.048	-0.021	0.0	-1.7	96.4	96.4	0.00
middle of raba	0.048	0.025	-0.048	-0.024	0.3	0.4	96.4	95.6	0.79
east of raba	0.048	0.021	-0.048	-0.020	0.3	0.4	96.4	95.7	0.73
T63	0.000	0.000	0.000	0.000			96.4	96.4	0.00
Line95	1.345	0.410	-1.341	-0.415	4.1	-4.8	96.5	96.2	0.31
Line96	0.076	0.002	-0.076	-0.002	0.0	-0.3	96.2	96.2	0.00
Line97	1.265	0.413	-1.265	-0.414	0.5	-0.6	96.2	96.1	0.04
tlfeet	0.076	0.002	-0.074	0.000	1.4	2.1	96.2	94.4	1.78
Line98	0.692	0.187	-0.692	-0.188	0.1	-0.9	96.1	96.1	0.02
Line114	0.572	0.227	-0.572	-0.227	0.1	-0.5	96.1	96.1	0.01
Line99	-0.305	-0.088	0.305	0.087	0.0	-0.4	96.1	96.1	0.00
Line100	0.191	0.067	-0.191	-0.067	0.0	-0.3	96.1	96.1	0.00
dream land 1	0.044	0.006	-0.044	-0.006	0.1	0.1	96.1	95.9	0.20
dream land 2	0.070	0.015	-0.069	-0.014	0.3	0.5	96.1	95.6	0.53
Line101	0.133	0.039	-0.133	-0.039	0.0	-0.2	96.1	96.1	0.00
midecin	0.058	0.028	-0.058	-0.028	0.2	0.2	96.1	95.7	0.37
Line102	0.133	0.039	-0.133	-0.039	0.0	-0.3	96.1	96.1	0.00
west 1 AUU	0.075	0.011	-0.075	-0.011	0.3	0.5	96.1	95.6	0.53
west 2 AUU	0.058	0.028	-0.058	-0.028	0.2	0.2	96.1	95.7	0.37
Line103	0.388	0.101	-0.388	-0.105	0.2	-4.5	96.1	96.0	0.06
Line104	0.386	0.105	-0.386	-0.107	0.1	-1.7	96.0	96.0	0.02
khrpet aisha	0.002	0.000	-0.002	0.000	0.0	0.0	96.0	96.0	0.04
Line105	0.341	0.097	-0.341	-0.100	0.1	-2.3	96.0	96.0	0.03
westren jalqnosa	0.045	0.010	-0.045	-0.009	0.3	0.5	96.0	95.2	0.85
Line106	0.058	0.015	-0.058	-0.020	0.0	-5.3	96.0	96.0	0.01
Line109	0.207	0.059	-0.207	-0.062	0.0	-2.6	96.0	96.0	0.02
middle jalqumya	0.076	0.025	-0.075	-0.025	0.4	0.6	96.0	95.3	0.66
Line108	0.058	0.020	-0.058	-0.021	0.0	-1.2	96.0	96.0	0.00
main om toot	0.058	0.021	-0.058	-0.021	0.2	0.3	96.0	95.5	0.52
Line110	0.188	0.047	-0.188	-0.049	0.0	-2.6	96.0	96.0	0.02

CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
eastren al-jalquoua	0.019	0.015	-0.019	-0.015	0.1	0.1	96.0	95.4	0.61
Line111	0.163	0.043	-0.163	-0.047	0.0	-3.8	96.0	95.9	0.02
marah karas	0.025	0.006	-0.025	-0.006	0.2	0.2	96.0	95.2	0.80
Line112	0.084	0.023	-0.084	-0.024	0.0	-0.9	95.9	95.9	0.00
wastren al-maghayer	0.078	0.024	-0.078	-0.023	0.6	1.0	95.9	94.9	1.05
Line113	0.011	-0.001	-0.011	-0.004	0.0	-5.3	95.9	95.9	0.00
eastern al-maghura	0.073	0.025	-0.073	-0.024	0.6	0.9	95.9	94.9	1.02
al-mtalleh	0.011	0.004	-0.011	-0.004	0.0	0.0	95.9	95.7	0.25
Line115	0.055	0.022	-0.055	-0.022	0.0	-0.3	96.1	96.1	0.00
Line116	0.517	0.205	-0.517	-0.206	0.1	-0.7	96.1	96.1	0.01
administration college	0.055	0.022	-0.055	-0.022	0.2	0.3	96.1	95.6	0.51
Line117	0.426	0.183	-0.426	-0.183	0.0	-0.3	96.1	96.1	0.00
registration bulding	0.091	0.023	-0.091	-0.023	0.3	0.5	96.1	95.6	0.46
Line118	0.314	0.139	-0.314	-0.140	0.0	-1.2	96.1	96.1	0.01
