DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
SAND MUSTAFA AL-REFAI

In Partial Fulfilment of the Requirements for The Degree of Master of Science in Electrical and Electronic Engineering

NICOSIA, 2016

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Approval of Director of Graduate School of Applied Sciences

Prof. Dr. İlkay SALİHOĞLU

We certify this thesis is satisfactory for the award of the degree of Masters of Science in Electrical and Electronic Engineering

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ACKNOWLEDGEMENTS

I would like to express my sincere appreciation and thanks to my supervisor, Assoc. Prof. Dr. M. Timur Aydemir , for his guidance and mentorship during my graduate studies. His impressive knowledge and creative thinking have been source of inspiration throughout this work.

My deepest gratitude goes to my parents, my wife, my brothers, sisters, and my son, to whom I am most indebted. I thank them for constant love, prayers, patience and support while I was studying abroad. I know I can never come close to returning their favor upon me.

A special thanks to my beloved Dad for his sacrifices, never-ending support and encouragement during my study. I would like to thank him for being a constant source of inspiration and motivation for me. Without him I would be no-where near what I have become today.

I will always be thankful to my friends and colleagues for their unlimited support. I extend my thanks to all the Libyan community that gave me a second family away from home.

To my parents and family….

ABSTRACT

Electrical energy is very important for sustainability and quality of life on this planet. Solar photovoltaic (PV) is one of the most adequate technologies used to convert the energy of the sun to electrical energy. Suitable exploitation of solar energy implies important diminution of the emissions of greenhouse gases.

In Libya, due to environmental, economic and development perspectives the Renewable Energy Authority of Libya (REAOL) is planning to implement a grid connected 14 MW photovoltaic (PV) power plant near the Houn city in the Jufra District in Libya. The implementation of such large scale solar project may affect the normal parameters of the existing power station. These parameters are mainly voltage control, stability, protection equipment, and harmonic distortion levels. Therefore, this thesis develops a study of the design of PV system to be implemented in Houn substation 220 kV. The study aims to find the optimal parameters of the PV system such that it can function correctly. In addition, it investigates the impact of integrating PV directly with the existing grid. Different analysis tools will be used to perform load flow analysis to ascertain the effect on the PV to the grid. Analysis of the voltage variations and voltage stability after the integration of the PV system will also be assessed. Harmonic distortion analysis of the system is also going to be experimented after the connection of the PV plant to ensure the conformity of the resulting system with the international power quality standards.

In order to prove the design validity of the proposed system, models and simulations in MATLAB/SIMULINK and ETAP program will be established for a practical distribution grid. Real loads and solar energy data will be used in the simulation models for more realistic design. The results obtained from the analysis will be presented, tabulated, and discussed throughout this work.

***Keywords*:** Solar energy; photovoltaic (PV); Houn city; Houn substation 220kV; MATLAB/Simulink; ETAP

ÖZET

Elektrik enerjisi gezegenimizdeki yaşamın sürdürülebilirliği ve kalitesi için çok önemlidir. Güneş enerjisini elektrik enerjisine dönüştürmek için kullanılan en uygun teknolojilerden biri fotovoltaik panellerdir. Güneş enerjisinden uygun biçimde yararlanarak sera etkisi yapan gazların yayımı azaltılabilir.

Libya Yenilenebilir Enerji Kurumu (REAOL) çevresel, ekonomik ve gelişim perspektifleri ile Jufra bölgesinin Houn şehri yakınlarında şebeke bağlantılı 14 MW gücünde fotovoltaik enerji tesisinin kurulumunu planlamaktadır. Bu ölçekte bir güneş enerjisi sisteminin kurulumu, mevcut enerji santralinin normal parametrelerini etkileyebilir. Bu parametrelerin başlıcaları gerilim kontrolü, kararlılık, koruma cihazları ve harmonik bozunum seviyeleridir. Bu tezde 220 kV gerilimli Houn şalt merkezinde kurulacak PV sistemin tasarımına yönelik bir çalışma gerçekleştirilmektedir. Çalışmanın amacı, PV sistemin işlevini doğru biçimde yerine getirebilmek için gerekli optimum parametrelerin bulunmasıdır. Ayrıca, PV sistemin mevcut şebekeye doğrudan bağlanmasının etkileri incelenmektedir. PV sistemin şebekeye etkisini değerlendirmek amacıyla yük akışı analizini yapmak için farklı analiz araçları kullanılmaktadır. PV sistemin entegrasyonunun bağlantısından sonra gerilimdeki değişimlerin ve gerilim kararlılığının analizi de gerçekleştirilmektedir. Sistemin uluslararası güç kalitesi standartlarına uygun davrandığını görmek için harmonik bozunum analizi de yapılmaktadır.

Önerilen sistemin tasarımının doğruluğunu göstermek için gerçek sistemin ve dağıtım şebekesinin MATLAB/SIMULINK ve ETAP programları ile modellemesi ve benzetimi gerçekleştirilmiştir. Daha gerçekçi bir tasarım için gerçek yük ve güneş enerjisi verileri kullanılmıştır. Çalışmada, analizlerden elde edilen veriler sunulmakta ve tartışılmaktadır.

***Anahtar Kelimeler*:** Güneş enerjisi; Photovoltaik (PV) enerji; Houn şehri; Houn 220 kV şaltmerkezi; MATLAB/Simulink; ETAP

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LIST OF ABBREVIATIONS

AC	Alternative Current
CB	Circuit Breaker
CHP	Combined Heat and Power
CP	Cathodic Protection
CPV	Concentrated Photovoltaic
CSA	Cross Sectional Area
CSES	Center of Solar Energy Studies
DC	Direct Current
DG	Distributed Generation
EIA	Energy Information Administration
ETAP	Electrical Transient Analyzer Program
FACTS	Flexible Alternative Current Transmission Systems
FC	Fuel Cell
GECOL	General Electrical Company of Libya
MATLAB	Matrix Laboratory
MPPT	Maximum Power Point Tracking
PCC	Point of Common Coupling
PU	Per Unit
PV	Photovoltaic
REAOL	Renewable Energy Authority of Libya
SCADA	Supervisory Control and Data Acquisition
STC	Standard Test Conditions
THD	Total Harmonic Distortion
UPS	Uninterruptible Power Supplies
VTs	Voltage Transformers

CHAPTER 1
INTRODUCTION

This work is an introduction of the Photovoltaic (PV) solar energy in the Libyan national electrical network. It represents a study of the implementation of 14 MW solar power station into Houn sub-station in Libya.

1.1 Introduction

Electrical energy is one of the most central human needs. Life without electrical energy is not imaginable. Nowadays Libya, similar to the other countries of the Middle East, uses oil and natural gas to produce its electrical energy needs. However, as these types of non-renewable energy sources will exhaust one day, it is very important to find alternative electrical energy sources like wind, sea waves, and solar energy. One of the great wealth that Libya has is the incredible distribution and amount of solar energy incident. Therefore, the significance of the investment in this source for the production of electrical energy by using the high efficiency photovoltaic generators becomes evident.

Normally power systems meet load growth demands through installation of centralized large generation plants, transmission lines and substations as well as distribution infrastructure. Figure 1.1 shows the traditional power delivery structure, from centralized generation to long distance transmission distribution. The generation station generates electricity at lower voltage level, generally 11 kV. This voltage is stepped up through a generation step up station. Stepped up voltage at the level of 220 kV or 400 kV is transmitted for long distances until the destination consumption areas. This power is then stepped down to different distribution levels according to consumers' needs. Solar generation is generally a small source of electric power generation ranging in size from less than a kW to tens of MW. PV sources are not generally part of the central power generation and are more suited to be installed near to the load, as shown, in the green distribution area in Figure 1.1.

Photovoltaic systems are widely used in different applications, from small cells in calculators that consume small amount of power to large scale PV plants that produce power in the range of many MW. Although there is a broad variety of PV applications, the main applications for PV systems are in the power generation on-board craft and in standalone systems in rural areas. In the last decades an important revolution in the use of grid-connected solar generators has been witnessed. The newly developed technologies encouraged consumers to start shifting toward the use of distributed energy resources like PV systems. Prices and initial installation costs of the PV systems have noticeably been decreased in the last 10 years especially with the exclusion of back-up batteries.

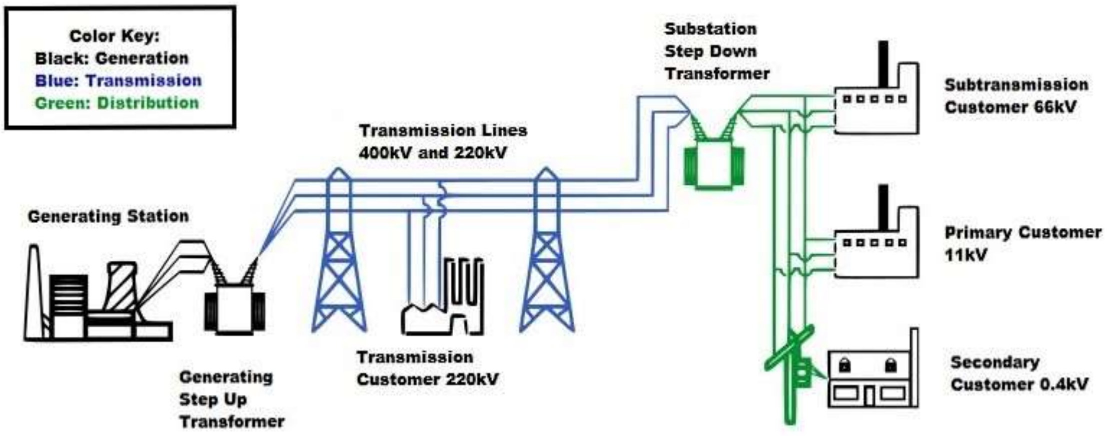

Figure 1.1: General power system topology (Condon, 2004)

Photovoltaic energy is one of the cleanest sources of renewable energy. The recent observations of the climatic alterations have encouraged the humanity for more investigation in the renewable resources of energy like solar. Although the technology was very costly in its beginnings, it has spread and has become very familiar and most used especially with the introduction of programs to encourage people to investigate in this technology. The use of distributed resources and especially PV systems in connection with power systems has many advantages such as (Steffel, et al., 2012):

- Voltage profile improvement.
- Voltage stability improvement for the whole system.
- Reactive power flow reduction.
- Power loss reduction.
- Pollution reduction.
- Maintenance cost reduction.

However, the use of individual solar applications or large scale PV generators can affect power systems and cause serious problems that need to be taken in consideration. For that reason, the penetration of distributed generation systems in the power systems has become one of the hottest topics of electrical power engineering. The variable nature of PV sources may cause serious power quality issues in the distribution systems. Such problems must be studied and mentioned preliminary to the installation of distributed generation system to avoid the failure of the systems. These problems or disadvantages can be summarized in the next few points (Coster et al., 2011; Steffel et al., 2012):

- Injection of harmonics due to the use of power inverters.
- The interruption of solar generation during night.
- The challenges of protection because of the bidirectional power flow.
- Over voltage of the systems.

In this work, the use of solar energy power station with a total capacity of 14 MW in the Libyan distribution station of Houn is studied. The study will include the effect of the solar power station on the stability of the distribution station. It will include the analysis of load flow, short circuit faults, system stability, and harmonics of the system after the installation of the solar station. The project was proposed by the Renewable Energy Authority of Libya (REAOL) to build a photovoltaic (PV) power plant. The power rating of this first grid-connected plant of Libya which will be near the city of Houn in the Jufra District is 14 MW. The project is expected to produce an annual net electricity of approximately 23,140 MWh. High technology PV modules, power electronic systems, transformers and protection devices will be employed in this plant. Measurement and communication equipment will also be used to ensure reliability and surveillance of the system. The geographical location of the proposed project activity is as shown in Figure 1.2. The town of Houn situates at the latitude of 29^{o} 08’ 52” N, and longitude of 16^{o} 00’ 57” E, at a distance of about 250 km from the coastal line and 700 km from the capital city of Libya. The total available area for the project is approximately 10 hectare. The plant is planned to be connected to the distribution substation of 66/11 kV near Houn station of 220 kV as explained in Appendix 1. The specifications of the solar panels that must be used as sited by the REAOL are shown in Table 1.1. The substation has 2 step down transformers 66/11 kV of 20 MVA each. The connection between the solar field and the 11 kV bus bar will be established through 7 step-up transformers of 3 MVA each. The voltage rating of these transformers is 0.4/11 kV and situated 100 m away from the field (UNFCCC, 2012). Figure 1.3 presents the schematic diagram of the connection between the solar system and the distribution grid through step-up transformers.

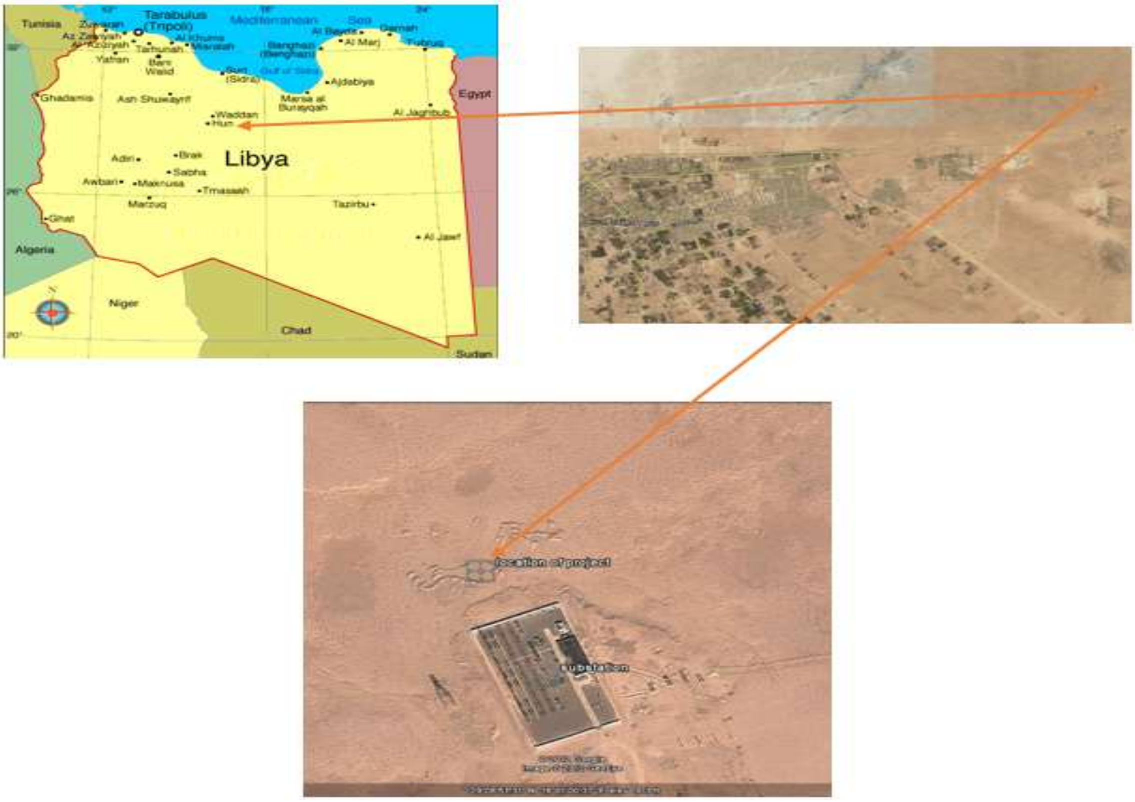

Figure 1.2: The location of the proposed project activity near the town of Houn, Jufra

Table 1.1: Technical specifications of PV modules to be used in Houn project

Parameter	Value
Cell type	Crystalline PV module
Power	Different power ratings: 230 – 245 Wp
Number of modules	~ 57,140 – 60,870
Module efficiency	14.1 – 15.1 %
Maximum rated current series	15 A
Power tolerance	+ / - 3 %
Maximum power voltage	29.4 – 30.7 V
Plant load factor	18.87 %

Figure 1.3: Schematic diagram of the connection of the solar station

1.2 Aim of the Thesis

Voltage control and stability are very critical for safe and reliable operation of power systems. They need to be taken in consideration during the generation, transmission and distribution levels of electric power. Voltage control for traditional power systems is well established. However, voltage control for distributed power systems is a rather new concept. Several researchers have been proposing new control algorithms to overcome the problems related to voltage regulation and stability so that renewable energy plants can be safely connected to national grids.

Libya is a country rich in solar energy and needs new power plants. Therefore it is expected that new solar energy projects will be carried out in near future, which means voltage stability and regulation problems should be studied before connecting these plants to existing networks.

The purpose of this work is to establish the analysis of the distributed solar generation that is planned in Houn in Libya. The analysis has the aim of determining the effect of installing 14 MW solar station connected to the distribution station of Houn. This analysis will focus on studying the voltage profile, voltage stability; short circuit faults, reactive power flow, and harmonic distortions due to the connection of the solar station to the distribution system at Houn. The study will discuss the general structure of the solar generation station and its components. The connection between the solar system and the power distribution station of Houn will also be discussed. A load flow and short circuit analysis of the studied systems will be performed in an attempt to obtain the optimal levels of voltage quality and stability of the system. In order to verify the feasibility and validity of the studied system, model of the distribution station combined and connected with the solar PV station will be built in ETAP software. Different analysis methods of load flow, short circuit, voltage stability, and harmonics are going to be analysed. Separately, modelling of the solar system will be discussed and studied to show the different parameters that affect the function of the solar cells. The model will be carried out using Matlab software and different operating conditions will be studied and discussed.

As a conclusion, the objectives of this study can be resumed in the next few points:

- To study the capability of solar generation systems in the load demand and power flow reduction at the distribution station level in Libya.
- To study the effect of connecting large scale commercial solar sources directly with the public grid. And to open the opportunity for future analysis of the techno-economic benefits of connecting large or small size solar projects to the Libyan National Grid.
- To inspect the consequences of grid connected solar systems on the voltage regulation levels in the public network in Libya and its participation in load reduction and stabilization of transmission systems.

1.3 Overview of the Thesis

In Chapter 2, a review of the existing literature on the topic is presented. In Chapter 3, discussion on the distributed generation systems is presented, the methodology followed in the thesis is described and the two simulation and analysis software programs are presented. In Chapter 4, the design and simulation of the grid connected plant are given. In Chapter 5, load flow, short circuit analysis, harmonic analysis and voltage profile studies are explained. In Chapter 6, results are discussed. In Chapter 7, the thesis is concluded and future work is discussed.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The Energy is defined conventionally as the capability of work production. The origin of the word energy comes from the ancient Greek. It is a compound term from the two Greek word “en” and “ergon”. The terms mean something that can work in the body. Scientists define the energy as the ability or capacity to perform work. The famous physician Max Planck has given a more accurate and scientific definition of the energy. He defined the energy as: “The ability of a system to produce outside activity” (Tzanakis, 2006).

Electrical energy has been the main source of energy for humanity during the last two hundred years. However, this energy is produced based on the burn of fossil fuels like gas and petrol oil. These fuels suffer from two disadvantages that pushed toward the investigation in new natural resources; these are the environment pollution and the non-renewable nature of these fuels. Scientists have focused on the investigation of renewable energy resource for electrical energy production. In the last decades, different technologies were developed to produce green energy. One of the main developed technologies was the solar energy technology. Throughout the course of its development, renewable solar energy has witnessed different revolutions in terms of power production, back-up and efficiency. Recently, solar or renewable energy systems became able to be connected directly to the electric grids. This allowed these systems to support the existing power generation systems directly with the minimum costs. They share now in a great amount of power production all around the world. However, these advantages were combined with some drawbacks concerning the effects of distributed generation systems which a term is describing all power sources that are connected to the main sources at any point- connected to the existing power systems. These drawbacks concern mainly the lack of stability, voltage regulation, and harmonic distortions caused by distributed generation systems.

2.2 Literature Review

Different researches were pointed toward the study and analysis of these drawbacks and different solutions to overcome their effects. (Coster, Myrzik, Kruimer, & Kling, 2011) Has discussed the effects of the Distributed Generation (DG) systems on the power grid stability as reported by Dutch distribution system operators. The authors discussed the different opportunities to handle network planning challenges in the existence of distributed sources. Paper demonstrated that voltage control issues and protection errors are rarely happening in compact power systems. A study of the issues combined with the use of distributed generation systems on the power grids was presented in (Therien, 2010). The author discussed different issues like voltage regulation, protection system faults, harmonics, power flow, and intermittency of power systems with DG. A case study of a grid connected solar system was presented to address the different issues related to the DG. In (Nazari & Ilic, 2008) different problems related to the use of distributed generation systems on power grids were discussed.

The effects of the location of DG and technology on the stability of the power system voltage were discussed in (Angelim & Affonso, 2016). In the paper, three distributed generation technologies were discussed and experimented. In addition, different DG locations were used and the effects on the stability of the power systems were discussed. An analysing method of the financial value of the DG systems was proposed and discussed in (Ault, McDonald, & Burt, 2003). The authors discussed different factors and issues concerning the DG systems. The developed function is helpful in determining the DG impact on the network, business, and the penetration of system. A case study of the United Kingdom distributed generation system was also discussed in this work. Line losses reduction due to the use of DG systems was discussed by (Dang, Yu, Dang, & Han, 2011). The work presented the study of radial feeder and distributed generator system under various load conditions. Results of losses reduction were presented and discussed. Impact of distributed generation on the dispatch of power systems was discussed in (Liu, Zhang, Zhou, & Zhong, 2012). Different renewable energy distributed generators were discussed and their impact was studied.

A study of the investigation of hybrid distributed generation system of wind, PV, and hydro power sources was presented by (Liu, Zhang, Zhou, & Zhong, 2012). The dynamic impact of these DG systems was analysed and presented (Olulope, Folly, & Venayagamoorthy, 2013). Different issues related to the placement of distributed generators into power grid were discussed in (Yadav & Srivastava, 2014). Review of the most DG technologies also was presented in this paper work. The work in (Zhao, Li, & Liu, 2014) discussed the analysis of distributed generators and the optimal design techniques of these generators.

CHAPTER 3
DISTRIBUTED GENERATION SYSTEMS

3.1 Introduction

Life cannot be imagined to have the same quality it is having without electricity. It is so important for life and human civilization. It is the source of light that clear the darkness, it is the way how we keep our foods in fridges, and it is the mean we use to operate our air conditioners, electricity is the invention that gives our life its comfort. None of our basic needs for comfort life can be achieved without electricity. TV's, cameras, personal computers, digital processors, phones, cellular phones, radio, modern cars, home appliances, and many other electronic devices could not happen to work without electricity. Based on reports of the Energy Information Administration (EIA); until 2030, the electrical energy is expected to remain the fastest developing form of energy worldwide (Dorian, Franssen, & Simbeck, 2006). The traditional resources used for electrical energy production have dangerous consequences on the environment especially under the actual and predicted electrical consumption rates.

The nature and sources of electricity is well known and understood. This knowledge allows various uses of electrical energy to be useful. Nowadays, the integration of clean electrical energy sources into the actual infrastructures is growing quickly; governments as well as environment organizations are paying more attention for the subject. However, governments need to do more efforts to increase the chances of renewable resources to be more competitive.

New policies and technologies aim to decrease environment pollution due to energy production by finding new clean, renewable, and low cost resources. Renewable resources like solar, wind, sea waves, and many other energy sources are nowadays more and more investigated. The use and development of these renewable clean free energy sources has led to the use of Distributed Generation systems DG.

3.2 Electric Power Networks vs. Distributed Generation

An electrical grid is an interrelated network of electrical components distributing electrical power between producers and clients. Power systems in our days are very complex grids that can be essentially categorized into four main groups: generation system, transmission system, distribution system, and different loads (Paolone & Cherkaoui). Figure 3.1 shows a general structure of the electric power grid. In the generation system, electricity is mostly produced by huge centrifuged alternators located in generation stations. The electrical power is usually generated under the level of 11 kV or 30 kV.

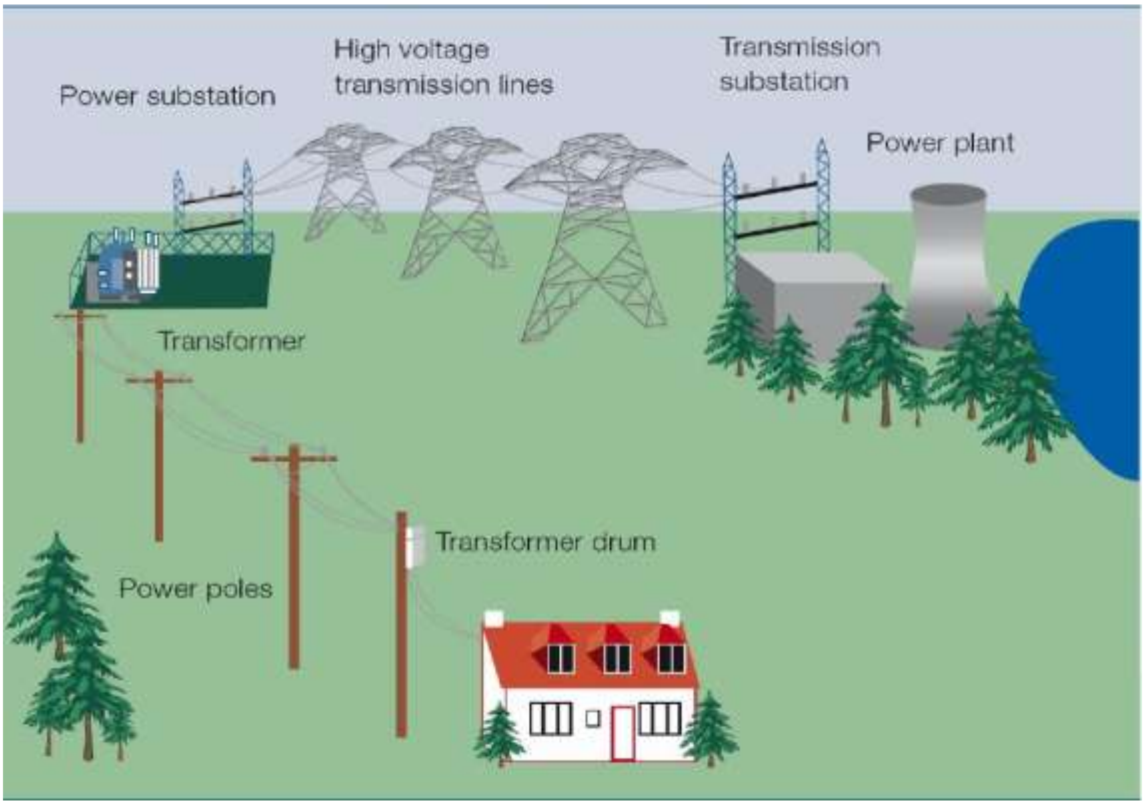

Figure 3.1: Structure of the electric power grid (Paolone & Cherkaoui)

Overhead transmission networks are responsible for the transmission of electrical power between different parts of the system. They transfer energy from main stations to distribution stations and between generation stations as well. The distribution grid can be either low or medium voltage distribution network. It uses transformers to step down high or extra high voltages to low level or medium level voltages. Transformers in the distribution unit feed electrical power to a number of secondary feeders whom consumer is connected to. Customers are connected to feeders either directly or through transformers to step down the voltage to a suitable level.

Distributed generation (DG) term is used to describe the use of group of interconnected small size power generators. These generators produce low voltage level electricity by usually using alternative fuel. The distributed generators are constructed such that they can be connected directly to the nearest available network and loads. A general description of a power system including distributed generation systems is present in Figure 3.2. Distributed generation is still used and considered as spare or emergency endorsement source of power and restricted to a limited part of grid tied sources.

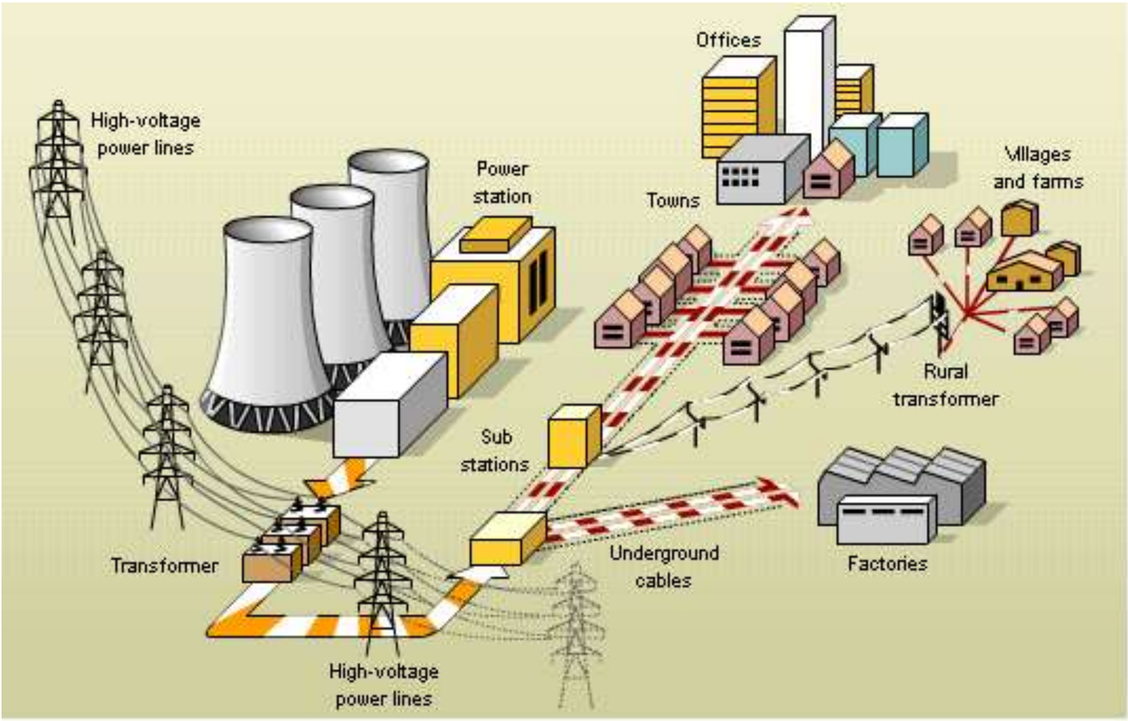

Figure 3.2: A power system with distributed generation (The grid as it is today, 2016)

DG systems are less used in many countries where prices of oil and natural gas are low, or where regulatory batteries are used. However, widespread of DG is being reconsidered due to the changes in relation between centralized and distributed power generation; in addition to the excessive use of natural gas and restrictions on the new transmission lines, and the new technologies that are implemented in the DG systems (The grid as it is today, 2016).

3.2.1 History of distributed generation

In 80s of the 19th century, the Pearl Street electric system that was created by Edison and served Wall Street and the near buildings can be considered as a distributed generation system. The same generation structure continued until the end of nineteenth century in the United State of America (USA) and around the world. Such systems served few small areas by direct current sources. Over more, individual factories were served individually by systems that supplied electric power with heating in Combined Heat and Power (CHP) systems (Hughes, 1993). The main struggle of the distributed Direct Current (DC) system was the huge amount of losses under low voltages. The transmission of electricity under low voltages for long distance causes a lot of power losses. As a result, other competitors supported the use of alternating current based systems. In the Alternative Current (AC) systems larger and spread out areas can be served easily. This was possible thanks for the invention of power transformers.

With technological developments in alternating current systems, more economical investments in large and centralized power systems were required. These centralized high load systems were built in huge networks. They have the ability to spread out in wide areas providing consistent services. Unfortunately, storage of large amounts of electrical power is very difficult; this implies the requirement that that demand and supply are balanced all the time. For more efficient use of the transmission and generation systems, different customers need to stabilize their consumption through days and seasons. The grouping of different industrial, commercial, and residential loads helps achieving smooth demand profile the maximum possible. This goal implies the service to be extended over larger areas and the interconnection of multiple areas together. Another motivation for the use of extended electrical services network was the availability of resources of energy. Mines and water hydraulic energy resources are mostly located far from centres of industrial and residential zones. The two possible choices were to transport fuel to the distributed power stations or to transmit the electrical energy from the places of energy resources using high voltage systems. By the 1930s, industrial states had established huge electrical grids, joining together around the steam turbine generation system. Smaller generation systems were then naturally melted and shut down. An increase from 80 MW generation station in 1920 to 600 MW unit in 1960 and then to 1400 MW in 1980 have been witnessed. The idea to return back to the distributed generation in the 20th century came after the petrol shocks in the 1970s and the need to increase the systems efficiencies. The efficiency of large scale economic generation system was limited to 33 % of the used energy (Nishida, et al., 2003).

Evolution of small scale distributed generation has led to important reduction in cost, increased reliability, and less pollution emissions of different turbines, fuel cells, engines, and solar panels. On another side, particularly in the past two decades; a great evolution in the management, monitoring, surveillance, and control systems has happened (Hamlyn, Cheung, Lin, Cungang, & Cheung, 2008) & (Lin, et al., 2009).

3.2.2 Types of distributed generation technologies

Actually, types of distributed generators extend to cover all types of power generation methods. These types include the traditional generators like oil and gas generators in addition to recently developed technologies like micro turbines, solar plants, wind farms and other sources of electrical energy.

3.2.2.1 Gas turbines

Gas turbines or power generation based on gas turbine technologies is common with very large generation capacities. Sizes of gas turbines vary from small gas turbines of 500 kW and reaching the capacity of huge gas stations of 50 MW. Gas turbines are very common due to low costs of their maintenance in addition to higher efficiency achieved due to the high ability for heat recovery. Gas turbines are the most favourite type for almost all distributed generation requirements (Davis, 2002).

3.2.2.2 Micro turbines

The same functional cycle of conventional turbines is implemented in micro turbines. However, micro turbines are commercially less developed compared to the mentioned conventional turbines. The development of micro turbine has started from the design of fast and small turbines. These turbines rotate at high speeds of up to 100000 cycles per minute. Their components like nozzles and burners are more and more compressed. Generally, the sizes of micro turbines range between 30 and 250 kW (Pilavachi, 2002). Micro turbines require less maintenance costs and use an air cooling system. However, micro turbines are a little bit less efficient than their conventional large sized gas turbines because of low functional temperatures.

3.2.2.3 Engines

The technology of internal combustion engines is a well-known and conventional engines structure. These engines are fed by natural or diesel oil. Natural gas engines are using spark ignition while diesel oil engines implement a compression ignition technology to fire. The energy of combustion is divided into three main parts; the first part is the mechanical energy that is converted into electricity with the ratio of 26-39 %; the second part is a useful heat that can be used for different goals and represent 46-60 %; the last part represents different losses of the engine due to radiations and exhaust gas losses in addition to gear box losses.

Power production engines are of the size of 1 MW typically. They are more and more used in distributed generation systems. They are increasingly being used in combined heat power for peak load or standby needs in different applications (Daley, ASCO Power Technol., & Siciliano, 2003).

3.2.2.4 Fuel cells

Fuel cells (FC) produce electromechanical energy out of chemical energy without the need for any thermal energy phase. Fuel cells have very high efficiency compared to other engines. In the fuel cell the hydrogen and the oxygen are fed to the cell. Chemical reactions combining hydrogen and oxygen molecules producing water and energy take place in the fuel cell. The oxidation of hydrogen to produce water creates equilibrium where electrons flow through an external electric structure providing energy. Unlike normal batteries, fuel cells can provide continuous energy provided with the two main functional elements which are oxygen and hydrogen. However, the direct oxidation of natural gas is still impossible which implies the conversion between different materials. This conversion is less efficient and still need more scientific researches and investigations.

Fuel cells have their own advantages including high power efficiency and performance under variable loading values. Their emissions are very small and they cause no noise. The main disadvantage of the use of fuel cells is as mentioned above the high initial costs.

3.2.2.5 Wind turbines

Wind power generation existed since long time and it can be considered as distributed generation sources if it is located near the demand source. Generally, areas with high and stable wind speed over the year can have wind turbine farms. The annual capacity factor of a good wind turbine area is 20-40 %. Typical wind turbine can provide its services for more than 20 years with six month interval maintenance. Rotating axe of the wind turbine transfer the mechanical energy from the wind to a gear box connected to an electrical generator. Normal wind turbine sizes range from few hundreds of watts for residential needs to huge turbines with the power of over 5 MW (Spera, 2009). The main disadvantages of wind power reside in the initial costs in addition to the intermittent nature of the energy source.

3.2.2.6 Photovoltaic solar cell

Solar cells have the ability to produce electricity directly from the sunlight by taking advantage of photovoltaic effect (Williams & Ogden, 1989). Solar cells are constructed totally of fixed parts; there are no rotating or moving parts within the solar cell. Typical photovoltaic cell can produce a maximum of 2 W and about 1.5 V. For commercial and technical reasons, multiple cells are normally grouped in series and parallel combinations to produce more power and higher voltage levels suitable to be used in different applications. The group of multiple series and parallel combined cells is called PV module.

3.3 Photovoltaic Systems

PV system is a system able to convert energy from the sun directly into electrical energy. The main part of the solar system is the solar cell combined in groups to produce solar modules and arrays. Solar systems are used to produce energy to be used in feeding different electrical loads. Solar cells produce DC electrical energy that can be used directly in feeding some types of DC loads; or converted through different converter types to feed other DC and AC loads. Solar systems can be connected together to form larger systems or even can be combined with public grids to exchange their power with. The general structure of the solar system is composed of a DC-DC converter, DC-AC inverter, battery system, controllers, protection devices, in addition to some auxiliary power sources and the loads. Recently, batteries in solar systems became an optional part in the grid tied solar systems; these systems exchange the energy directly with the electric grid with the need to locally stock it. By consequence, costs of grid tied solar systems have reduced to half the initial costs.

Solar systems can be found in different forms and sizes from residential application size of less than 10 kW to medium size of 10-100 kW, and other large systems with production capacity of more than 100 kW. These systems are either used as standalone systems, hybrid systems in combination with other energy sources, or connected directly to the power grid to exchange energy interactively.

Commercial solar modules produce the energy from the sun with an approximate energy efficiency of 10-20 %. This means that 10-20 % of the solar energy falling on the module is being captured and converted to electricity. Scientists and research laboratories are making huge efforts to increase these efficiency ratios and decrease the costs of solar applications. As a result for these efforts appeared the solar cells or Concentrated Photovoltaic Cells (CPV). These systems focus solar energy on multi-junction solar cell to increase cell's efficiency. In CPV systems, the solar cells are fit in concentrating collectors. Concentrating collectors use mirrors or lens to concentrate the light of the sun on the solar cells. Some special tracking systems are used with CPV systems to ensure continuous tracking of the sunlight. The main advantage of CPV systems is the very high efficiency achieved. Some references concluded that CPV can produce an energy efficiency of up to 50 % (Luque, 2011). However, the need for special sophisticated tracking systems is one of CPV's costs.

3.3.1 Advantages and drawbacks of solar energy

Solar energy has its own advantages and disadvantages, the advantages of solar energy systems can be resumed by (Deendayal, 2012):

1- Solar energy is available mostly everywhere and solar systems are flexible; they can be used in different manners and can be easily implemented.
2- Solar energy is available when its need is maximum, the peak demand happens in midday when the solar energy produces its maximum energy.
3- Solar structures can work for long periods of time with the minimum maintenance and operating costs.
4- Solar energy is clean and environment friend, it is safe and cause minimal pollution.
5- Solar systems are modular; any extra power generation can be added easily with no extra needs or expenses.
6- Solar systems are the perfect choice to be implemented in remote areas as they are cheap and reliable compared to the creation of public grids infrastructures.
7- The main and most important advantage of solar systems is that their source of energy is infinite, charge free, and accessible all the time.

Although solar energy is clean and cheap source of power, it still presents some disadvantages. The main disadvantages of solar energy are:

1- Solar energy needs to be stocked in batteries especially in remote areas; that amplify the expenses and imply extra maintenance costs.
2- The most important drawback of solar energy resides in its initial costs if compared to other large scale electrical power sources. However, in the last 10 years the costs of the solar energy have decreased to about 50 % due to the use of new technologies in their production and development.
3- Another drawback of solar systems is the variable output power that is a function of the solar irradiation and temperature. Areas that have short day times or covered by clouds for long periods will produce very low amounts of energy. Over more, the efficiency of solar arrays is less than 20 %; this means more and more reduction in power generation.

3.4 Energy Potential in Libya

Libya is one of the main exporting countries in Africa and the world with 6 million populations spread over its area of 1.75 million square kilometres. Weather in Libya is Middle Eastern hot in summer and warm in winter. Like most of Middle East countries, Libya has high average solar irradiation that makes it a great solar energy potential. The daily average irradiation varies between 7.1 kWp and 8.1 kWp (Mondal & Denich, 2009). Figure 3.3 presents the solar map of Libya showing the solar energy distribution in the Libyan territories. Until 2011, Libya had a large electric grid with big and well-arranged infrastructures. 12000 km of high voltage networks combined with 12500 km of medium voltage grid in addition to 7000 km of low voltage grid constructed the main nerves of the Libyan national grid (Hassan, Nafeh, H.Fahmy, & El-Sayed, 2010). However, after the war in 2011 the situation in Libya has changed and national electric grid became unable to feed the country with the required energy. Many high and medium voltage transmission lines were destroyed during and after the war and couldn’t serve the distribution stations. Power consumption in Libya is in continuous growth. Load profile in Libya during the years 2003-2012 is presented in Figure 3.4. It shows a constant annual increase in the consumption during this period except for 2011 where political and civil was events have affected all the fields of the life including the energy consumption and production. Many generation and distribution station went off service during the war that has a great effect on the overall energy sector. Figure 3.5 demonstrates the growth in Libyan electricity generation during the period extending from 2003 until the year 2012. The figure shows that the energy production was growing in a fixed rate of approximately 7.6 % between 2003 and 2010. However, the energy production sector has faced some troubles during the year 2011 as a result of the political and security instability. However, during the year 2012 the energy production sector has recovered its normal growth rate and the annual production reached the value of 35000 GWh.