Line123	0.112	0.044	-0.112	-0.046	0.0	-1.3	96.1	96.1	0.00
Cable7	0.140	0.000	-0.140	-0.021	0.0	-21.2	96.1	96.1	0.00
Line120	0.099	0.129	-0.099	-0.130	0.0	-0.7	96.1	96.1	0.00
princec palce	0.075	0.012	-0.075	-0.011	0.6	0.8	96.1	95.2	0.85
Cable8	0.085	0.009	-0.085	-0.018	0.0	-8.4	96.1	96.1	0.00
grand plaza DL	0.055	0.012	-0.055	-0.011	0.3	0.5	96.1	95.4	0.67
royal	0.085	0.018	-0.084	-0.017	0.3	0.4	96.1	95.7	0.41
Line121	0.056	0.011	-0.056	-0.012	0.0	-0.6	96.1	96.1	0.00
Line122	0.043	0.119	-0.043	-0.119	0.0	-0.3	96.1	96.1	0.00
dream land	0.056	0.012	-0.056	-0.011	0.2	0.3	96.1	95.7	0.42
sport stidum 1	0.021	0.059	-0.021	-0.059	0.1	0.2	96.1	95.8	0.33
sport stidum 2	0.021	0.059	-0.021	-0.059	0.1	0.2	96.1	95.8	0.33
Line124	0.030	0.003	-0.030	-0.004	0.0	-1.2	96.1	96.1	0.00
Line125	0.082	0.042	-0.082	-0.046	0.0	-3.2	96.1	96.1	0.01
tneen main	0.030	0.004	-0.030	-0.004	0.1	0.2	96.1	95.6	0.53
Line126	0.081	0.045	-0.081	-0.046	0.0	-0.7	96.1	96.1	0.00
esfalt	0.001	0.000	-0.001	0.000	0.0	0.0	96.1	96.1	0.01
Line127	0.061	0.037	-0.061	-0.037	0.0	-0.2	96.1	96.1	0.00
mass stone	0.020	0.009	-0.020	-0.009	0.0	0.0	96.1	96.0	0.12
Line244	0.001	0.000	-0.001	0.000	0.0	-0.6	96.1	96.1	0.00
mass stones	0.060	0.037	-0.059	-0.037	0.2	0.3	96.1	95.7	0.42
zakarneh 1	0.001	0.000	-0.001	0.000	0.0	0.0	96.1	96.1	0.01
Line130	0.125	0.042	-0.125	-0.043	0.0	-0.6	96.4	96.4	0.00

CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line131	3.071	3.083	-3.069	-3.082	1.2	0.4	96.4	96.4	0.03
al-masa3eed	0.125	0.043	-0.123	-0.040	1.7	2.5	96.4	94.7	1.73
Line132	3.049	3.079	-3.046	-3.078	3.0	1.0	96.4	96.3	0.07
anabosa	0.021	0.003	-0.021	-0.003	0.0	0.1	96.4	96.1	0.23
Line133	2.872	3.019	-2.871	-3.018	1.0	0.3	96.3	96.3	0.02
abu omar	0.174	0.060	-0.172	-0.056	2.0	3.0	96.3	94.8	1.51
Line134	2.871	3.018	-2.864	-3.016	6.9	2.1	96.3	96.1	0.17
Line161	2.679	2.977	-2.678	-2.977	1.2	0.4	96.1	96.1	0.03
abo shehab	0.185	0.039	-0.183	-0.037	1.4	2.0	96.1	95.2	0.89
Line136	2.678	2.977	-2.675	-2.976	3.3	0.9	96.1	96.0	0.08
Line137	0.130	0.065	-0.130	-0.065	0.0	-0.3	96.0	96.0	0.00
Line138	2.544	2.911	-2.542	-2.910	2.2	0.6	96.0	95.9	0.06
tubas weel	0.130	0.065	-0.128	-0.062	2.1	3.1	96.0	93.9	2.10
Line139	2.542	2.910	-2.539	-2.909	3.2	0.9	95.9	95.9	0.08
Line162	1.058	0.312	-1.058	-0.313	0.3	-0.6	95.9	95.8	0.02
Line175	1.448	2.586	-1.444	-2.586	4.6	0.6	95.9	95.7	0.14
amnawaqa2	0.032	0.011	-0.032	-0.010	0.2	0.3	95.9	95.2	0.69
Line141	0.038	0.004	-0.038	-0.008	0.0	-3.3	95.8	95.8	0.00
Line145	1.020	0.309	-1.020	-0.309	0.2	-0.5	95.8	95.8	0.02
Line142	0.038	0.008	-0.038	-0.010	0.0	-2.6	95.8	95.8	0.00
Line143	0.034	0.009	-0.034	-0.010	0.0	-1.1	95.8	95.8	0.00
khalt el looz	0.004	0.001	-0.004	-0.001	0.0	0.0	95.8	95.7	0.08