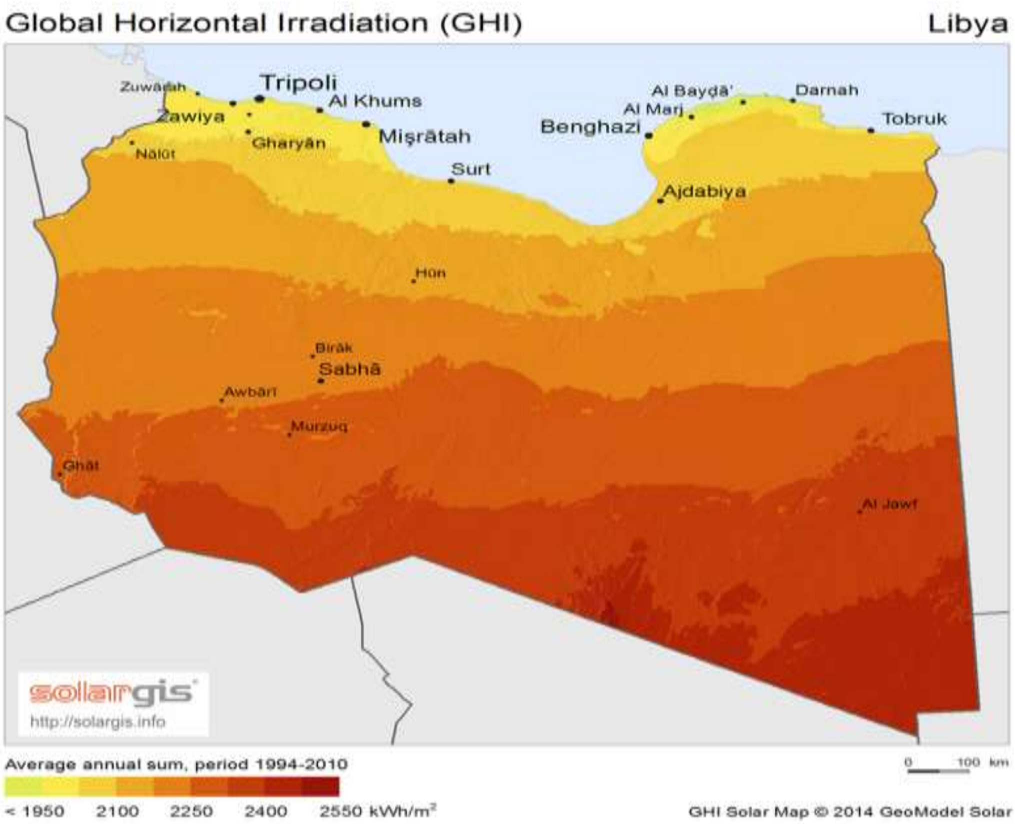

Figure 3.3: Solar map in Libya (Solargis, 2016)

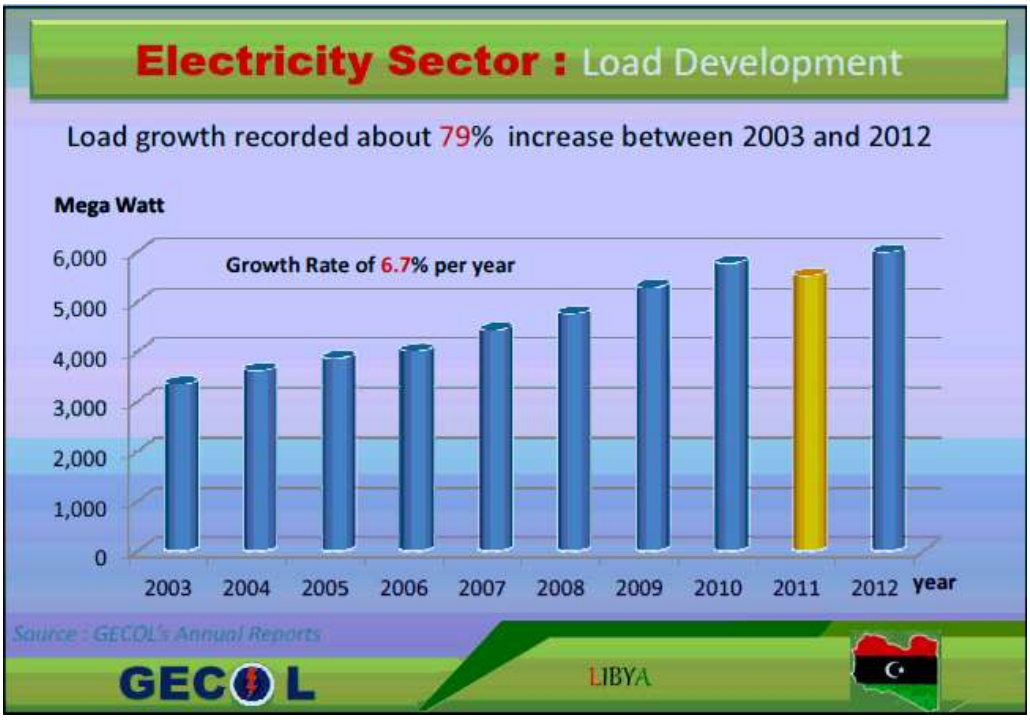

Figure 3.4: Load growth in Libya 2003-2012 (Ibrahim & Khalifa, 2003)

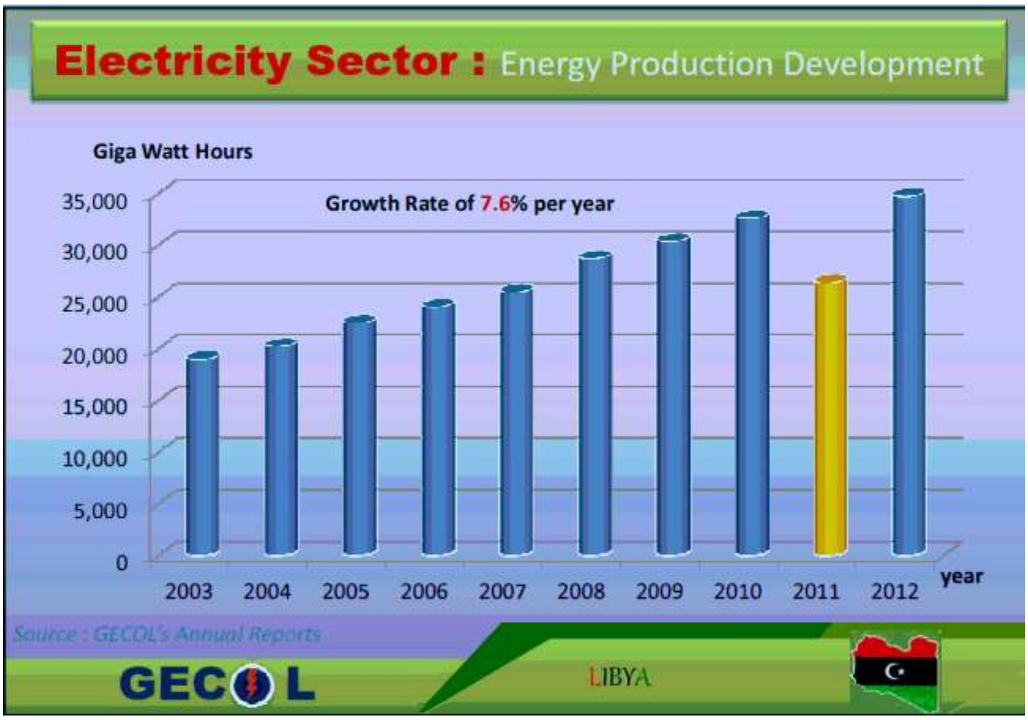

Figure 3.5: Electricity production growth in Libya between 2003 and 2012 (Ibrahim & Khalifa, 2003)

3.4.1 Photovoltaic applications in Libya

The investigation in solar potential in Libya is still weak and need more plans and governmental support. There exist four main applications of solar energy sector in Libya; these are solar energy for communication systems, cathodic protection, rural electrification and water pumping.

3.4.1.1 PV system for Libyan microwave communication networks

The Libyan communication networks consist of about five hundred stations of repeaters. In the end of the year 1997, 9 rural stations were driven using solar systems. The approximate total peak power demand was about 10.5 kW peak. Among the 9 solar energy powered communication stations, four stations solar systems are still working after more than 30 years of service. The batteries of the system were replaced many times with an average life time of 8 years. On the other hand, the other stations that use diesel generators have faced many struggles due to the lack of diesel and maintenance. Problems include continuous interruption in the communication services and stolen fuel and engine parts. One of the most famous cases was in Zalaf station that went of service for 17 days during the year 1997 (saleh, 2006). Nowadays, more than 80 communication stations in Libya are using solar energy to obtain their power needs. This increase in the number of solar energy powered stations is due to the success of solar energy applications and the reductions in the costs of solar applications. Figure 3.6 shows the relation between the number of diesel based communication stations compared to those powered using solar energy sources between the years 1980 and 2003 (Ibrahim & Khalifa, 2003).

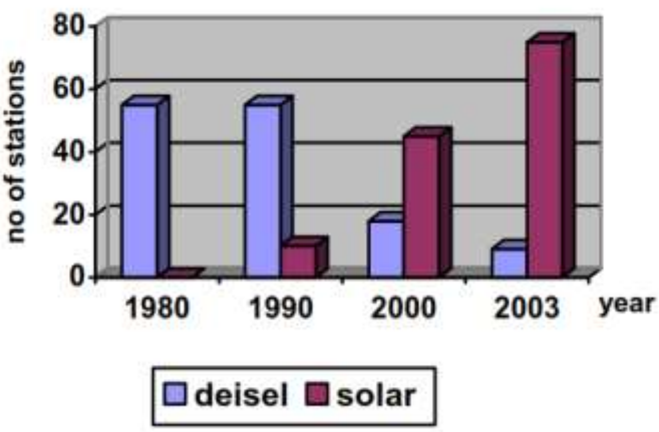

Figure 3.6: PV and diesel stations in the communication network
(Ibrahim & Khalifa, 2003)

3.4.1.2 Solar energy for cathodic protection

The Cathodic Protection (CP) stations are usually situated at large distances from public networks; this signifies that it's impossible practically to use the public grids in feeding these stations with their power requirements. A cathodic protection station requires up to 15 kWh daily. Solar systems offer a perfect and reliable source of energy for CP stations. Solar systems must be chosen to fit best the load profile of a CP station. Solar systems for CP stations can be set up in any place near to the station to convert directly the sun energy to the required type of energy need by the station. For reasons related to maintenance of diesel generators, the need for continuous supply of fuel. In addition to the lack of power grids that solar resources were chosen as the best alternative for CP station empowerment (Al-Jadi, EKhlat, & Krema, 2012). The first system used in CP stations in Libya was set up into service in 1976, CP stations comes the next in the total accumulated solar power in Libya after communication systems. By the year 2005 over than 300 CP stations were powered using solar energy systems in Libya. The total set up systems produced about 450kW peak (Al-Jadi, EKhlat, & Krema, 2012).

3.4.1.3 Rural electrification with PV systems

The main problems that face the planners of power distribution systems in different countries can be concluded in low population, and distance from the existing networks. The extension of high voltage lines to cover rural areas through the desert is a very costly process and needs special budgets. In the less populated countries of the developing countries, just main cities are empowered through the public network. The electrification of rural areas is accomplished by the use of other resources available within the possibilities of the governments.

As an example, in a 200 citizen's village located at a distance of fifteen kilometres from the distribution station in Libya, and considering an average annual individual consumption of 1000 kWh, the village will need 200 MWh per year. A price of 0.75 $/kWh will be charged to be able to provide such a village with electricity from this station without loss which is 10 times the actual national tariff in Libya. For such reason, a rural area was accepted to be a place having 200 citizens and situated at a distance more than 5 km from the low voltage grid (Al-Jadi, EKhlat, & Krema, 2012).

The Libyan national plan to cover all the cover all the remote areas by electricity is to electrify all distributed houses and villages in addition to water pumping units. A project for the electrification of 10 villages was presented earlier to be established as a first step in this plan (Al-Jadi, EKhlat, & Krema, 2012). Some of these villages are:

a) Mrair Gabis village.
b) Swaihat village.
c) Intlat village.
d) Beer al-Merhan village.
e) Wadi Marsit village.
f) Intlat village.

The first works of installation of solar systems in this project was initiated in 2003. The total number of installed projects by the General Electrical Company of Libya (GECOL) was 340 with capacity of 220 kW peak. Projects that are installed by the Center of Solar Energy Studies (CSES) and the Saharian Center is about 125 kW peak divided on 150 individual projects. The applications were as following:

- 380 projects for isolated houses.
- 30 projects for police stations.
- 100 projects for street lighting.

3.4.1.4 PV systems for water pumping

Water pumping is one of the most suitable applications of solar energy systems. The variable nature of the produced solar power is acceptable in water pumping applications. The project of water pumping included the installation of 35 individual solar projects. The total power generated by these projects is 96 kWp. Table 3.1 shows the total solar power generation for different applications in Libya until the year 2014 (Al-Jadi, EKhlat, & Krema, 2012).

Table 3.1: The total installed PV capacity in Libya

APPLICATIONS	NUMBER OF SYSTEMS	TOTAL POWER [KWP]
COMMUNICATION	100	420
CATHODIC PROTECTION	300	540
RURAL ELECTRIFICATION	510	345
WATER PUMPING	40	110
TOTAL	**950**	**1415**

3.5 Methodology of the Work

In this research, a large scale grid connected photovoltaic system is designed with 14 MW installed capacity. Details of the design include the total number of PV modules, inverter, cables and circuit breakers. In this study, the main system design is undertaken based on the amount of generated power. The generated output power from the PV system is at 0.4 kV voltage level. It is stepped up through 0.4 kV to 11 kV bus-bars by 7 step-up distribution transformers with 3 MVA rating each. The output of the power transformer is synchronized to the national grid at Houn substation less than 100 m of the supply point. To achieve the power ratings, 7 arrays with 2 MW for each array resulting at 14 MW generated power were adopted.

Results and objectives of this study presented in three main areas. Detailed design section, Matlab/Simulink PV Simulation, and power analysis studies using ETAP. Design section starts with considering the methods of connection of solar arrays and their connection with the inverter and power transformers, cables selection, inverter selection, and protective devices selection. Load flow, short circuit, harmonics and voltage stability studies were carried out. The results of power flow, busses voltages, busses angles and line losses were compared. Flow chart of the methodology is depicted below in Figure 3.7.

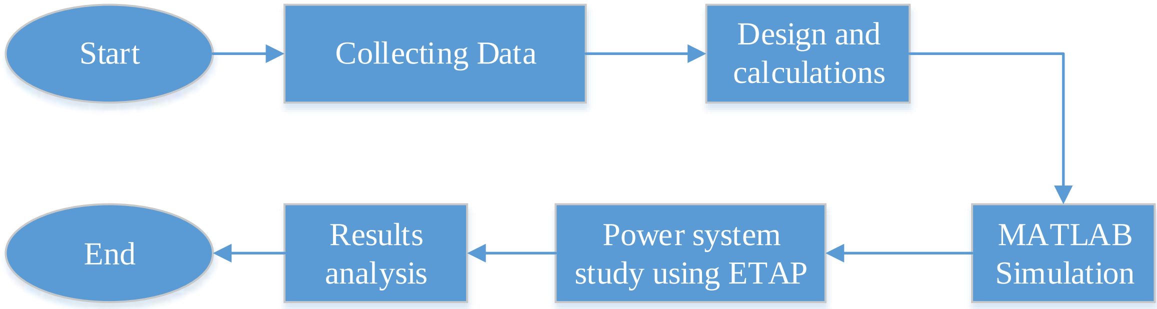

Figure 3.7: Flow chart of the station design and analysis process

3.6 Modelling and Analysis Software

In this work, two software packages have been used which are:

3.6.1 MATLAB / SIMULINK (version 7.8.0.347 (R2009a))

The Matlab is a high level powerful programming language dedicated for technical processing and mathematics purposes, it has an easy to use and manipulate user interface. Matlab environment presents mathematical problems and solutions simple and familiar mathematical notation. Matlab has a very powerful graphical user interface called Simulink. Simulink is used to build easily models for different systems. The interactive graphical environment of Simulink simplified the process of modelling processes or systems, removing all necessity of writing differential equations in programming languages (MathWorks, 2016).

3.6.2 ETAP (version 12.6.0H)

ETAP is the most wide-ranging analysis software that is designed especially to design and apply tests of power systems. ETAP program can use real data obtained from normal operation of the systems to perform offline data analysis, simulation, energy management, and load control. The name ETAP stands for (Electrical Transient Analyzer Program). It is designed to be used by engineers to perform different tasks of power systems analysis for different areas of industries in a one package.

CHAPTER 4
DESIGN AND SIMULATION OF GRID CONNECTED PV SYSTEM FOR LIBYAN NATIONAL GRID

4.1 Introduction

In this chapter, the details of the design and calculations of 14 MW PV integrated to the Libyan national grid at Houn city which is the capital of the Jufra District in Libya will be presented. Also, mathematical modelling of the PV panels used in the design will be discussed and presented; Matlab simulations of the panels will also be discussed and presented in this chapter.

4.2 Design Procedure of the PV Station

This section introduces the design procedure before the integration of solar PV power system into an existing grid with power generation of 14 MW. The main system design is undertaken based on the amount of generated power (14 MW). The generated voltage is 0.4 kV and it will be stepped up to 66 kV. It is stepped up through two stages:

- First stage: voltage step-up from 0.4 kV to 11 kV by seven step-up distribution transformers with 3 MVA rating each.

- Second stage: voltage step-up from 11 kV to 66 kV by two step-up power transformers with 12.5 MVA rating.

The output voltage of the power transformer is synchronized to the national grid at Houn main substation. To achieve the power ratings, 7 PV arrays with 2 MW for each array resulting at 14 MW generated power will be used.

PV modules must be selected based on some criterions related to their efficiency, price, warranty, life period, and atmospheric conditions. The selection must take these considerations in account in order to guarantee the best performance, highest benefit, reliability, at suitable prices. The first decision is to choose between mono-crystalline and poly-crystalline modules. The choice must consider the price and efficiency as the first criterions as the other criterions are approximately the same. Generally, the prices of poly-crystalline are more expensive than the mono-crystalline panels. However, the efficiency in poly crystalline modules is a little better than mono crystalline panels. Due to the high costs of the project as the project needs a huge number of PV panels to generate the required power of 14 MW. The Renewable Energy Authority of Libya “REAOL” decided to use mono crystalline panels. Suniva ART245-60 modules of 240 Wp solar panels are going to be used in the project. ART245-60 module is a well-known robust solar cell’s type that is designed to be used in grid tied solar projects and power stations. The characteristics of the ART245-60 are taken under STC “Standard Test Conditions” in laboratory environment. The standard conditions are 1000W/m^2 irradiation, 25°C, and 1.5 solar spectrum air mass. Basic features of the used modules are presented in Table 4.1 while the detailed data sheet of the module is presented in Appendix 2 (Suniva, 2010).

Table 4.1: Basic features of the discussed PV modules

Maximum power	240 W
Voltage @ maximum power point	30.9 V
Current @ maximum power point	7.95
Open circuit voltage	37.4
Short circuit current	8.44
Cells per module	60
β (Voltage de-rating factor (V_{oc} % / °C))	-0.332
α (Current de-rating factor (I_{sc} % / °C))	0.035
γ (Power de-rating factor (P_{max} % / °C))	-0.465

4.2.1 Design and selection of grid tied inverter

Inverter is a power electronic device used to invert/convert electrical energy from DC to AC. The inverter is actually bi-directional device; the power conversion is achieved from AC to DC or from DC to AC. However, it is mainly used as an AC generator (Rashid, 2001). The DC side of the inverter is fed from a battery or a group of batteries while the AC side can be connected directly or via a special transformer to increase the voltage level and improve the quality of the generated voltage. Inverters are used in UPS systems, static compensators, active filters, flexible alternative current transmission systems (FACTS), and many other applications (Rashid, 2001). The development of power electronic technologies has led to a great evolution in the voltage source inverters topologies and control schemes. Recently, synchronised or grid connected inverters are widely spread and used in renewable energy applications. Such inverters has the ability to synchronise there output voltage and current with the grid's voltage. They can be directly connected to existing power grid and interchange energy with the latter. Grid connected inverters have greatly decreased the costs of solar and wind energy systems as they reduced the need for batteries to backup generated energy. Instead, generated energy is being fed directly to the grid that is considered as a huge battery for the power system.

Two types of inverters can be used in large scale projects; these are multiple string inverter and central inverter. Multi string inverter topology is presented in Figure 4.1-a. Each group of panels or strings are connected together and fed to a suitable DC-AC inverter. The group of inverters are then connected individually and separately to the grid. The main advantage of this topology is the use of small size and rating inverters instead of using one large inverter in central topology. It also requires less maintenance in general than the other topology. The failure of one inverter in a string system causes the failure of a part of the system and not the whole system. Over more, the maintenance required will be considered for that one inverter and not for the whole system. However, the initial cost of string inverter based system is higher than the central inverter. String inverters are still new topologies and not used too much in large scale stations. One more advantage of the string inverter is that it can be connected with strings with different angles and different voltage levels. Central inverters are the most used in power stations. Figure 4.1-b shows the topology of the central inverter. Multiple PV strings are combined in a one DC box out of which one connection is fed to a high rated inverter. The DC connection of multiple strings implies that their tilt angle and generated power are exactly the same. Central inverter requires less space and less initial costs compared to string inverters. However, the failure of the inverter causes the failure of the whole system (Cenergypower, 2014).

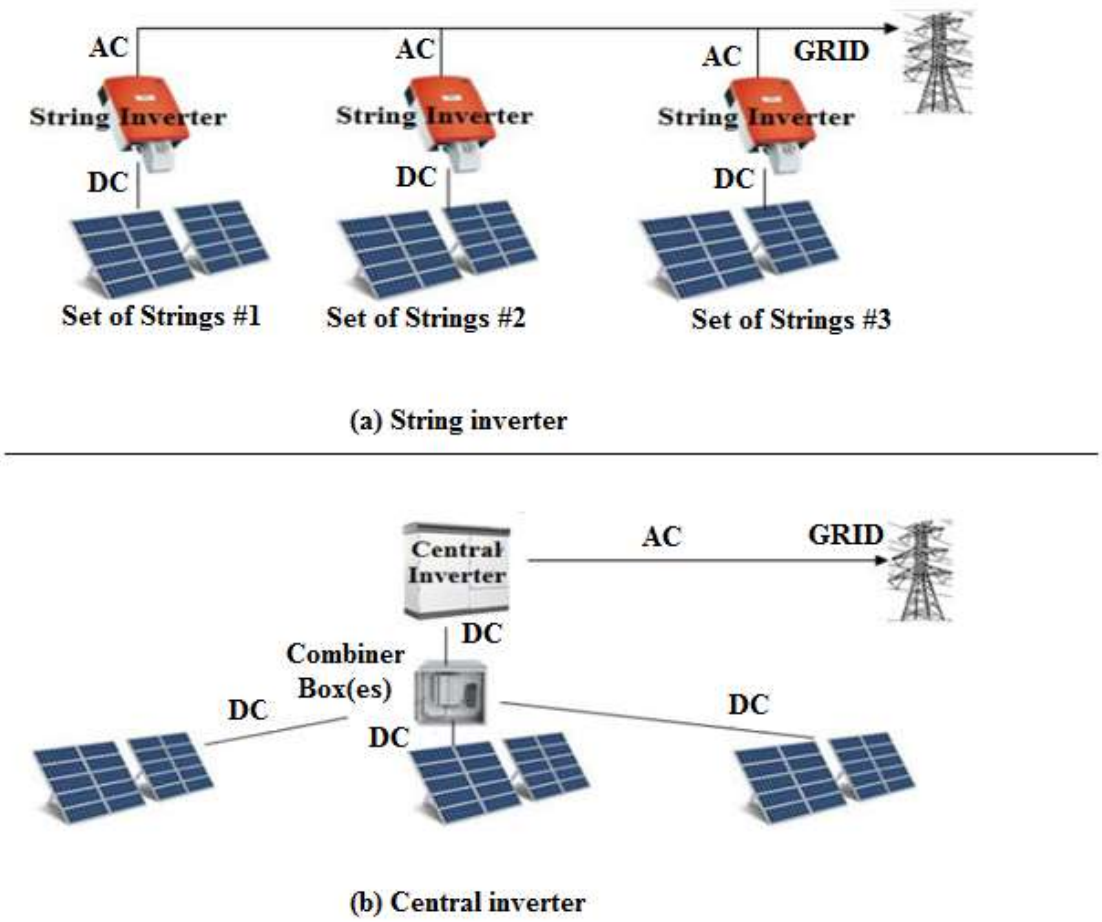

Figure 4.1: **(a) -** String inverter a vs. (**b) -** Central inverter (Cenergypower, 2014)

Due to the low initial costs and the familiarity of central inverter in similar applications as it is used widely all over the world in similar applications, central inverter has been chosen to be implemented in this work. Details of the design and sizing of the system are going to be discussed in the next sections of this chapter.

4.2.1.1 Design of the central inverter

The aim of the present study is to design a large scale grid connected PV generator. The design must take different rating and power calculations in consideration to avoid future failures and problems as much as possible. The system is going to be connected to the Houn station in the Jufra district. The capacity of the solar system is decided to be 14 MW of mono crystalline solar panels. The design needs to consider the maximum input voltage for the inverter to find the maximum series strings or modules. Also, the maximum current rating of the inverter is used to decide the parallel strings that are going to be fed. Cables sizes also must consider the current rating of the strings. Central inverters of 1 MW rating from ABB were chosen to be used in the project. Total of 14 inverters are going to be connected and used in the system. Central inverter PVS800-57-1000 kW-C model is used. Main features of this inverter’s model are presented in Table 4.2 while the documentation is provided in Appendix 3 (ABB, 2014). To accomplish the design task of the project, the total power was divided on seven fields. Each field has a power capacity of 2 MW. The design considers the calculations for one field and then generalized for the rest of the fields of project. Given that the maximum power of each module is 240 Wp, the total number of modules to be used in each field can be found easily by:

Number of modules per field = $\frac{2000\text{ kW}}{240\text{W}} = 8333$ PV module

Table 4.2: Features of the ABB 1 MW central inverter used

Model	**PVS800-57-1000kW-C**
Rated power	1000 kW
Maximum power	1200 kW
DC voltage range (MPPT)	600-850 V
Maximum DC voltage	1100 V
Maximum DC current	1710 A
DC inputs	8-20
Nominal AC voltage (3-phase)	400 V
Nominal AC current	1445 A

The total number of the PV modules in the project is then given by:

Total number of modules = 8333×7=58,331 PV module.

It is important to remember here that the power ratings given in the datasheet of the solar modules are measured under standard test conditions that are difficult to be achieved in real life. The real maximum power obtained from the module is mostly less than this value due to high temperature and low irradiation levels. The open circuit voltage values given in Table 4.1 were given at standard temperature of 25 degrees. However, the temperature is variable that can decrease to less than zero or more than 60 at the cell’s surface. For this reason, open circuit voltage values are going to be calculated at the highest and lowest temperature limits of the modules that are -40 and 90 degrees. The next relation can be used to give an approximation of the open circuit voltage.

$$V(T) = V_{@25^{\circ}C} \times (1 + \beta \times \Delta T) \tag{4.1}$$

Where β is the temperature de-rating factor shown in table 4.1. The maximum and minimum voltages of the system can be given as:

$$(V_{OC})_{@-40\,^{\circ}C} = 37.4 \times\ [1 + (-0.332) \times (-40 - 25)/100] = 45.6\,V$$

$$(V_{OC})_{@90\,^{\circ}C} = 37.4 \times [1 + (-0.332) \times (90 - 25)/100] = 29.32\,V$$

$$\begin{aligned}(V_{MPP})_{@-40\,^{\circ}C} &= 30.9 + (-0.332\,\%) \times \Delta T = 20.9 + (-0.00332) \times (-65) \times 29.8 \\ &= 36.2V\end{aligned}$$

$$(V_{MPP})_{@+90\,^{\circ}C} = 30.90 - 0.00332 \times \Delta T \times 30.9 = 30.90 - 65 \times 0.00332 = 24.32V$$

From Table 4.2, the maximum permissible DC input voltage is 1100 V, and the maximum power point voltage ranges between 600 and 850 V. It is important to notice that both the open circuit and maximum power point voltages are maximal at the minimum temperature -40°C and minimum at 90°C. These values are important to find the number of series connected modules per each string that can be connected to the inverter. These values are going to be calculated at the minimum acceptable temperature that is -40°C.

$$Number\ of\ modules\ per\ string = \frac{V_{MPPinverter}}{V_{MPP@-40^{\circ}C}} = \frac{850}{36.2} = 23.4 \tag{4.2}$$

The optimum number of modules per string is found to be 23 modules per string. Now it is important to find the maximum possible number of modules per string as follows:

$$modules\ per\ string_{\max} = \frac{V_{\max inverter}}{V_{OC@-40^{\circ}C}} = \frac{1100}{37.4} = 29.4 \tag{4.3}$$

That means the maximum allowed number of series modules is 29 modules. The optimal design implies that the number of series module will be between 23 and 29 modules as maximum. In order to find the maximum number of parallel strings, it is important to consider the short circuit and maximum power point currents. The number of strings is found as follows:

$$String_{number\max/inverter} = \frac{I_{\max inverter}}{I_{SC\,module}} = \frac{1710}{8.49} = 201.4 strings \quad (4.4)$$

This means that a maximum of 201 parallel strings can be connected at the input of the inverter. For each inverter, taking in consideration the total number of modules per field found previously to be 8333 modules that will be distributed on two inverters. That means each inverter will be connected to a total of 4167 modules. If we accept that each string will contain 26 series modules for better performance and security, the number of parallel string is then given by:

$$String_{number/inverter} = \frac{Strings\ per\ inverter}{Modules\ per\ string} = \frac{4167}{26} = 160 < 201 \quad (4.5)$$

From the previous calculation it was found that the design must use 160 strings of 26 modules each respecting the inverter and modules specifications. Figure 4.2 shows the connection of the strings and modules as calculated previously.

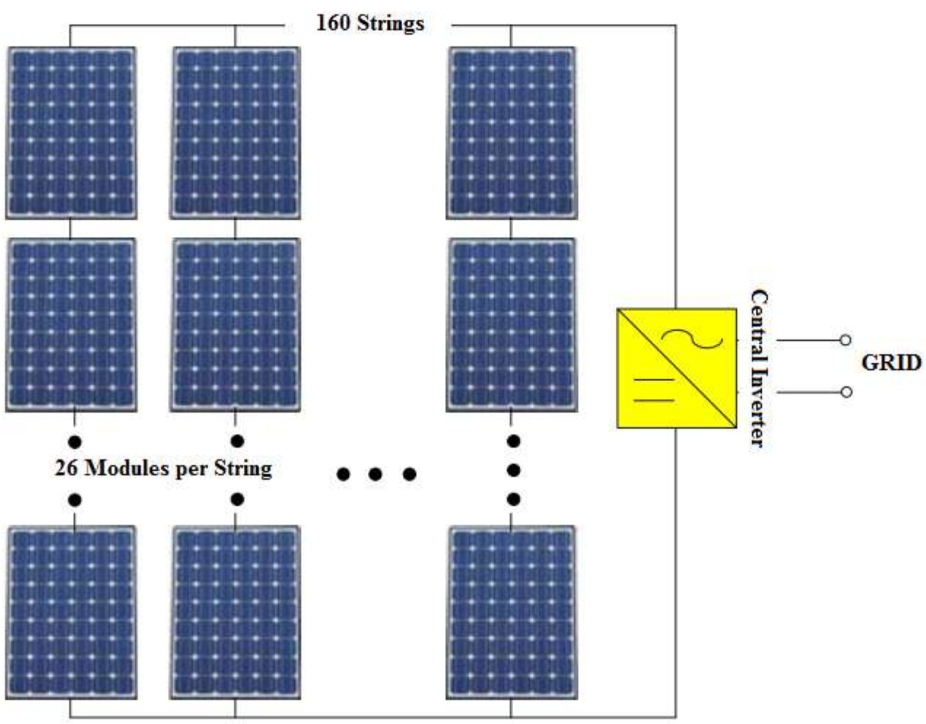

Figure 4.2: The array configuration of the central inverter

4.2.2 Layout of grid connected PV system with the central inverters

Since there exist 7 distribution transformers with 3 MVA rating each, the modules were distributed on 14 arrays. Each two arrays were connected to 1 transformer through two separate central inverters. The seven transformers primary sides are connected to the 11 kV grid bus bar. Inverters are connected to the panels such that each inverter is connected with 160 parallel strings, and 26 modules per string in series. Figure 4.3 below presents the connection scheme of the arrays, inverters, transformers and bus bars.

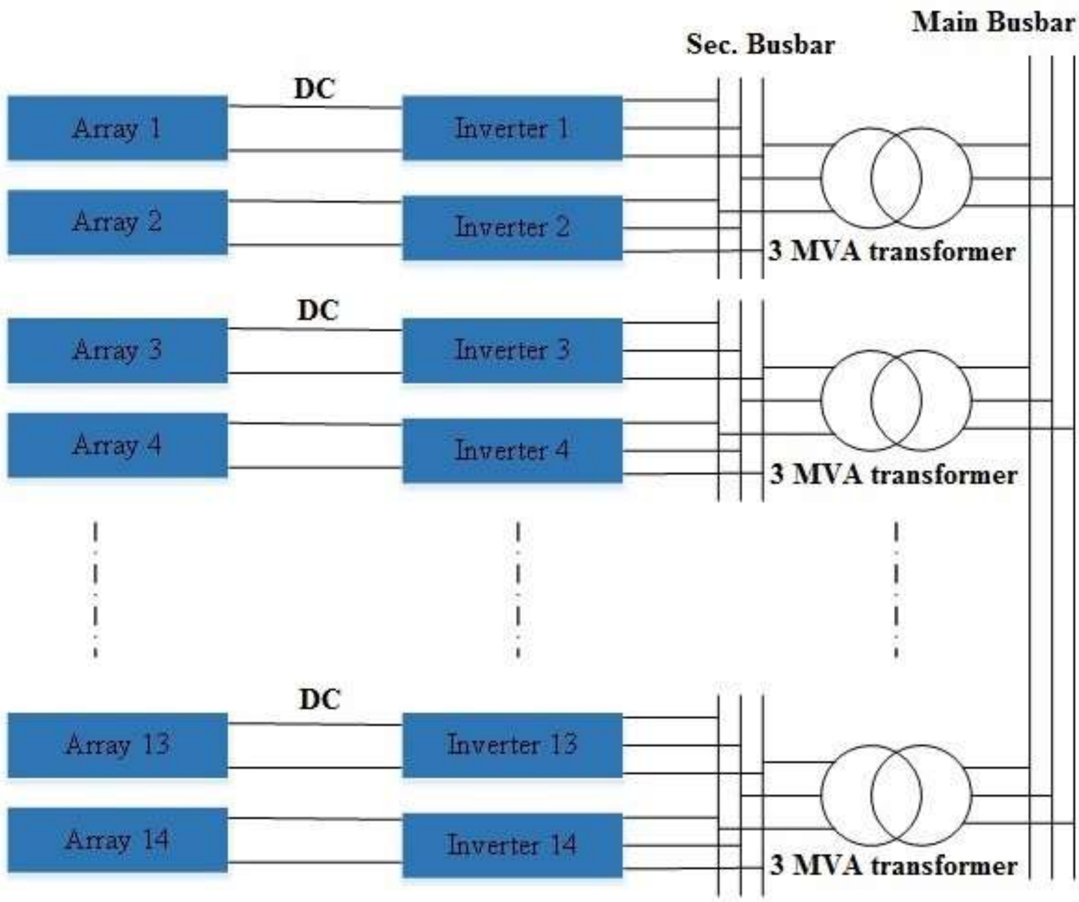

Figure 4.3: General structure of the arrays with the inverters

The wiring diagram connection of the inverters output to the main AC combiner box is shown in Figure 4.4. It must be mentioned here that the output of the main combiner box was connected to a step-down distribution transformer from the secondary side. This transformer is selected to be (11/0.4) kV, since it is connected to the inverter from the 0.4 kV level side. The 11 kV voltage level is selected because the Houn station has an 11 kV bus-bars. The connection between each two elements is done through special AC protection and disconnection circuits to ensure the total safety of equipments and persons against any faults or electric hazards as shown in Figure 4.4. These protection circuits in addition to the suitable cable sizing calculations are going to be discussed in the next parts of this work gradually.

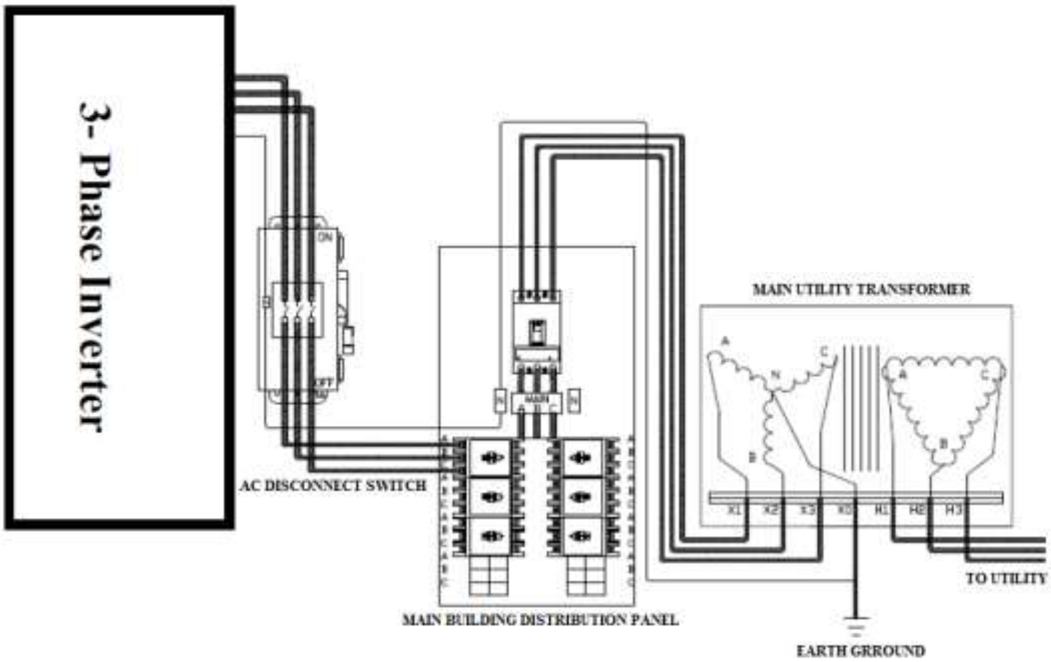

Figure 4.4: Wiring diagram of connection of inverters output to main combiner box

4.2.3 Cable sizing

Cable sizing is one of the most important issues in electrical works and installations. It is a very vital measure of security to ensure the capability of connection wires to handle all types of electrical and electromagnetic stresses under the different possible atmospheric conditions. In addition, the wiring must not affect the performance of the designed system due to extra losses caused by wrong sizing of cables. Cables must be sized to withstand the current flowing through it, to support short circuit fault levels for short periods until the tripping of protection circuits, to handle changes in temperature and moisture, to be able to withstand the voltage levels they are carrying, and to ensure the minimum possible voltage drop. The voltage drop in a wire can be given by:

$$V_d = \frac{\rho \times l}{A} \times 2 \times I \qquad (4.6)$$

Where:

ρ : is the resistivity of used wire which is normally taken to be 0.0183 Ωmm^2/m for copper.

l = the length of cables in meters.

I = the current through the cables in amperes.

A is the cross sectional area (CSA) in mm^2.

The multiplication by 2 accounts for total circuit wire length. We can rearrange the above equation to obtain the following equation:

$$A = \frac{2 \times \rho \times l \times I}{V_{d\max}} \tag{4.7}$$

In the design of the system, a maximum cable voltage drop of 5 % was used and this is the maximum allowable voltage drop in the international standards.

4.2.3.1 Sizing cables between PV modules

The cable is sized based on the following information:

Length of cable is 1.5 m, while the maximum current that can flow through the wire is given by:

$$I_{\max} = 1.25 \times I_{SC\,\mathrm{mod}ule} = 1.25 \times 8.44 = 10.55A \tag{4.8}$$

Where, the factor of 1.25 was considered for reason of security. The maximum allowable voltage drop is given by:

$$V_{MPP\,\mathrm{mod}ule} \times 5\% = 30.4 \times 5\% = 1.52V \tag{4.9}$$

The wires are considered copper wires that have resistivity of 0.0183 Ωmm^2/m, from which the cross sectional area is found as:

$$A = \frac{2 \times \rho \times l \times I}{V_{d\max}} = \frac{2 \times 0.0183 \times 1.5 \times 10.55}{1.52} = 0.38mm^2 \tag{4.10}$$

This means that any cable of cross-sectional area above 0.38 mm^2 can be used for the wiring between PV modules. However, this value is suitable to ensure the minimum voltage drop, but it is not enough to ensure that the wires can handle the maximum current flowing through it. By referring to the NEC tables for cable sizing it is found that a wire of 1.5 mm^2 is needed to withstand a current of 9A while a wire of 2.5 mm^2 is needed to withstand 16A. In our application the maximum current with safety factor is 10.55, then the best choice is a 2.5 mm^2 wire. It is important to notice that special insulated DC wires with PVC cover are used. This insulation is suitable to be used under ultraviolet rays without need for any extra covering.