Line144	0.034	0.010	-0.034	-0.011	0.0	-0.9	95.8	95.8	0.00
shereen	0.034	0.011	-0.034	-0.011	0.2	0.3	95.8	95.1	0.73
Line146	0.953	0.276	-0.953	-0.278	0.5	-1.5	95.8	95.8	0.06
mo2ayad fridges	0.067	0.033	-0.066	-0.032	0.4	0.6	95.8	95.1	0.74
Line147	0.034	0.007	-0.034	-0.009	0.0	-1.2	95.8	95.8	0.00
Line148	0.919	0.270	-0.918	-0.274	1.1	-3.3	95.8	95.6	0.12
mohafada	0.034	0.009	-0.034	-0.008	0.1	0.2	95.8	95.3	0.43
Line149	0.870	0.260	-0.869	-0.262	0.7	-2.3	95.6	95.6	0.08
weel	0.048	0.014	-0.048	-0.014	0.1	0.1	95.6	95.4	0.25
Line150	0.095	0.032	-0.095	-0.032	0.0	-0.3	95.6	95.6	0.00
Line163	0.774	0.230	-0.774	-0.230	0.1	-0.3	95.6	95.5	0.01
first of the town	0.095	0.032	-0.094	-0.031	1.0	1.5	95.6	94.2	1.33
Line152	0.719	0.218	-0.719	-0.219	0.2	-0.9	95.5	95.5	0.02
police	0.055	0.012	-0.055	-0.011	0.3	0.5	95.5	94.9	0.67
Line153	0.075	0.022	-0.075	-0.023	0.0	-0.6	95.5	95.5	0.00

CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line154	0.047	0.016	-0.047	-0.016	0.0	-0.6	95.5	95.5	0.00
Line155	0.596	0.182	-0.596	-0.183	0.2	-1.7	95.5	95.5	0.04
burhan	0.075	0.023	-0.074	-0.022	0.6	0.9	95.5	94.5	1.01
al-battman	0.047	0.016	-0.047	-0.015	0.6	0.9	95.5	93.9	1.65
Line156	0.397	0.132	-0.397	-0.134	0.1	-1.3	95.5	95.5	0.02
Line164	0.123	0.031	-0.123	-0.031	0.0	-0.1	95.5	95.5	0.00
national security	0.077	0.020	-0.076	-0.019	1.0	1.4	95.5	93.9	1.55
Line157	0.255	0.085	-0.255	-0.085	0.0	-0.3	95.5	95.5	0.00
alrfaid	0.141	0.049	-0.139	-0.046	2.2	3.3	95.5	93.5	1.98
Line158	0.217	0.075	-0.217	-0.076	0.0	-1.2	95.5	95.5	0.01
Line160	0.038	0.010	-0.038	-0.011	0.0	-1.4	95.5	95.5	0.00
Line159	0.147	0.055	-0.147	-0.056	0.0	-1.5	95.5	95.4	0.01
alBATTAH	0.070	0.021	-0.069	-0.020	0.8	1.2	95.5	94.0	1.48
ALMISHMAS	0.147	0.056	-0.144	-0.052	2.4	3.6	95.4	93.3	2.14
alrass	0.038	0.011	-0.038	-0.011	0.2	0.2	95.5	95.0	0.51
Line165	0.123	0.031	-0.123	-0.033	0.0	-2.3	95.5	95.5	0.01
Line167	0.107	0.028	-0.107	-0.031	0.0	-3.8	95.5	95.5	0.01
RAS AL-MATTALEH	0.016	0.005	-0.016	-0.005	0.0	0.1	95.5	95.1	0.35
Line168	0.016	-0.003	-0.016	0.002	0.0	-1.6	95.5	95.5	0.00
Line171	0.091	0.035	-0.091	-0.035	0.0	-0.8	95.5	95.5	0.00
Line169	0.008	-0.005	-0.008	-0.002	0.0	-6.7	95.5	95.5	0.00
ALJALHOOM	0.008	0.003	-0.008	-0.003	0.0	0.0	95.5	95.3	0.18
ATOOF	0.008	0.002	-0.008	-0.002	0.0	0.0	95.5	95.3	0.16
Line172	0.080	0.032	-0.080	-0.032	0.0	-0.3	95.5	95.5	0.00
Line173	0.011	0.004	-0.011	-0.006	0.0	-2.3	95.5	95.5	0.00
MAWAFAQ FAKHRY	0.080	0.032	-0.079	-0.031	0.3	0.4	95.5	95.0	0.47
HAKIM	0.011	0.006	-0.011	-0.006	0.0	0.0	95.5	95.4	0.07
Line176	1.444	2.586	-1.437	-2.585	6.2	0.8	95.7	95.5	0.18
Line177	0.063	0.030	-0.063	-0.031	0.0	-0.6	95.5	95.5	0.00
Line178	1.374	2.554	-1.373	-2.554	1.5	0.2	95.5	95.5	0.04
pickle factory	0.063	0.031	-0.063	-0.030	0.3	0.4	95.5	94.9	0.63
Line179	0.003	0.001	-0.003	-0.002	0.0	-0.6	95.5	95.5	0.00
Line180	1.370	2.553	-1.368	-2.553	2.2	0.3	95.5	95.4	0.07
keshda main	0.003	0.002	-0.003	-0.002	0.0	0.0	95.5	95.2	0.25
Line181	-2.080	1.203	2.081	-1.203	1.0	-0.1	95.4	95.4	0.02
Line182	3.447	1.350	-3.443	-1.349	4.5	1.2	95.4	95.3	0.13
Line192	-2.081	1.203	2.082	-1.203	1.0	-0.1	95.4	95.5	0.02

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ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line183	3.343	1.284	-3.339	-1.283	3.8	1.0	95.3	95.2	0.11
dewan	0.100	0.065	-0.099	-0.064	0.9	1.3	95.3	94.1	1.15
Line184	1.001	0.518	-1.001	-0.518	0.2	-0.3	95.2	95.2	0.02
Line200	2.338	0.765	-2.336	-0.765	1.4	0.0	95.2	95.1	0.06
Line185	0.746	0.393	-0.745	-0.394	0.3	-1.2	95.2	95.1	0.04
Line196	0.256	0.125	-0.256	-0.125	0.0	-0.3	95.2	95.2	0.00
Line186	0.745	0.394	-0.745	-0.395	0.1	-0.5	95.1	95.1	0.02
Line187	0.675	0.365	-0.675	-0.366	0.1	-0.6	95.1	95.1	0.02
Line195	0.070	0.029	-0.070	-0.030	0.0	-0.9	95.1	95.1	0.00
Line188	0.272	0.162	-0.272	-0.165	0.1	-3.0	95.1	95.1	0.03
Line189	0.135	0.070	-0.135	-0.070	0.0	-0.3	95.1	95.1	0.00
khalet al qaser 1	0.202	0.112	-0.198	-0.107	3.3	4.9	95.1	92.9	2.15
khalet al qaser 2	0.067	0.022	-0.067	-0.022	0.2	0.3	95.1	94.7	0.37
mohammad al basher	0.272	0.165	-0.268	-0.159	3.9	5.9	95.1	93.1	1.92
Line190	0.135	0.070	-0.135	-0.072	0.0	-2.2	95.1	95.1	0.01
Line191	0.030	0.015	-0.030	-0.019	0.0	-3.3	95.1	95.1	0.00
faysel well	0.105	0.057	-0.104	-0.056	0.6	0.8	95.1	94.4	0.71
huseen al araj	0.030	0.019	-0.030	-0.018	0.1	0.2	95.1	94.5	0.54
Cable44	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable45	0.487	-0.164	-0.379	0.208	107.9	44.2	113.7	95.7	18.04
Cable48	-0.054	0.018	0.055	-0.018	0.8	0.1	113.7	115.2	1.50
Cable49	-0.054	0.018	0.055	-0.018	0.8	0.1	113.7	115.2	1.50
Cable50	-0.054	0.018	0.055	-0.018	0.8	0.1	113.7	115.2	1.50
Cable51	-0.054	0.018	0.055	-0.018	0.8	0.1	113.7	115.2	1.50
Cable52	-0.054	0.018	0.055	-0.018	0.8	0.1	113.7	115.2	1.50
Cable53	-0.054	0.018	0.055	-0.018	0.8	0.1	113.7	115.2	1.50
Cable54	-0.054	0.018	0.055	-0.018	0.8	0.1	113.7	115.2	1.50
Cable126	-0.054	0.018	0.055	-0.018	0.8	0.1	113.7	115.2	1.50
T1	0.379	-0.208	-0.372	0.219	7.2	10.8	95.7	95.5	0.20
T2	-0.372	0.219	0.379	-0.208	7.2	10.8	95.5	95.7	0.21
T3	-0.336	0.187	0.341	-0.179	5.7	8.6	95.5	95.7	0.24
T6	-0.228	0.112	0.232	-0.106	3.9	5.9	95.5	95.9	0.38
T7	-0.403	0.248	0.411	-0.235	8.6	12.9	95.5	95.6	0.17
T8	-0.372	0.219	0.379	-0.208	7.2	10.8	95.5	95.7	0.20
Cable66	0.049	-0.016	-0.049	0.016	0.7	0.1	115.1	113.8	1.35
Cable86	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35