4.2.3.2 Sizing of cable from PV array bus-bar to inverter

The cable is sized based on the following information:

Length of cable is 20 m, the maximum current from array is 8.44 × 160 ×1.25 = 1688A. The maximum voltage drop is given by:

$$V_d = 5\% \times V_{DC\min} = 5\% \times 600 = 30V \tag{4.11}$$

The minimum cross sectional area is found by:

$$A = \frac{2 \times \rho \times l \times I}{V_d} = \frac{2 \times 0.0183 \times 20 \times 1688}{30} = 41.2mm^2 \tag{4.12}$$

That means the minimum cable cross sectional area needed to ensure acceptable voltage drop is 41.2 mm^2, however; the design must consider the cables' ampacity. As the wires need to handle an amount of current of 1688A, by referring to the cable tables it is found that the maximum cable size is 240 mm^2 and can handle a maximum of 400A. A good choice of cables was found to be 6 wires of 150 mm^2 that can handle a maximum of 1722A.

4.2.3.3 Sizing of cable from inverter to main junction (inverter / distribution panel)

The cable is sized based on the following information:

Maximum length of cable is 30 m; the maximum current from inverter at full load on each phase (line) is given by:

$$I_{phase} = \frac{Inverter\,VA_{\max}}{V_{LL} \times \sqrt{3}} = \frac{1200}{400 \times \sqrt{3}} = 1.73kA \tag{4.13}$$

The maximum allowable voltage drop is given by:

$$V_{d\max} = 5\% \times 400 / \sqrt{3} = 11.5V \tag{4.14}$$

The minimum cross sectional area correspondent to voltage drop can be calculated by:

$$A = \frac{2 \times \rho \times l \times I}{V_{d\max}} = \frac{2 \times 0.0183 \times 30 \times 1730}{11.5} = 165.2mm^2 \tag{4.15}$$

By considering the cable ampacity, 6 cables of 185 mm^2 should be used to connect each inverter to the bus bar.

4.2.4 Sizing of circuit breakers

Circuit breakers are installed in the system to protect against over current of the circuits and sized to not be below 125 % of the current flowing through the wiring. The circuit breakers used in this installation must be bi-directional. However, the sizing of circuit breakers should be less than the maximum ampacity of the protected cables in the circuit.

4.2.4.1 Sizing of circuit protection between PV array and inverter

There are generally two ways of undertaking the circuit protection between PV array and Inverter.

1- Each parallel string of modules can be fused before entering DC collection point.
2- The total output of the PV array is fused before being joined to the inverter.

In this study installation, the first option is used because that makes it easier to find suitable DC circuit breakers at suitable prices.

The maximum current is 1.25 × short circuit current of modules (8.44 amperes) = 1.25 × 8.44 = 10.55A

Therefore the minimum rate of DC circuit protection is $\frac{125}{100} \times 10.55 = 13.18\ A$ per parallel string.

4.2.4.2 Sizing of circuit protection on every phase output of inverter

The maximum current from inverter at full load on each phase (line) was found earlier in this chapter, the current was 1730A per phase. During the cable sizing calculations it was found that we need to use 6 cables of 185mm^2. The best circuit breaker value for this cable size is 300A circuit breaker. That means 6 circuit breakers with capacity of 300A are going to be used at the output of the inverter.

4.2.5 Synchronization with the system

In a grid tied system, the synchronisation is a very important notion to take care of. The connection between two power sources needs to take in consideration that the two sources have the same variables. The variables that must be equal are the voltage, the phase, and the frequency. The connection between sources is done just when these three variables are equal in both sources. There are two connection points between the grid and the solar system; these are the 0.4 kV level bus-bar and the 11 kV level bus-bar. Synchronization must be achieved when there is a closed loop system; this is implemented by using Synchro-check relay. Two voltage transformers (VT$_S$) on phase measure the voltages, one on the system circuit side and the other on the bus-bar. The Synchro-check relay compares the line voltage and the bus-voltage, and then a closing pulse command comes from the SCADA centre, and closes a normally open contactor if the synchronization conditions are achieved, then the circuit breaker closes. The synchronisation is very important to protect the systems from being short circuit connected to each other and it is used in all stations to connect multiple sources of power. Table 4.3 resumes the cable and circuit breaker sizing of the designed system as per calculation.

Table 4.3: Cable sizing for the PV system

Cable	Cable Length (m)	Cable size (mm^2)	CB rating
Sizing cables between PV modules	1.5	2.5	No
Cables from PV array to the inverter	20	6×150	No
Sizing of AC wires	30	6×185	300

4.3 PV Modelling Using SIMULINK

4.3.1 Electrical circuit models of PV modules

Models of photovoltaic cell provide a comprehensive description of the behaviour of photovoltaic cell for scientists to be able to study it. A well-known model commonly used in the electrical engineering is the so called single diode PV cell model. The ideal photovoltaic cells model consists of a single diode connected in parallel with a light generated current source (I_{sc}) as shown in Figure 4.5. The equation for the output current is given by:

$$I = I_{sc} - I_D \tag{4.16}$$

While the diode's current is given by:

$$I_D = I_0 \left[e^{\frac{qV}{KaT}} - 1 \right] \tag{4.17}$$

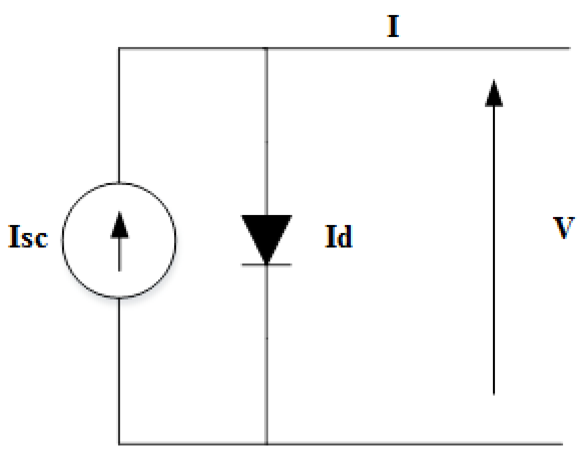

Figure 4.5: Solar cell's model using single diode

The light generated electric current depends on both temperature of the cell and irradiance. It is measured under laboratory special conditions. Thus:

$$I_{sc} = I_{scref} + k_i (T_k - T_{ref}) \times \sigma / 1000 \tag{4.18}$$

Where:

I_{sc}: is the light generated current at the STC (25ºC and 1000W/m^2).

K_i: is the short circuit current/temperature coefficient at I_{SCref} (0.0017 A/K).

T_k and T_{ref}: are the actual and reference temperature in Kelvin.

σ: is the irradiation on the device surface, and 1000W/m^2 is the STC value.

The model presented in Figure 4.5 cannot describe the total behaviour of the cell under all environmental variations. Some extra losses need to be considered in a more practical model as shown in Figure 4.6; R_s and R_p are the series and parallel resistance losses.

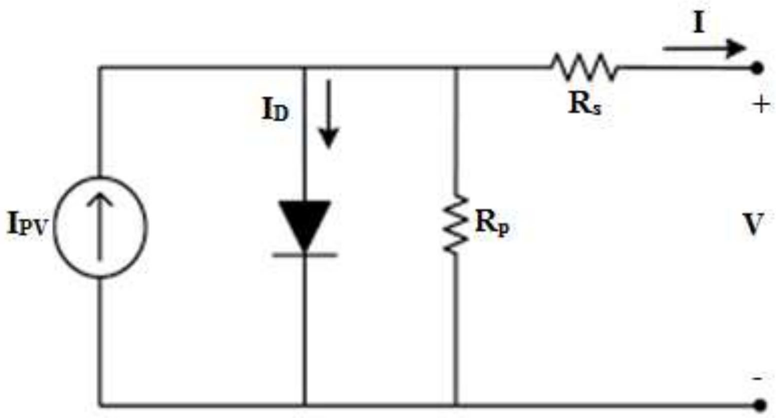

Figure 4.6: Solar cell model using single diode with R_s and R_p

In this model, a photo electric current source I_{sc} depending on the solar radiation, cell temperature and voltage, a diode whose inverse saturation current is a function of temperature, and two series and shunt resistances to represent different losses in the cell are used. The formula that describes the *I-V* characteristic of the cell in Figure 4.6 is given by:

$$I = I_{sc} - I_D - \frac{V_D}{R_p} \tag{4.19}$$

The reverse saturation current I_{rs} is given as:

$$I_{rs} = I_{sc\,ref}\left[\exp\left(\frac{qV_{oc}}{N_s\,K\,AT}\right) - 1\right] \tag{4.20}$$

The module's saturation current I_Q changes with the cell temperature and is given by:

$$I_Q = I_{rs}\left[\left(T/T_{ref}\right)^3 e^{qcg/AK} \times \left(1/T_{ref} - 1/T\right)\right] \tag{4.21}$$

Where, I_Q is the diode saturation current (A). The formula describing the output current of a PV cell or module of the single diode equivalent circuit is given by:

$$I_{pv} = N_p\,I_{sc} - N_s\,I_o\left\{\exp\left(\frac{q\left(V_{pv} + I_{pv}\,R_s\right)}{N_s\,AKT}\right) - 1\right\} - V_{pv} + \left(\frac{I_{pv}\,R_s}{R_p}\right) \tag{4.22}$$

Where:

K: is Boltzmann's constant (1.38×10^{-23} J K^{-1}).

q: is the electronic charge (1.602×10^{-19} C).

T: is the cell temperature (K).

A: is the diode ideality factor.

R_s: the series resistance (Ω).

R_p: is the shunt resistance (Ω).

N_s: is the number of cells connected in series = 26.

N_p: is the number of cells connected in parallel = 160.

$V_{pv} = V_{oc} = 37.30$ V.

The formula described by equation 4.22 depends on the solar irradiance, and the cell temperature (Abdulkadir, Samosir, & Yatim, 2012). Nameplate values of solar arrays are given under STC conditions. Real operation conditions differ from the STC. The use of the simple model of solar cell in our work simplifies the work without affecting the accuracy or generalization of the theory. It makes it easier for power electronic engineers to consider this model while working with power converters. The value of the shunt resistance R_p is typically high such that it can be neglected (Abdulkadir, Samosir, & Yatim, 2012) (Yusof, 2004).

4.3.2 Simulink modelling for PV module

Mono-crystalline 240W PV Module is taken as the reference module for simulation and the data sheet details are given in Table 4.1. In addition the simulation for one array of 2 MW is conducted and then the simulation is generalized to all arrays in a similar way. A block diagram of the model based upon the equations of PV model is represented in Simulink environment as given in Figures 4.7, 4.8 and 4.9.

These models are developed in moderate complexity to include the temperature dependence of the photo current source, the saturation current through the diode, and a series resistance is considered based upon the shackle diode equations described previously. Since the main objective is to develop a functional PV model for the Simulink environment, the system is modelled to supply power to the load.

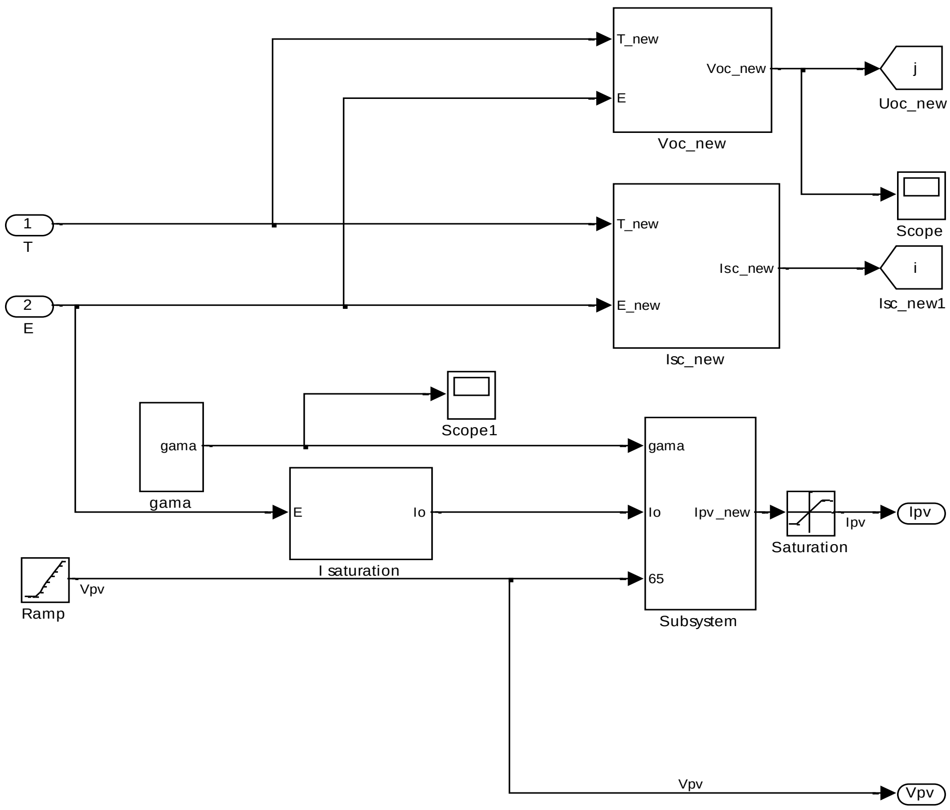

Figure 4.7: Block diagram of the model based upon the equations of PV model

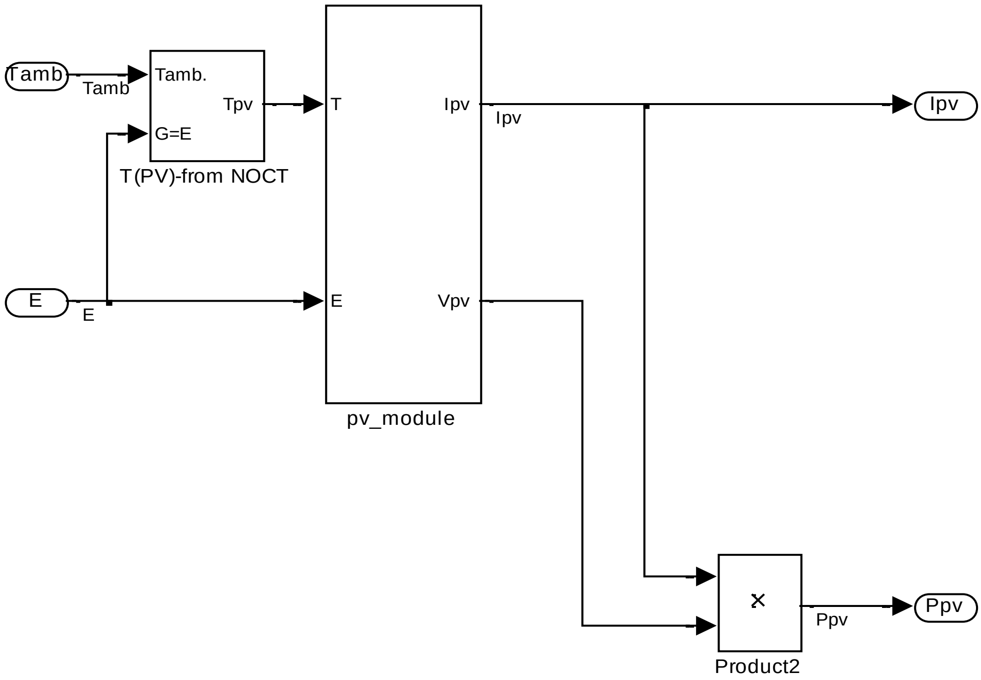

Figure 4.8: Masked PV module in Simulink

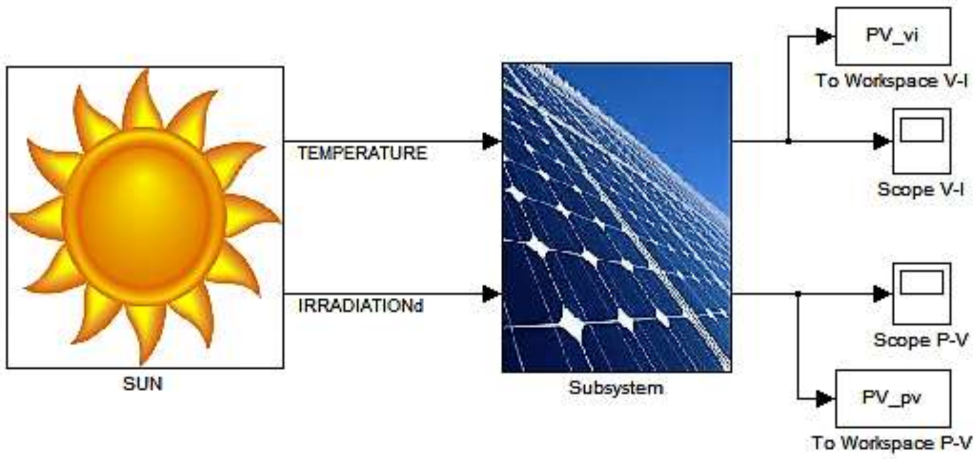

Figure 4.9: The final model of PV system

4.3.3 PV Simulation results and discussions

The model discussed previously and shown in Figures 4.7, 4.8 and 4.9 was simulated under different conditions to evaluate the different characteristics of the PV modules. Figure 4.10 presents the V-I curve of the system simulated in Matlab environment. The simulation has considered 160 strings of 26 series modules parallel connected. The curves show the variations in voltage and current under different irradiation levels and fixed temperature of 25°C. Figure 4.11 presents the P-V curve of the same system under same conditions of temperature and irradiation. These two figures show that the system has one peak at which the system can provide the maximum power.

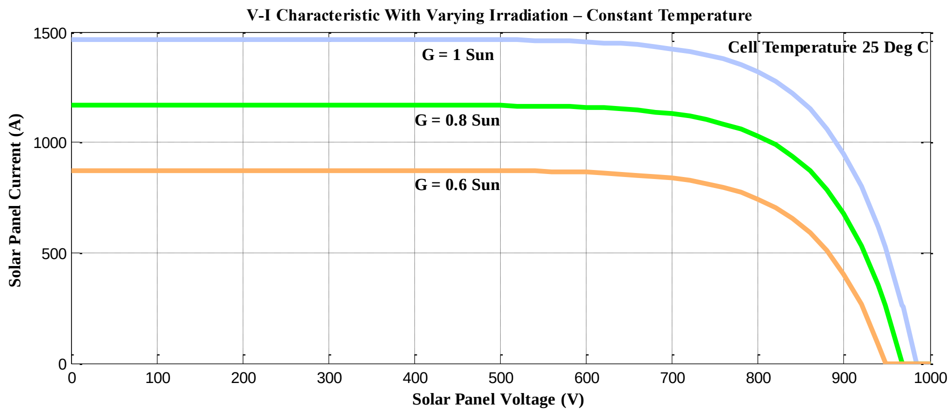

Figure 4.10: Simulink model of solar panel (160 strings) V-I characteristic curves

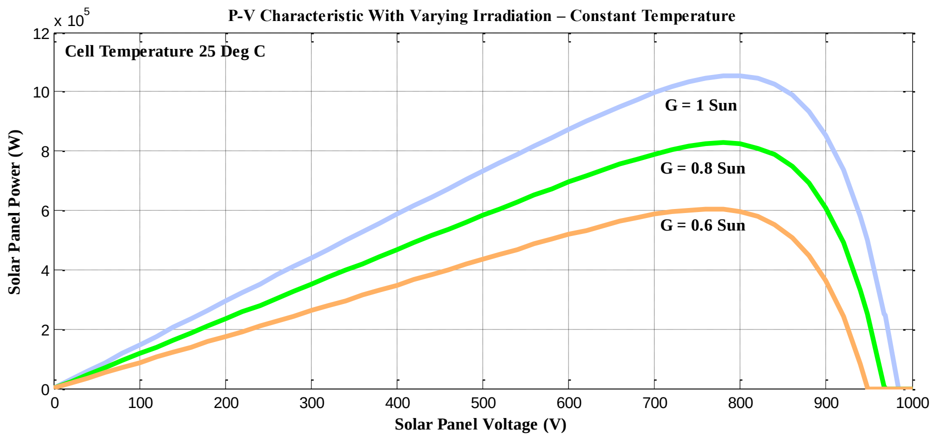

Figure 4.11: Simulink model of solar panel (160 strings) P-V characteristic curves

Figures 4.12 and 4.13 present the variations in the I-V and P-V curves under variable temperature and a solar irradiation of $1000W/m^2$. The figures show that the higher the temperature the lower generated power becomes. Also, the figures show that the generated voltage decreases slightly with the increase in temperature of the cells.