Cable87	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35

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ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Cable88	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35
Cable89	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35
Cable90	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35
Cable91	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35
Cable92	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35
Cable93	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35
Cable120	0.487	-0.163	-0.379	0.208	108.2	44.3	113.8	95.7	18.07
Cable128	-0.049	0.016	0.049	-0.016	0.7	0.1	113.8	115.1	1.35
Cable67	0.049	-0.016	-0.049	0.016	0.7	0.1	113.3	111.9	1.37
Cable69	-0.054	0.018	0.055	-0.018	0.9	0.1	111.9	113.5	1.52
Cable70	-0.054	0.018	0.055	-0.018	0.9	0.1	111.9	113.5	1.52
Cable71	-0.054	0.018	0.055	-0.018	0.9	0.1	111.9	113.5	1.52
Cable72	-0.054	0.018	0.055	-0.018	0.9	0.1	111.9	113.5	1.52
Cable73	-0.054	0.018	0.055	-0.018	0.9	0.1	111.9	113.5	1.52
Cable118	-0.054	0.018	0.055	-0.018	0.9	0.1	111.9	113.5	1.52
Cable121	0.427	-0.144	-0.341	0.179	85.8	35.1	111.9	95.7	16.23
Cable130	-0.054	0.018	0.055	-0.018	0.9	0.1	111.9	113.5	1.52
Cable79	0.055	-0.018	-0.054	0.018	0.9	0.1	108.5	106.9	1.59
Cable80	0.055	-0.018	-0.054	0.018	0.9	0.1	108.5	106.9	1.59
Cable81	0.055	-0.018	-0.054	0.018	0.9	0.1	108.5	106.9	1.59
Cable82	0.055	-0.018	-0.054	0.018	0.9	0.1	108.5	106.9	1.59
Cable83	0.055	-0.018	-0.054	0.018	0.9	0.1	108.5	106.9	1.59
Cable122	0.270	-0.091	-0.232	0.106	37.6	15.4	106.9	95.9	11.01
Cable123	-0.411	0.235	0.541	-0.182	129.8	53.2	95.6	115.3	19.62
Cable124	-0.379	0.208	0.487	-0.164	107.9	44.2	95.7	113.7	18.04
mawfak al-fakhry	0.070	0.030	-0.070	-0.030	0.2	0.3	95.1	94.7	0.43
Line197	0.184	0.083	-0.184	-0.085	0.0	-1.8	95.2	95.2	0.01
agricultural project	0.072	0.043	-0.071	-0.042	0.3	0.4	95.2	94.7	0.50
Line198	0.096	0.060	-0.096	-0.060	0.0	-0.5	95.2	95.1	0.00
Line199	0.067	0.019	-0.067	-0.022	0.0	-3.3	95.2	95.1	0.01
kazeyt samara	0.021	0.006	-0.021	-0.006	0.0	0.0	95.2	95.0	0.18
thiab	0.096	0.060	-0.096	-0.059	0.5	0.8	95.1	94.5	0.69
al-ashqar stone cutter	0.067	0.022	-0.067	-0.022	0.2	0.3	95.1	94.8	0.37
Line201	0.116	0.074	-0.116	-0.075	0.0	-1.1	95.1	95.1	0.01
Line203	2.220	0.692	-2.219	-0.692	0.6	-0.1	95.1	95.1	0.03
Line202	0.116	0.075	-0.116	-0.076	0.0	-1.0	95.1	95.1	0.00
abo hameed	0.116	0.076	-0.116	-0.075	0.8	1.1	95.1	94.3	0.85

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ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Line204	0.035	0.019	-0.035	-0.020	0.0	-1.0	95.1	95.1	0.00
Line205	2.185	0.673	-2.182	-0.673	2.1	-0.2	95.1	95.0	0.10
al-kharaz	0.035	0.020	-0.035	-0.020	0.2	0.4	95.1	94.2	0.95