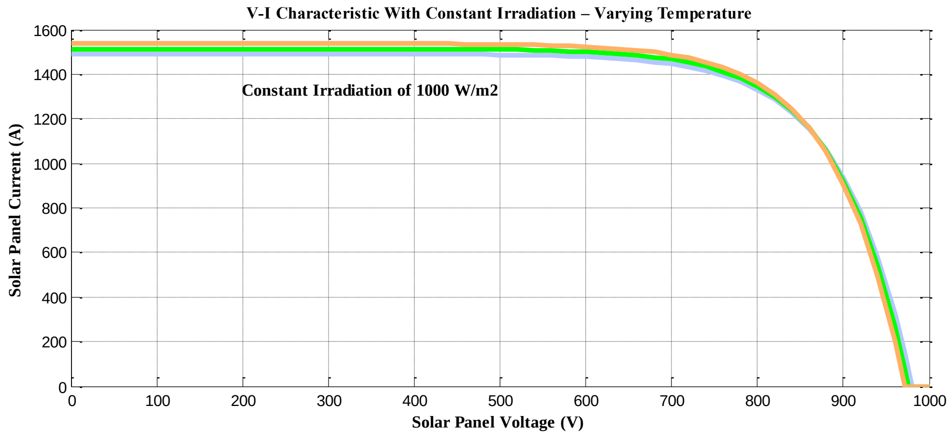

Figure 4.12: Simulink model of solar panel (160 strings) V-I characteristic curves

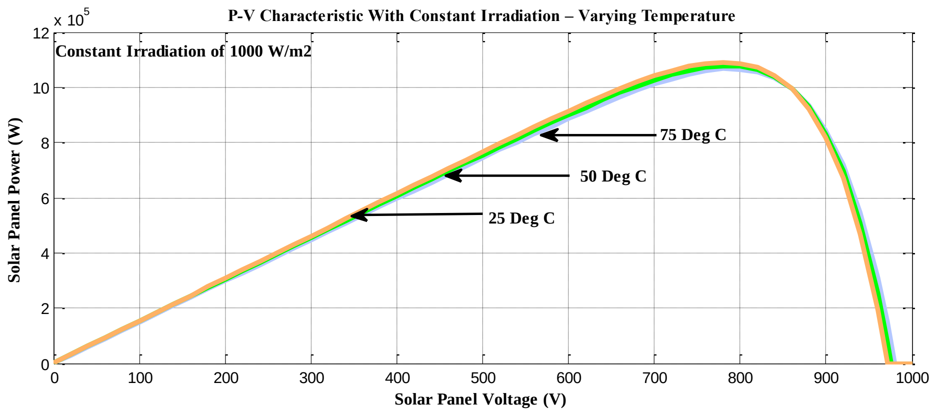

Figure 4.13: Simulink model of solar panel (160 strings) P-V characteristic curves

CHAPTER 5

POWER SYSTEM STUDIES FOR PV INTEGRATION

5.1 Introduction

This chapter introduces the electrical power system studies for the project using ETAP software. The used methodology is as shown in the flow chart of Figure 5.1 below:

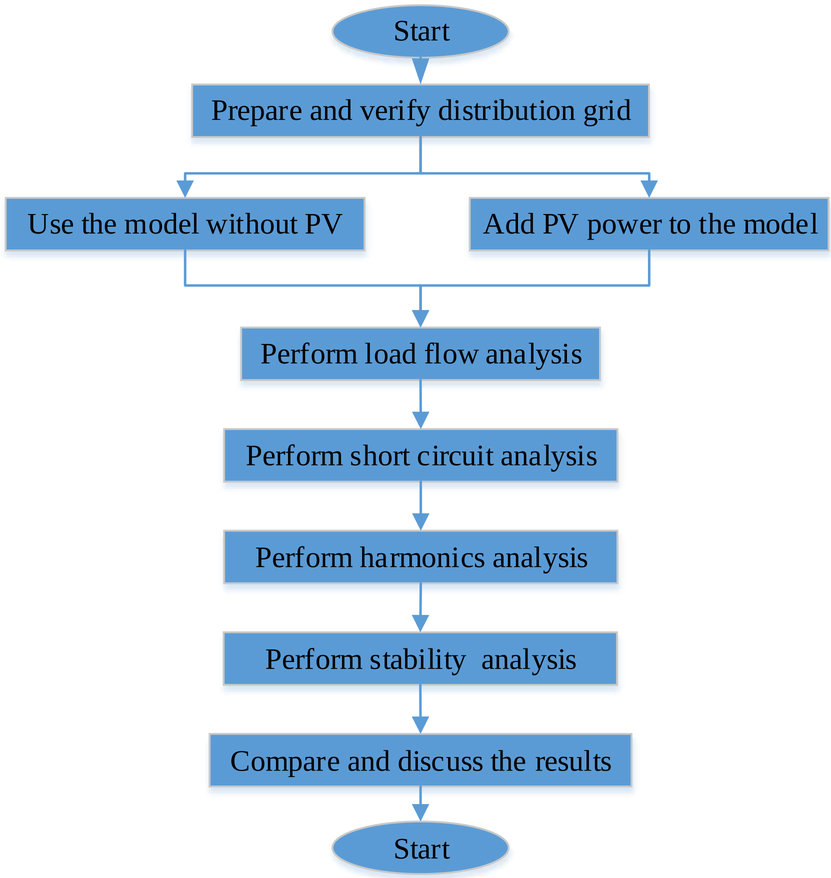

Figure 5.1: Electrical power system study methodology flow chart

5.2 Load Flow Study and Analysis Using ETAP

ETAP software uses the buses voltages, flow of current and power in the system, and branches power factor to perform load flow analysis. It is a very powerful software that can analyse the load flow for loop or radial electrical systems. Furthermore, ETAP software is designed to be able to perform different types of load flow analysis based on the custom choices and purposes of the specific case.

The purpose of load flow analysis in ETAP is to build an extensive idea about the behaviour of the power system under different supply and load conditions. It helps electrical power systems planners to design and test the performance of their systems prior to their installation and during their real time operation. It is also used to detect and forecast possible faults or power flow problems to propose the suitable solutions. The load flow Study is capable to define and adjust the parameters of the system for each case separately. ETAP has multiple choices to define the display options based on the user's needs and requirements from load flow analysis.

Load flow analysis in ETAP is based mainly on numerical solutions of systems of differential equations.

5.2.1 Load flow simulation using ETAP

This section discusses the implementation of Houn substation project simulation with the 14 MW PV plant as presented in Figure 5.2. Figure 5.2 shows the components of the Houn substation in addition to the PV Plant model in ETAP. As discussed earlier in chapter 4, PV arrays are connected through 7 transformers to the 11 kV bus-bars. The latter are connected through 2 step-up transformers to buses 11 and 12 as shown in the figure. The figure shows the load flow results for each one of the buses and branches.

On the figure buses voltages can be seen in per unit (PU). It is important to mention that in Figure 5.2 the PV plant is disconnected. The voltage on the 66 kV bus 1 is 99.12 % while the power of the PV plant is zero. Figure 5.3 shows the system load flow after the connection of PV plant. The voltage at bus 1 has increased to 99.39 % while a total of 11641 kW is flowing from the PV plant to the system. Power factor of the PV plant is approximately 1.

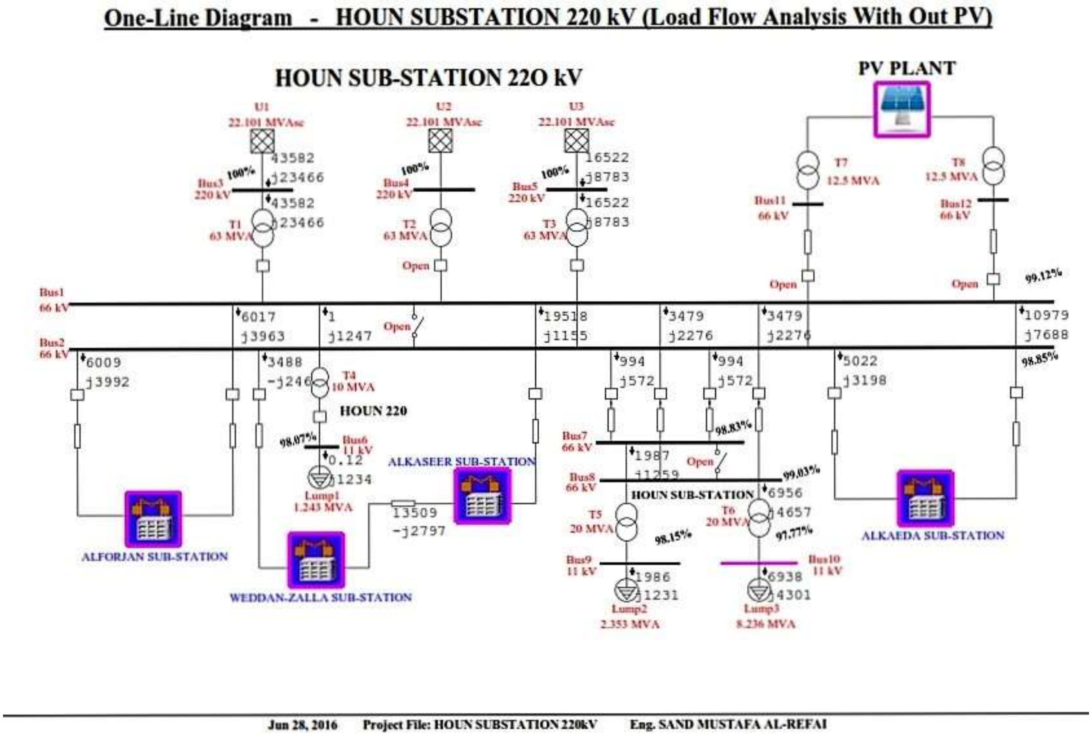

Figure 5.2: Load flow simulation with PV disconnected

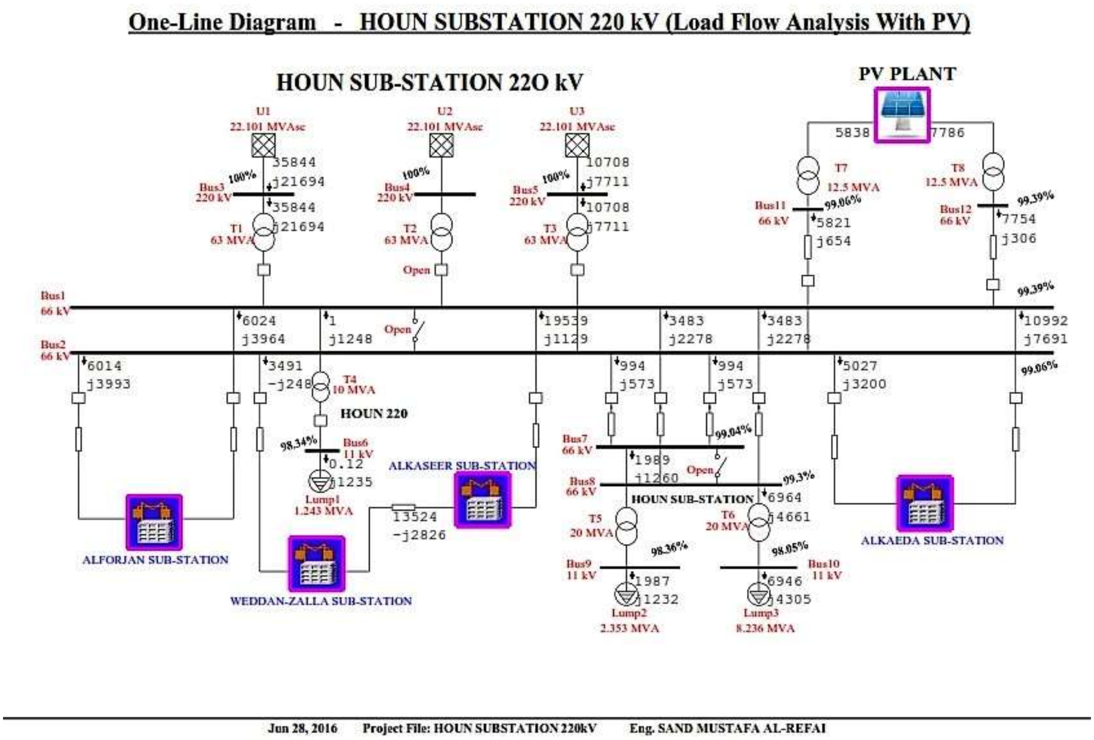

Figure 5.3: Load flow simulation with PV connected

5.3 Short Circuit Study and Analysis Using ETAP

The ETAP has the functionality of Short Circuit analysis in electrical distribution systems. It can find the short circuit currents and the contributions of each load in the short circuit. Fault duties are based on the new editions issued by IEC and ANSI/IEEE standards (ETAP, 2016). ETAP presents a very powerful short circuit detection and calculation ability. It is one of the main short circuit analysis software used in power systems by power engineers to estimate the effects of short circuit consequences in power systems.

5.3.1 Short circuit simulation using ETAP

Short circuit analysis was performed on the substation of Houn without PV plant as shown in Figure 5.4 and with the PV plant connected as shown in Figure 5.5. The figures show the short circuit currents at all buses and branches. It is obvious that the existence of PV plant in Figure 5.5 has increased the short circuit currents slightly at most of buses. However, the increase in short circuit current levels is very small and doesn't introduce extra problems.

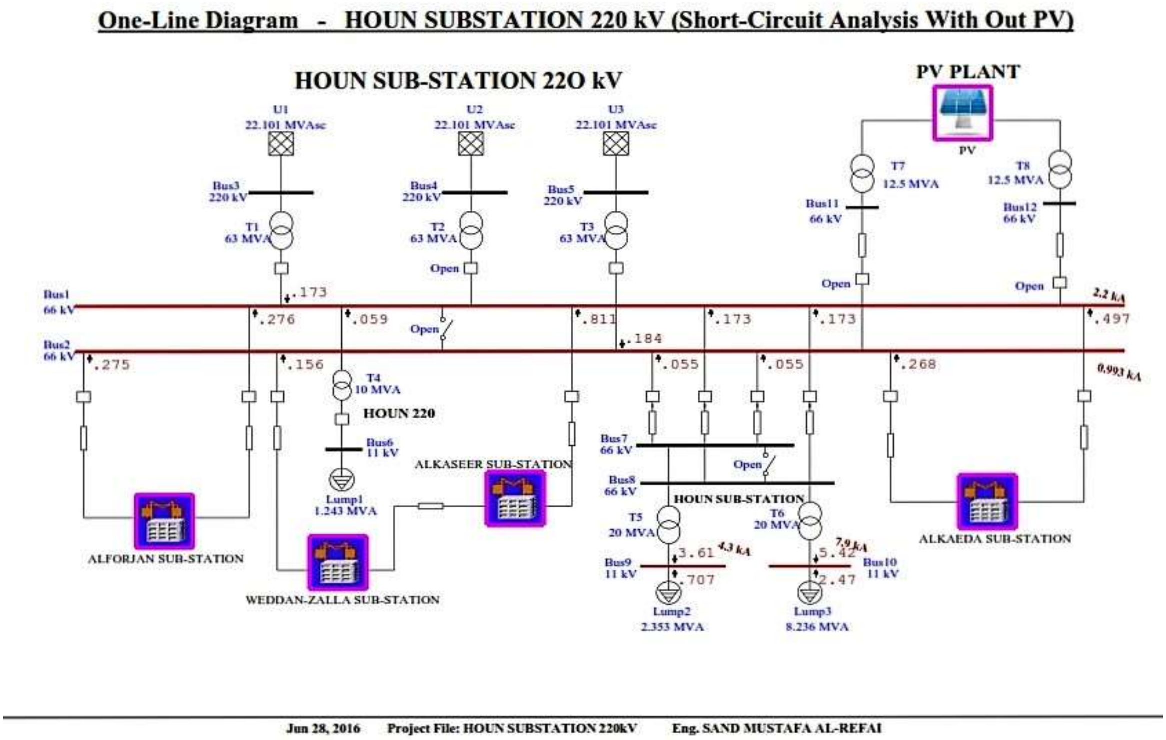

Figure 5.4: Short circuit simulation with PV disconnected

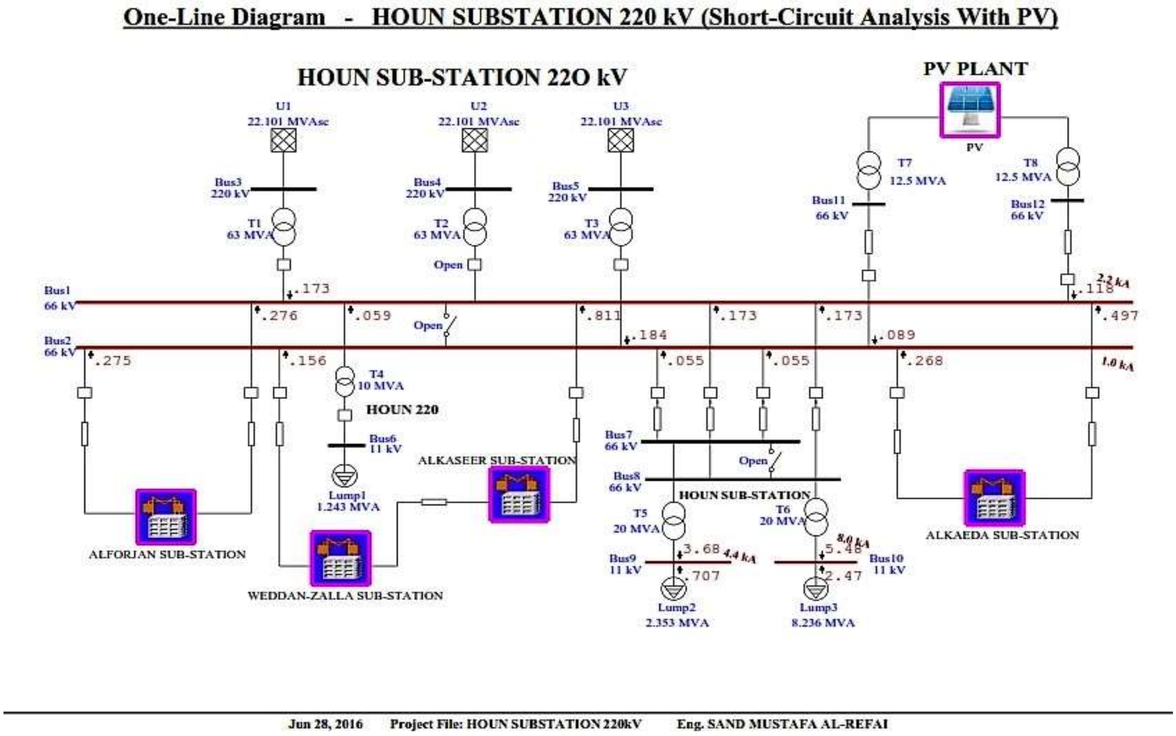

Figure 5.5: Short circuit simulation with PV connected

5.4 Harmonics Study and Analysis Using ETAP

As a result of the continuously increasing uses of power electronic equipment like variable speed motor drives, UPS systems, power converters, rectifiers, and different power electronic devices, power quality of system's voltage and current is strictly affected in different areas. Components of higher frequencies start to circulate in power systems causing the wave forms of voltage and current to be distorted. Such higher frequency components are integer multipliers of the fundamental frequency which are known by the term harmonics. The harmonic emitting devices are called nonlinear loads and include power electronic switching devices, transformers, motors, fluorescent lights, arc furnaces and many other different devices. Such devices cause very serious problems affecting the power quality of power systems.

The existence of harmonics in any power system causes different problems and effects that include but not limited to over temperature of equipment, low power factor of devices, low performance of electrical components, unexpected behaviours of protective devices, interferences with communication systems, resonance with other equipment that cause failure of these equipment, noise, vibration of electrical motors, and other effects. Over more, harmonic currents don’t stay near to their source; instead, they penetrate the electrical distribution networks and start circulating throughout the electric systems. The circulation of harmonic currents in the electric systems distorts electric voltages fed to the other users and the harmonic problem is accumulated. This phenomenon has become a main hot topic for power quality as a result of the increasing spread of electronic devices and equipment in power systems.

Using computer simulation, the problem of power system harmonics can be modelled and analysed. The ETAP harmonic analysis module offers a great tool to model different power system elements and equipment accurately to study their frequency dependency, nonlinear behaviour, and other effects of the presence of harmonic currents and voltages.

5.5 Transient Stability Study and Analysis Using ETAP

The ETAP is constructed to study the system’s dynamic behaviour and steady state limits of a power system. This study or analysis is implemented before, throughout, and following changes or disturbances in the electric systems. The program implements the events and activities defined by the user to analyse the system. It then determines the response of the system to these events. These analyses are important to determine the protective and design parameters of the system.

Voltage profile is the numerical description of the system voltages at a given point, generally a bus or a node of the electric system at some determined circumstances. Examples of voltage profile are: no load profile, light load profile, full load profile, and finally overload profile. In the most of power systems, voltage is limited to predefined values that shouldn’t be exceeded. Some variations in the voltage profile parameters can lead the system to instability. Voltage stability is a description of the ability of the system to preserve steady state parameters and voltages at their state values after different faults or occurrences (Cutsem & Vournas, 1998).

CHAPTER 6
RESULTS ANALYSIS OF POWER SYSTEM STUDIES

6.1 Introduction

To simulate a real system, models of each element have to be built and incorporated in the power system simulation software ETAP. This provides the ability to simulate load flow, short circuit, harmonics and stability analysis work in the same software environment. This chapter introduces the results and analysis for electrical power system studies for the project using ETAP software.

6.2 Load Flow Analysis

Load flow analysis is a great tool that produces essential computation practice in order to establish the characteristics of power system under steady state conditions. In this thesis load flow analysis for Houn substation which consists of 42 buses, 14 transmission lines and 26 transformers in addition to switches and circuit breakers as shown in the single line diagram Figure 5.2 and Figure 5.3. Modelling and simulation are carried out by using ETAP simulation software for two cases; first case without PV connection and the second case with PV connection. The results are tabulated as shown in Appendixes 4 and 5.