Line206	1.123	0.402	-1.123	-0.403	0.5	-0.9	95.0	95.0	0.04
Line231	1.059	0.271	-1.059	-0.271	0.2	-0.3	95.0	95.0	0.02
Line207	0.217	0.086	-0.217	-0.086	0.0	-0.6	95.0	94.9	0.01
Line209	0.905	0.318	-0.905	-0.319	0.5	-1.6	95.0	94.9	0.06
Line208	0.058	0.017	-0.058	-0.019	0.0	-2.1	94.9	94.9	0.00
refat	0.080	0.034	-0.079	-0.034	0.5	0.7	94.9	94.2	0.77
refat 2	0.080	0.034	-0.079	-0.034	0.5	0.7	94.9	94.2	0.77
safeena	0.058	0.019	-0.058	-0.019	0.2	0.3	94.9	94.4	0.51
Line210	0.757	0.251	-0.757	-0.251	0.0	-0.2	94.9	94.9	0.01
Line225	0.068	0.028	-0.068	-0.030	0.0	-1.2	94.9	94.9	0.00
Line226	0.080	0.040	-0.080	-0.044	0.0	-3.6	94.9	94.9	0.01
Line215	0.552	0.192	-0.552	-0.194	0.2	-1.9	94.9	94.8	0.04
Line243	0.205	0.059	-0.205	-0.060	0.0	-0.5	94.9	94.9	0.00
Line212	0.169	0.046	-0.169	-0.048	0.0	-1.4	94.9	94.9	0.01
al-hesba	0.036	0.013	-0.036	-0.013	0.1	0.2	94.9	94.4	0.52
Line213	0.069	0.018	-0.069	-0.019	0.0	-1.2	94.9	94.9	0.00
kazeya	0.100	0.030	-0.099	-0.029	0.7	1.0	94.9	94.0	0.85
Line214	0.039	0.008	-0.039	-0.010	0.0	-1.8	94.9	94.9	0.00
school	0.030	0.011	-0.030	-0.011	0.1	0.1	94.9	94.6	0.27
abo shehadeh	0.039	0.010	-0.039	-0.010	0.2	0.2	94.9	94.4	0.50
Line216	0.396	0.131	-0.396	-0.133	0.1	-2.2	94.8	94.8	0.03
al bassateen	0.156	0.063	-0.155	-0.061	1.1	1.7	94.8	93.9	0.93
Line217	0.305	0.105	-0.305	-0.108	0.1	-2.7	94.8	94.8	0.03
abo khadeer	0.091	0.028	-0.090	-0.026	0.9	1.3	94.8	93.6	1.23
Line218	0.269	0.099	-0.269	-0.099	0.0	-0.2	94.8	94.8	0.00
abo tareq	0.036	0.009	-0.036	-0.009	0.1	0.1	94.8	94.6	0.18
Line219	0.269	0.099	-0.269	-0.102	0.1	-2.9	94.8	94.8	0.03
Line220	0.072	0.029	-0.072	-0.029	0.0	-0.3	94.8	94.8	0.00
Line221	0.076	0.018	-0.076	-0.020	0.0	-1.1	94.8	94.8	0.00
Line222	0.121	0.055	-0.121	-0.055	0.0	-0.4	94.8	94.8	0.00
mamdooh	0.072	0.029	-0.072	-0.028	0.4	0.6	94.8	94.1	0.67
farah	0.076	0.020	-0.076	-0.019	0.4	0.6	94.8	94.1	0.62
Line223	0.100	0.048	-0.100	-0.049	0.0	-0.6	94.8	94.8	0.00
Line224	0.021	0.007	-0.021	-0.008	0.0	-1.4	94.8	94.8	0.00

CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd % Drop in Vmag
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	
sameer motlaq	0.100	0.049	-0.099	-0.048	0.8	1.1	94.8	93.7	1.01
essawi	0.021	0.008	-0.021	-0.008	0.1	0.1	94.8	94.4	0.31
al hafria	0.068	0.030	-0.068	-0.029	0.5	0.8	94.9	93.8	1.05
Line227	0.011	0.007	-0.011	-0.007	0.0	-0.3	94.9	94.9	0.00
Line228	0.069	0.037	-0.069	-0.038	0.0	-1.2	94.9	94.9	0.00
yaseed east	0.011	0.007	-0.011	-0.007	0.0	0.0	94.9	94.7	0.20
Line229	0.008	0.003	-0.008	-0.003	0.0	-0.6	94.9	94.9	0.00
Line230	0.061	0.036	-0.061	-0.038	0.0	-2.5	94.9	94.9	0.01
kasaret abo asaad	0.061	0.038	-0.061	-0.038	0.3	0.5	94.9	94.2	0.69
yaseed west	0.008	0.003	-0.008	-0.003	0.0	0.0	94.9	94.8	0.12