Tabulated reports show that integrating a PV system into Houn distribution network improves the system voltage profile as can be observed in most of the busses and particularly bus 10 which became normal after it was critical before connecting the PV system. The importance of the load flow analysis is to make sure that the distribution network is safe enough to be connected with PV generators. The results obtained from the load flow study of Houn substation show that the use of PV generators at Houn power station is safe, feasible, and advantageous. It can noticeably improve the voltage stability at each bus of the system, and increase the voltage profile.

6.3 Short Circuit Analysis

The short circuit of power system under consideration is performed to identify the strong and weak buses in the power system under disturbance. The possibilities for a short circuit in three phase system are as follows:

1- Symmetrical three phase fault.
2- Single Line to Ground fault.
3- Line to Line fault.
4- Double Line to Ground fault.

Short circuit analysis basically based on finding the steady state solution of the power system under study. This information is needed to determine the required interrupting capacity of the circuit breakers and to design proper relaying system (Saadat, 2010). To get enough information, different types of faults are simulated at different locations and the study is carried out for two cases; first case, without PV connection to Houn network, and the second case when the PV plant is connected to Houn network. In this thesis the ETAP report results of short circuit studies is tabulated as shown in Appendixes 6 and 7. The reports include the following information:

1- Short circuit contributions from all buses connected to the faulted buses or between any other two buses specified in the input, or both.
2- Voltage at the remote buses where fault contributions are specified by (1).
3- System X/R ratio at the fault point for medium voltage circuit breaker interrupting duty with its associated multiplying factor.
4- Symmetrical and asymmetrical current for breaker momentary duty.
5- Local and remote fault contributions.

The report includes input data, total fault level at each faulted bus, and also contributions from all connecting buses. Short circuit studied diagrams for Houn network as depicted in Figure 5.4 and Figure 5.5 showing all system faulted busses results.

6.4 Harmonics Analysis

Harmonics were presented earlier in this work and they present one of the most important problems in power systems. PV systems can represent a source of harmonics to the grid under some conditions; produced harmonics can be the effect of the solar panels instable functionality due to variable irradiations or from the power electronic elements used as interface. However, it is important to notice here that modern power inverters provide high power quality factors. The injected harmonics by such inverters are mostly high order harmonics that can be filtered easily.

In this research work simulations were carried out for the system under consideration, to obtain the voltage and current waveforms at bus bars 1 and 2 which are the Point of Common Coupling (PCC), where the study were performed for two cases one without PV connection, and the other with PV connection. Figure 6.1 shows the waveforms of the bus 1 voltage before the connection of PV plant. Figure 6.2 presents the Total Harmonic Distortion (THD) amounts of all buses after connecting the PV plant.

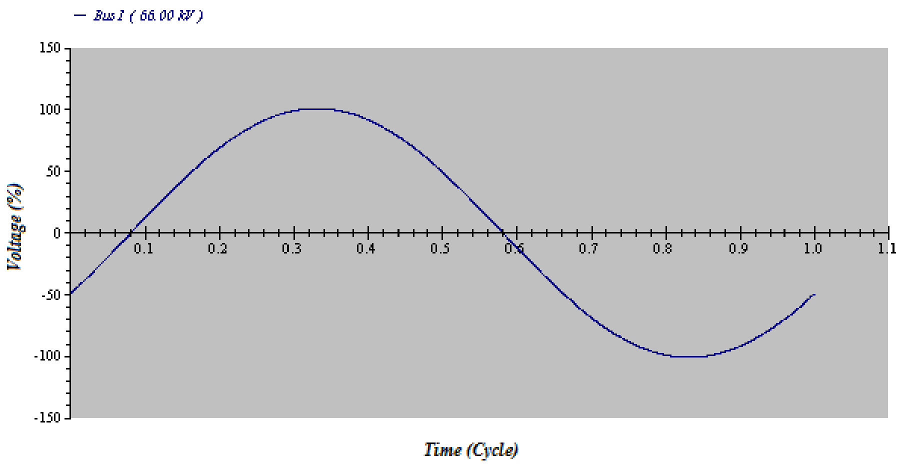

Figure 6.1: Voltage waveform at bus 1 with PV disconnected

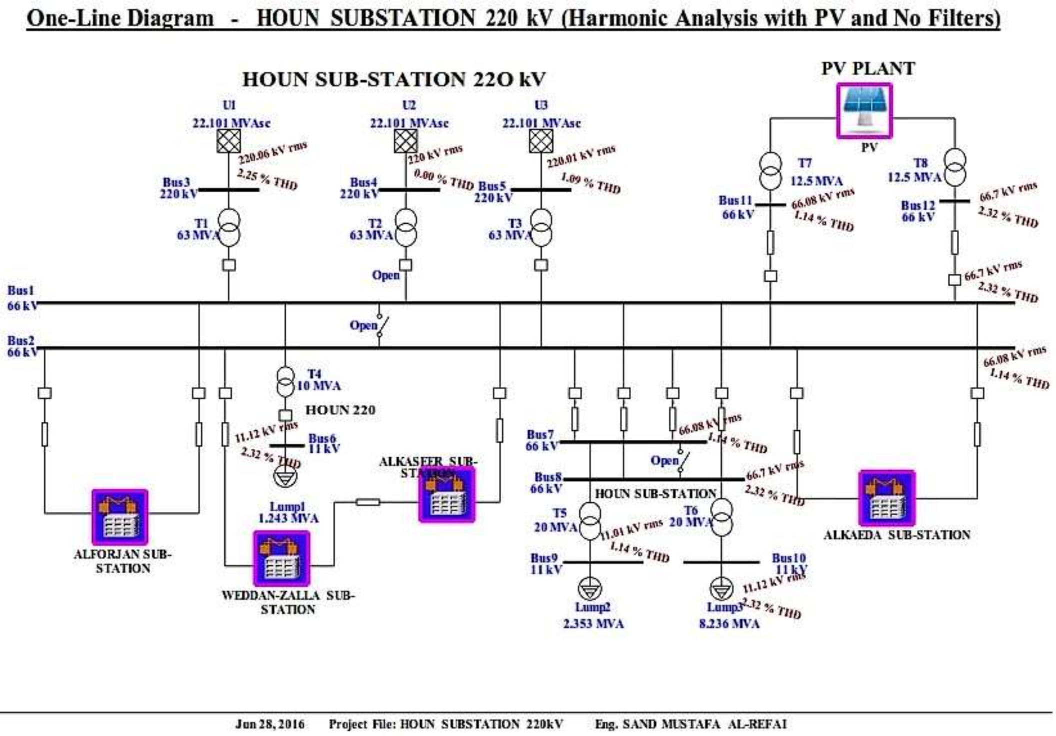

Figure 6.2: Analysis results of harmonic with PV connected

Figure 6.3 presents the waveform and spectrum of the bus 1 voltage after the connection of the PV plant.

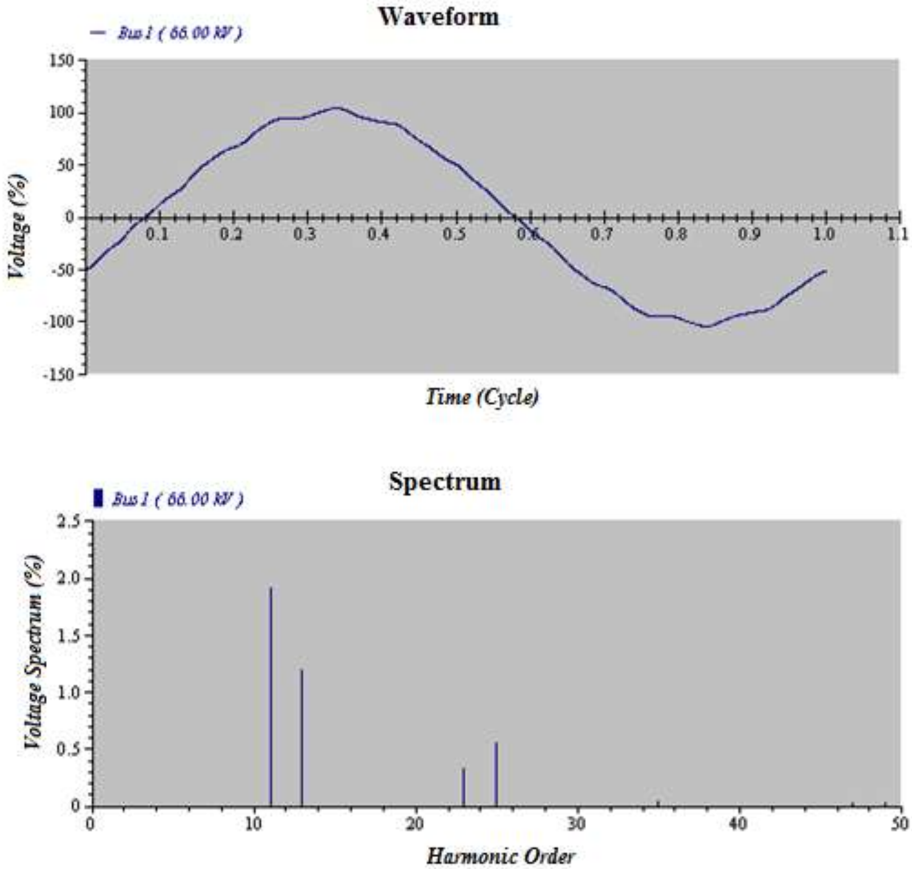

Figure 6.3: Waveform and spectrum of bus1 voltage after using PV plant

From Figure 6.2 it can be noticed that THD values of voltages at buses 1 and 2 are 2.33 % and 1.15 % respectively. The results show that the injection of solar power through solar inverters causes the injection of voltage harmonics into the power system. However, the THD values after the use of PV plant are still less than 5 % and don't cause any problems according to different international standards like IEC.

To improve the stability condition such as reducing the 5th and higher orders harmonics and reduce the harmonic content in the waveforms, passive filters can be connected at the common coupling busses as shown in Figure 6.4. The figure shows that the use of harmonic passive filters has reduced the THD value of voltage to 0.63 % at bus 1 and 0.41 % at bus 2. It is important to mention here that the filter was tuned specifically to cancel the 11th harmonic as it was the dominant harmonic as shown in Figure 6.3. It is important to notice that the 11th harmonic was cancelled as shown in Figure 6.5. Another filter tuned at the 13th harmonic could reduce more the THD and increase the power quality at bus 1 and bus 2.

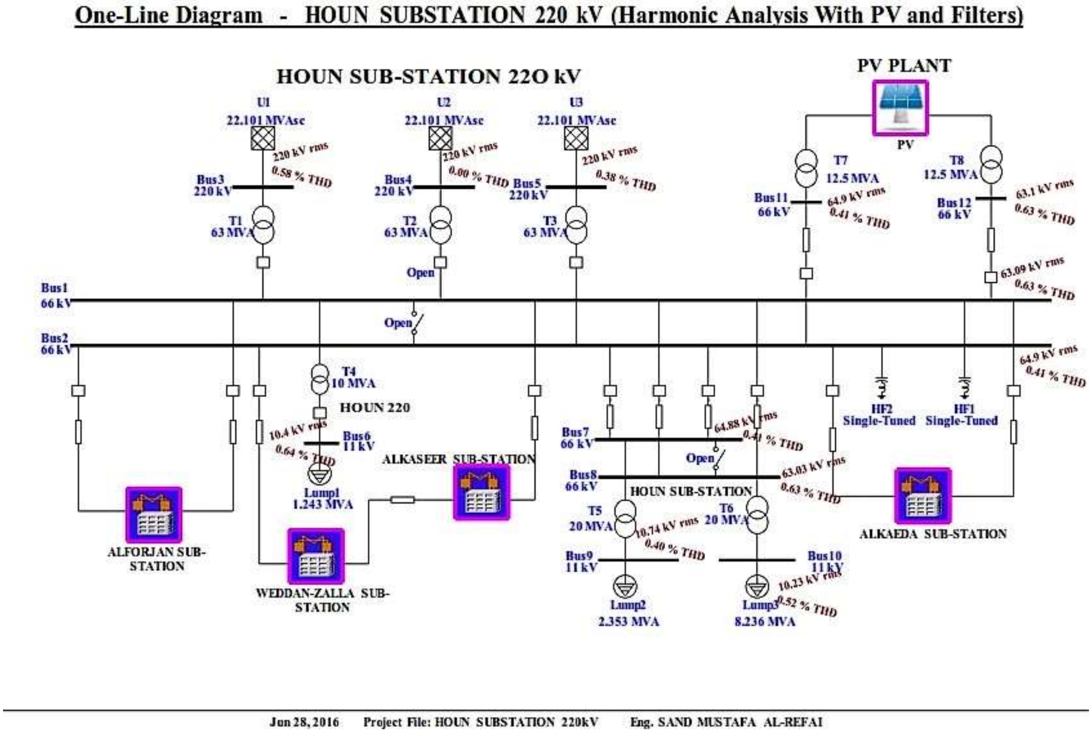

Figure 6.4: Harmonic study with filters and PV connection

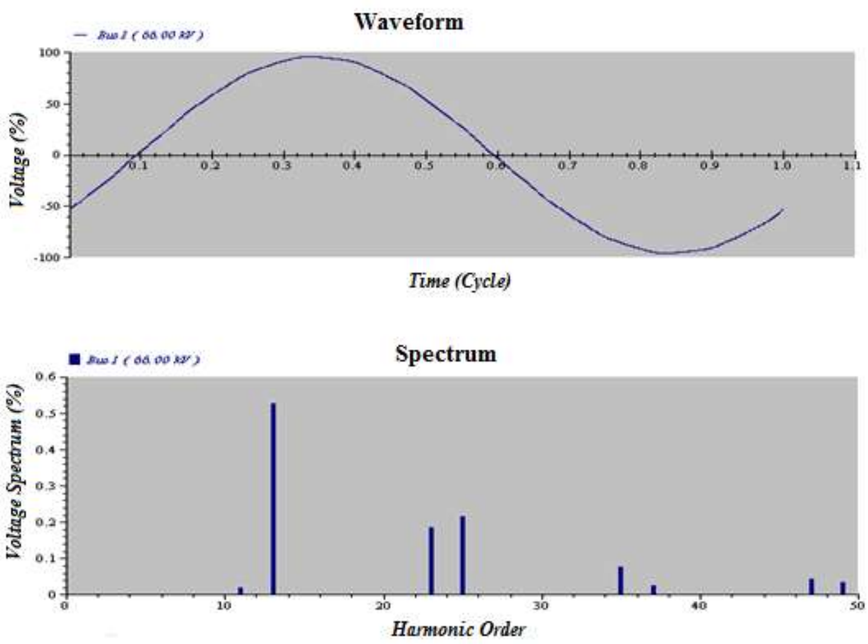

Figure 6.5: Bus 1 voltage waveform and spectrum with filters and PV connection

The complete reports of the study including THDV value with filters are depicted in the Appendixes 8, 9, 10 and 11.

6.5 Transient Stability Analysis

Stability of power system is the criterion that guarantees it to keep in equilibrium point under normal conditions; also to return to its initial stable conditions after the occurrence of different disturbances. Unacceptable voltage profiles can be the main consequence of the incapability of the system to feed the required reactive power to the load. Under normal operating conditions, the magnitude of the bus voltage boosts proportional to the increase in the injected reactive power on the same bus. However, unstable system occurs when the voltage of the bus decrease with the increase of reactive power injection. The voltage instability is a local problem; however, its effects can spread all over the system due to the relation between active power, reactive power, and bus voltage.

Solar systems are nonlinear configurations because of the discrete operation and existence of the sunlight, in addition to the switching scheme of the power electronic converters and DC-AC inverter devices. The output voltage in a solar system, the generated current, and the produced power are subject to dynamic variations at real time basis. The connection of such type of systems has its side effects on the other different components of the power system and its stability especially the power factor and voltage profile. In this thesis PV plant is integrated at bus 1 and bus 2 as shown previously.

Dynamic voltage stability simulations were carried out using the ETAP software. Simulation results demonstrate that connecting the PV to Houn substation increases the voltage profile at the particular bus bar. Thus, integrating of a PV system into a distribution network improves the system voltage stability.

In transient stability we studied about the behavior of the system under consideration during the disturbance for large interval in both cases. The results are shown in Figure 6.6 and Figure 6.7. The complete reports of the study for both cases are depicted in the Appendixes 12 and 13. Figure 6.6 shows the transient voltage that follows a three phase fault applied to bus 1 and bus 5 with PV disconnected. It demonstrates a voltage change of up to 200 % in bus 1 voltage. After the connection of PV plant, the same fault was executed and results were shown in Figure 6.7. The transient voltage has decreased to 140

% and the time of transient was also decreased. These two figures show that the connection of PV plant help stabilizing the power system and reducing the transient effects.

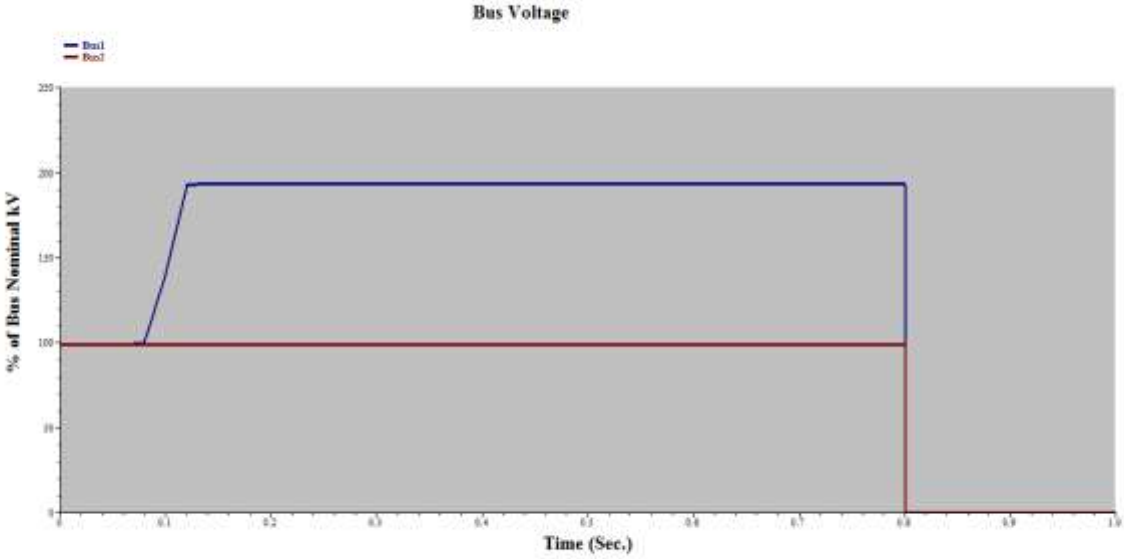

Figure 6.6: Percentage of bus nominal (kV) without PV connection

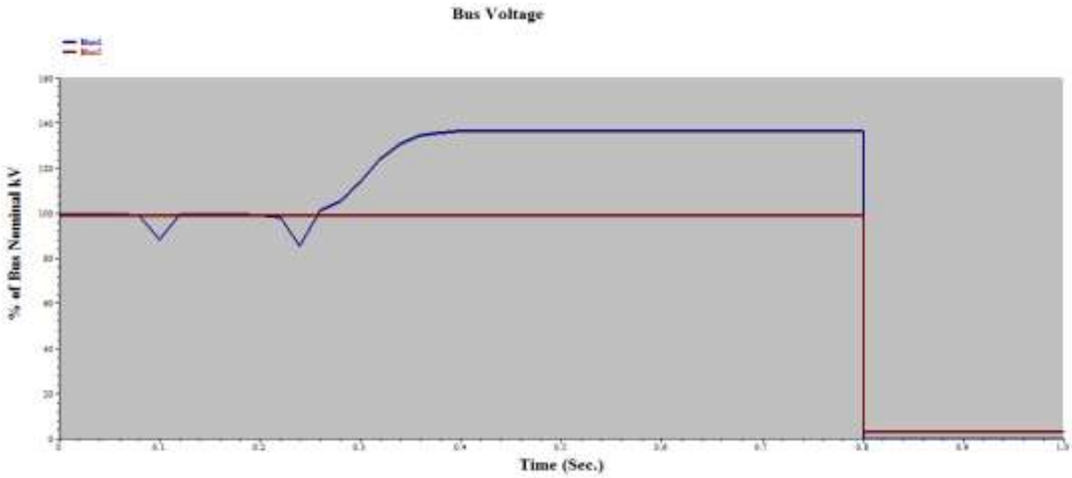

Figure 6.7: Percentage of bus nominal (kV) with PV connection

CHAPTER 7
CONCLUSION AND FUTURE WORK

7.1 Conclusion

Libya is very wealthy in the solar energy and gains a huge prospective for solar power generation plants. Solar energy is variable in the nature and depends on the site. The unpredictable nature of this energy source has its great impact on the power system operation and planning. The aim of this specific work is to evaluate the effect of the integration of solar power generator in the city of Houn distribution station in Libya. This aim was achieved by developing the design of PV system to be implemented in Houn substation 220 kV. Sizing of PV system, inverters and cables were obtained.