Line232	0.248	0.070	-0.248	-0.070	0.0	-0.2	95.0	95.0	0.00
Line233	0.154	0.031	-0.154	-0.032	0.0	-0.7	95.0	95.0	0.00
Line236	0.656	0.169	-0.656	-0.170	0.1	-0.6	95.0	95.0	0.01
weastern	0.248	0.070	-0.242	-0.061	6.6	9.8	95.0	91.7	3.27
Line234	0.018	0.002	-0.018	-0.003	0.0	-0.3	95.0	95.0	0.00
Line235	0.136	0.030	-0.136	-0.030	0.0	-0.2	95.0	95.0	0.00
school.	0.136	0.030	-0.134	-0.027	1.9	2.9	95.0	93.3	1.68
tubas well	0.018	0.003	-0.018	-0.003	0.0	0.0	95.0	94.9	0.13
Line237	0.568	0.151	-0.568	-0.152	0.1	-0.9	95.0	95.0	0.02
al-shareef	0.088	0.018	-0.088	-0.018	0.3	0.5	95.0	94.5	0.43
Line238	0.074	0.015	-0.074	-0.015	0.0	-0.5	95.0	95.0	0.00
Line239	0.474	0.129	-0.474	-0.130	0.0	-0.5	95.0	94.9	0.01
Line242	0.012	0.002	-0.012	-0.003	0.0	-0.6	95.0	95.0	0.00
malhameh	0.008	0.006	-0.008	-0.006	0.0	0.0	95.0	94.9	0.06
al-3een	0.074	0.015	-0.074	-0.015	0.2	0.3	95.0	94.6	0.36
Line240	0.391	0.074	-0.391	-0.074	0.0	-0.1	94.9	94.9	0.00
well	0.083	0.056	-0.082	-0.055	0.6	0.9	94.9	94.0	0.97
Line241	0.338	0.058	-0.338	-0.058	0.0	-0.2	94.9	94.9	0.00
stadium	0.053	0.016	-0.053	-0.015	0.3	0.5	94.9	94.2	0.71
old station	0.338	0.058	-0.331	-0.047	7.2	10.9	94.9	92.5	2.45
sameeh abo khezaran	0.012	0.003	-0.012	-0.003	0.0	0.0	95.0	94.9	0.10
Cable95	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable98	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable99	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable100	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable101	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable102	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48

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CKT / Branch	From-To Bus Flow		To-From Bus Flow		Losses		% Bus Voltage		Vd
									% Drop
ID	MW	Mvar	MW	Mvar	kW	kvar	From	To	in Vmag
Cable103	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable104	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable105	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable106	0.055	-0.018	-0.054	0.018	0.8	0.1	116.7	115.3	1.48
Cable107	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable108	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable109	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable110	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable111	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable112	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable113	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable114	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
Cable115	0.055	-0.018	-0.054	0.018	0.8	0.1	115.2	113.7	1.50
					1030.7	257.7			

ETAP

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