In order to verify the design validity, different simulation models using MATLAB and ETAP programs have been built and carried out. Real load and solar energy data were used in the simulation to achieve more realistic results that can help for future analysis and planning processes.

Investigation of the impact of 14 MW PV plant on Houn distribution power system in this thesis was carried out and some analyses were established. The first study was concerned by the slow variations in the common coupling point’s voltage. The second study was concentrated on the study of short circuit faults at the coupling point of Houn power station. These studies were performed in order to verify whether the Houn substation is capable to hold the planned generation plant. After those studies were performed, another analysis of the voltage stability on Houn station before and after the consideration of the solar plant was carried out. Finally, the effect of PV system on the power quality at the coupling point was studied by using the harmonic analysis tools.

The obtained results from the load flow analysis show that the implementation of PV solar generation station at Houn power distribution station develops the voltage profile and increase the stability of the system. Distribution lines’ losses are found to be decreased as an effect of the implementation of the solar system. The applied analyses have shown that the power station of Houn is in good status and its voltage profile is healthy before and after the use of PV generation system.

The implementation of PV plant connected to the station of Houn has shown capability of decreasing the transient effects of buses faults. This means an increased stability compared with the high transient when the PV plant is not connected. The connection of the PV plant has caused the injection of some voltage harmonics that started to spread over the network. However, the amount of generated harmonics was within the international limits stated by different standards. Tuned filters for the dominant harmonics were installed on the connection buses to cancel these harmonics. Analyses have shown that these filters were able to reduce the harmonics significantly.

From the work done in this thesis it can be concluded that the addition of support PV power generation of 14 MW increases the efficiency of the Houn power station and improves the voltage profile of all station buses. After applying a fault at 66 kV and 11 kV busses, it’s found that the PV system is capable to develop the voltage steady and dynamic state stability of Houn power distribution station. The PV system responded to the faults by sharing in the voltage recovery during the fault and after it. No system tripping was detected throughout or after the disturbance.

7.2 Future Work

Any scientific research can’t cover all aspects and investigates all important points at once; some points need to be reinvestigated and studied in future works. Separately from the studies applied in the course of this thesis work; that seems to be of the highest importance, further studies of the impact of the solar systems on the connected power systems and distribution stations needs to be penetrated. After the integration of DG stations, power flow becomes bi-directional. In this case, different protection and interruption systems need to be studied and introduced into the stations. Future works that are recommended in other stages of this work are:

1- The reliability analysis on the distribution station of the security and adequacy of the proposed system especially keeping in mind the intermittent function of PV stations.

2- Further studies on the protection profile after the injection of PV generators.

3- The frequency stability of the power station under the effects of PV systems.

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APPENDICES

APPENDIX 1

HOUN SUBSTATION LOADS

MEDIUM VOLTAGE NETWORK MANAGEMENT CONSOLE

DETECTING LOADS TRANSFORMERS (66/30/11 kV)

	SUB STATION	NUMBER	VOLTAGE	CAPACITY MVA	MW	TOTAL
1	HOUN	1	66/11	20	7	9
		2	66/11	20	2	
2	ALKAEDA	1	66/11	20	5	16
		2	66/11	20	11	
3	WEDDAN	1	66/11	20	3.5	9
		2	66/11	20	5.5	
4	ALFORJAN	1	66/11	15	6	12
		2	66/11	15	6	
5	ALKASEER	1	66/11	20	3	3
		2	66/11	20	0	
6	ZALLA	1	66/11	10	5	7
		2	66/11	10	2	
7	ZALLA ROAD TRANSFORMER	1	66/11	10	6	6
8	HOUN 220	1	66/11	10	0	0

APPENDIX 2

MODULE DATASHEET

Suniva® ART245-60 Monocrystalline Solar Modules

ELECTRICAL DATA (NOMINAL)

The electrical data apply to standard test conditions (STC): Irradiance of 1000 W/m² with AM 1.5 spectra at 25°C.

Power Classification (Max.)	Pmax (W)	235	240	245
Voltage at Max. Power Point	Vmp (V)	30.00	30.40	30.90
Current at Max. Power Point	Imp (A)	7.84	7.89	7.95
Open Circuit Voltage	Voc (V)	37.30	37.30	37.40
Short Circuit Current	Isc (A)	8.38	8.44	8.49

The rated power may only vary by -0/+4.99 Wp and all other electrical parameters by ± 5%.

DIMENSIONS AND WEIGHTS

Cells / Module	60
Module Dimensions	1657 x 987 mm; 65.24 x 38.86 in.
Module Thickness (Depth)	42 mm; 1.65 in.
Approximate Weight	19 kg; 42 lbs.

CHARACTERISTIC DATA

Type of Solar Cell	High-efficiency Suniva® 3 busbar monocrystalline cells of 156 x 156 mm
Frame	Silver anodized aluminum alloy
Glass	Anti-reflective coating, tempered & low-iron
Junction Box	IP67 rated; IEC & UL listed; with internal bypass diodes
Cable & Connectors	4 mm² cable with MC4 connectors; cable length approximately 1 m

TEMPERATURE COEFFICIENTS

Voltage	β, Voc (%/°C)	-0.332
Current	α, Isc (%/°C)	+0.036
Power	γ, Pmax (%/°C)	-0.460

LIMITS

Max. System Voltage	1000 VDC
Operating Module Temperature	-40°C to +90°C
Storm Resistance	Tested to IEC 61215 for wind loads of 5400 Pa (204 mph)

Suniva® reserves the right to change the data at any time.

Suniva
The Brilliance of Solar Made Sensible

Mixed Sources FSC

Please recycle.

10/06/10

APPENDIX 3

ABB CENTRAL INVERTER

ABB central inverters
PVS800
100 to 1000 kW

Technical data and types

Type designation PVS800-57	-0100kW-A 100 kW	-0250kW-A 250 kW	-0315kW-B 315 kW	-0500kW-A 500 kW	-0630kW-B 630 kW	-0875kW-B 875 kW	-1000kW-C 1000 kW
Input (DC)							
Maximum input power ($P_{PV,max}$) [1]	120 kWp	300 kWp	378 kWp	600 kWp	756 kWp	1050 kWp	1200 kWp
DC voltage range, mpp ($U_{DC,mpp}$)	450 to 825 V	450 to 825 V	525 to 825 V	450 to 825 V	525 to 825 V	525 to 825 V	600 to 850 V
Maximum DC voltage ($U_{max(DC)}$)	1000 V	1000 V	1000 V	1100 V	1100 V	1100 V	1100 V
Maximum DC current ($I_{max(DC)}$)	245 A	600 A	615 A	1145 A	1230 A	1710 A	1710 A
Number of protected DC inputs	1 (+/-) /4 [2]	2, 4, 8 (+/-)	2, 4, 8 (+/-)	4 to 15 (+/-)	4 to 15 (+/-)	8 to 20 (+/-)	8 to 20 (+/-)
Output (AC)							
Nominal power ($P_{N(AC)}$) [3]	100 kW	250 kW	315 kW	500 kW	630 kW	875 kW	1000 kW
Maximum output power [4]	100 kW	250 kW	345 kW	600 kW	700 kW	1050 kW	1200 kW
Power at cosφ = 0.95 [3]	96 kW	240 kW	300 kW	475 kW	600 kW	830 kW	950 kW
Nominal AC current ($I_{N(AC)}$)	195 A	485 A	520 A	965 A	1040 A	1445 A	1445 A
Nominal output voltage ($U_{N(AC)}$) [5]	300 V	300 V	350 V	300 V	350 V	350 V	400 V
Output frequency	50/60 Hz	50/60 Hz	50/60 Hz	50/60 Hz	50/60 Hz	50/60 Hz	50/60 Hz
Harmonic distortion, current [6]	< 3%	< 3%	< 3%	< 3%	< 3%	< 3%	< 3%
Distribution network type [7]	TN and IT	TN and IT	TN and IT	TN and IT	TN and IT	TN and IT	TN and IT
Efficiency							
Maximum [8]	98.0%	98.0%	98.6%	98.6%	98.6%	98.7%	98.8%
Euro-eta [8]	97.5%	97.6%	98.3%	98.2%	98.4%	98.5%	98.6%
Power consumption							
Own consumption in operation	310 W	310 W	310 W	490 W	490 W	650 W	650 W
Standby operation consumption	60 W	60 W	60 W	65 W	65 W	65 W	65 W
External auxiliary voltage [9]	230 V, 50 Hz	230 V, 50 Hz	230 V, 50 Hz	230 V, 50 Hz	230 V, 50 Hz	230 V, 50 Hz	230 V, 50 Hz
Dimensions and weight							
Width/Height/Depth, mm (W/H/D)	1030/2130/690	1830/2130/680	1830/2130/680	2630/2130/708	2630/2130/708	3630/2130/708	3630/2130/708
Weight appr. [10]	550	1100	1100	1800	1800	2320	2320

[1] Recommended maximum input power
[2] Optional MCB inputs, 80 A inputs
[3] 100 and 250 kW units at 40 °C. 315 and 630 kW at 45 °C. 500, 875 and 1000 kW at 50 °C.
[4] At 25 °C. See the user manual for details.
[5] +/- 10%
[6] At nominal power
[7] Inverter side must be IT type
[8] Without auxiliary power consumption at min U_{DC}
[9] 115 V, 60 Hz optional
[10] For the smallest number of protected inputs. See the user manual for details.

APPENDIX 4
LOAD FLOW ANALYSIS WITHOUT PV

Project:	MASTER THESIS	ETAP		Page:	1
Location:	HOUN CITY - LIBYA	12.6.0H		Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department			SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case:	LF	Revision:	Base
Filename:	HOUN SUBSTATION 220kV			Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Load Flow Analysis (Without PV)

Loading Category (1): Design

Generation Category (1): Design

Load Diversity Factor: None

	Swing	V-Control	Load	Total
Number of Buses:	3	0	26	29

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of Branches:	15	0	0	14	0	0	29

Method of Solution:	Adaptive Newton-Raphson Method
Maximum No. of Iteration:	99
Precision of Solution:	0.0001000
System Frequency:	50.00 Hz
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus1	66.000	1	99.4	-4.2								
Bus2	66.000	2	99.1	-1.2								
Bus3	220.000	1	100.0	0.0								
Bus4	220.000	3	100.0	0.0								
Bus5	220.000	2	100.0	0.0								
Bus6	11.000	1	98.3	-4.2	0.000	0.995	0.000	0.249				
Bus7	66.000	2	99.0	-1.2								
Bus8	66.000	1	99.3	-4.3								
Bus9	11.000	2	98.4	-1.8	1.600	0.992	0.400	0.248				
Bus10	11.000	1	98.0	-6.3	5.600	3.471	1.400	0.868				
Bus13	66.000	1	98.6	-4.7								
Bus14	66.000	2	98.2	-1.7								
Bus15	11.000	1	99.0	-7.6	4.800	2.975	1.200	0.744				
Bus16	11.000	2	98.6	-4.7	4.800	2.975	1.200	0.744				
Bus17	66.000	1	99.2	-5.9								
Bus18	66.000	2	99.0	-1.6								
Bus19	11.000	1	99.0	-7.5	4.400	0.000	1.100	0.000				
Bus20	11.000	2	98.9	-2.6	2.800	0.000	0.700	0.000				
Bus21	66.000	1	99.2	-6.5								
Bus22	11.000	1	98.7	-9.4	4.800	0.000	1.200	0.000				
Bus23	66.000	1	99.5	-6.9								
Bus25	11.000	1	98.4	-7.9	1.600	0.991	0.400	0.248				
Bus27	66.000	1	99.1	-4.9								
Bus28	11.000	1	98.7	-5.8	2.400	1.487	0.600	0.372				
Bus29	11.000	1	98.7	-5.8	2.400	1.487	0.600	0.372				
Bus30	66.000	1	98.8	-4.6								
Bus31	66.000	2	98.8	-1.4								
Bus32	11.000	1	98.3	-7.8	8.800	5.455	2.200	1.364				
Bus33	11.000	2	100.7	-2.8	4.000	2.479	1.000	0.620				
Total Number of Buses: 29					47.999	23.307	12.000	5.827	0.000	0.000	0.000	0.000

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus3	220.000	Swing	1	100.0	0.0					
Bus4	220.000	Swing	3	100.0	0.0					
Bus5	220.000	Swing	2	100.0	0.0					
						0.000	0.000			

Line/Cable Input Data

Line/Cable			Length				Ohms or Siemens/1000 m per Conductor (Cable) or per Phase (Line)		
ID	Library	Size	Adj. (m)	% Tol.	#Phase	T (°C)	R	X	Y
Line1		674	19300.0	0.0	1	75	0.056003	0.374255	0.0000031
Line2		674	19300.0	0.0	1	75	0.056001	0.342069	0.0000034
Line3		674	23000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line4		674	15000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line5		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line6		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line7		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line8		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line9		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line10		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line11		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line12		674	21000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line13		674	161000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line14		674	140000.0	0.0	1	75	0.056001	0.342069	0.0000034

Line / Cable resistances are listed at the specified temperatures.

Project:	MASTER THESIS	ETAP	Page:	6
Location:	HOUN CITY - LIBYA	12.6.0H	Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department		SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case: LF	Revision:	Base
Filename:	HOUN SUBSTATION 220kV		Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

2-Winding Transformer Input Data

Transformer		Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	Phase	MVA	Prim. kV	Sec. kV	% Z1	X1/R1	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
T1	3-Phase	63.000	220.000	66.000	12.50	45.00	0	0	0	0	3.750	12.5000	Dyn	0.000
T3	3-Phase	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0.625	12.5000	Dyn	0.000
T4	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T5	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T6	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	1.250	10.0000	Dyn	0.000
T9	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500	Dyn	0.000
T10	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500	Dyn	0.000
T11	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T12	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T13	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T14	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T16	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000	Dyn	0.000
T17	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000	Dyn	0.000
T18	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000	Dyn	0.000
T19	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000	Dyn	0.000

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.46	20.58	20.59	
T3	2W XFMR	Bus5	Bus2	0.44	19.96	19.97	
T4	2W XFMR	Bus1	Bus6	6.40	83.25	83.50	
T5	2W XFMR	Bus7	Bus9	2.50	49.94	50.00	
T6	2W XFMR	Bus8	Bus10	2.53	50.56	50.63	
T9	2W XFMR	Bus13	Bus15	6.68	86.90	87.15	
T10	2W XFMR	Bus14	Bus16	6.68	86.90	87.15	
T11	2W XFMR	Bus17	Bus19	2.50	49.94	50.00	
T12	2W XFMR	Bus18	Bus20	2.50	49.94	50.00	
T13	2W XFMR	Bus21	Bus22	6.40	83.25	83.50	
T14	2W XFMR	Bus23	Bus25	6.40	83.25	83.50	
T16	2W XFMR	Bus27	Bus28	2.51	50.25	50.31	
T17	2W XFMR	Bus27	Bus29	2.51	50.25	50.31	
T18	2W XFMR	Bus30	Bus32	2.59	51.81	51.88	
T19	2W XFMR	Bus31	Bus33	2.59	51.81	51.88	
Line1	Line	Bus2	Bus14	2.48	16.58	16.77	0.2607629
Line2	Line	Bus1	Bus13	2.48	15.16	15.36	0.2842267
Line3	Line	Bus2	Bus18	2.96	18.06	18.30	0.3387157
Line4	Line	Bus27	Bus17	1.93	11.78	11.94	0.2209015
Line5	Line	Bus1	Bus27	1.03	6.28	6.37	0.1178142
Line6	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line7	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line8	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line9	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line10	Line	Bus2	Bus31	1.03	6.28	6.37	0.1178142
Line11	Line	Bus1	Bus30	1.03	6.28	6.37	0.1178142
Line12	Line	Bus17	Bus21	2.70	16.49	16.71	0.3092622
Line13	Line	Bus17	Bus23	20.70	126.43	128.11	2.3710100
Line14	Line	Bus21	Bus23	18.00	109.94	111.40	2.0617480

LOAD FLOW REPORT (Without PV)

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
Bus1	66.000	99.118	-5.1	0	0	0	0	Bus13	6.017	3.963	63.6	83.5	
								Bus27	19.518	1.155	172.6	99.8	
								Bus8	3.479	2.276	36.7	83.7	
								Bus8	3.479	2.276	36.7	83.7	
								Bus30	10.979	7.688	118.3	81.9	
								Bus3	-43.474	-18.606	417.3	91.9	3.750
								Bus6	0.001	1.247	11.0	0.1	
Bus2	66.000	98.852	-1.9	0	0	0	0	Bus14	6.009	3.992	63.8	83.3	
								Bus18	3.488	-0.246	30.9	-99.8	
								Bus7	0.994	0.572	10.1	86.7	
								Bus7	0.994	0.572	10.1	86.7	
								Bus31	5.022	3.198	52.7	84.4	
								Bus5	-16.507	-8.089	162.7	89.8	0.625
* Bus3	220.000	100.000	0.0	43.582	23.466	0	0	Bus1	43.582	23.466	129.9	88.0	
* Bus5	220.000	100.000	0.0	16.522	8.783	0	0	Bus2	16.522	8.783	49.1	88.3	
Bus6	11.000	98.071	-5.1	0	0	0.000	1.234	Bus1	0.000	-1.234	66.0	0.0	
Bus7	66.000	98.828	-1.9	0	0	0	0	Bus2	-0.994	-0.629	10.4	84.5	
								Bus2	-0.994	-0.629	10.4	84.5	
								Bus9	1.987	1.259	20.8	84.5	
Bus8	66.000	99.027	-5.2	0	0	0	0	Bus1	-3.478	-2.329	37.0	83.1	
								Bus1	-3.478	-2.329	37.0	83.1	
								Bus10	6.956	4.657	73.9	83.1	
Bus9	11.000	98.146	-2.5	0	0	1.986	1.231	Bus7	-1.986	-1.231	124.9	85.0	
Bus10	11.000	97.770	-7.2	0	0	6.938	4.301	Bus8	-6.938	-4.301	438.2	85.0	1.250
Bus13	66.000	98.344	-5.6	0	0	0	0	Bus1	-6.004	-4.158	65.0	82.2	
								Bus15	6.004	4.158	65.0	82.2	
Bus14	66.000	98.015	-2.4	0	0	0	0	Bus2	-5.996	-4.155	65.1	82.2	
								Bus16	5.996	4.155	65.1	82.2	
Bus15	11.000	98.692	-8.5	0	0	5.968	3.699	Bus13	-5.968	-3.699	373.4	85.0	4.375
Bus16	11.000	98.339	-5.4	0	0	5.960	3.694	Bus14	-5.960	-3.694	374.2	85.0	4.375
Bus17	66.000	98.917	-6.8	0	0	0	0	Bus27	-13.472	2.810	121.7	-97.9	
								Bus21	6.602	-1.319	59.5	-98.1	
								Bus23	1.390	-1.644	19.0	-64.6	
								Bus29	5.480	0.153	48.5	100.0	
Bus18	66.000	98.765	-2.3	0	0	0	0	Bus2	-3.484	-0.062	30.9	100.0	
								Bus20	3.484	0.062	30.9	100.0	

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
Bus19	11.000	98.740	-8.4	0	0	5.472	0.000	Bus17	-5.472	0.000	290.9	100.0	
Bus20	11.000	98.661	-3.3	0	0	3.481	0.000	Bus18	-3.481	0.000	185.2	100.0	
Bus21	66.000	98.938	-7.5	0	0	0	0	Bus17	-6.590	1.092	59.1	-98.7	
								Bus23	0.604	-1.398	13.5	-39.6	
								Bus22	5.986	0.306	53.0	99.9	
Bus22	11.000	98.422	-10.4	0	0	5.962	0.000	Bus21	-5.962	0.000	318.0	100.0	
Bus23	66.000	99.263	-7.9	0	0	0	0	Bus17	-1.385	-0.656	13.5	90.4	
								Bus21	-0.603	-0.621	7.6	69.6	
								Bus25	1.988	1.277	20.8	84.1	
Bus25	11.000	98.077	-8.8	0	0	1.984	1.230	Bus23	-1.984	-1.230	124.9	85.0	
Bus27	66.000	98.847	-5.8	0	0	0	0	Bus17	13.509	-2.797	122.1	-97.9	
								Bus1	-19.478	-1.026	172.6	99.9	
								Bus28	2.984	1.912	31.4	84.2	
								Bus29	2.984	1.912	31.4	84.2	
Bus28	11.000	98.428	-6.7	0	0	2.981	1.848	Bus27	-2.981	-1.848	187.0	85.0	0.625
Bus29	11.000	98.428	-6.7	0	0	2.981	1.848	Bus27	-2.981	-1.848	187.0	85.0	0.625
Bus30	66.000	98.515	-5.5	0	0	0	0	Bus1	-10.961	-7.688	118.9	81.9	
								Bus32	10.961	7.688	118.9	81.9	
Bus31	66.000	98.594	-2.1	0	0	0	0	Bus2	-5.019	-3.290	53.2	83.6	
								Bus33	5.019	3.290	53.2	83.6	
Bus32	11.000	98.056	-8.7	0	0	10.914	6.765	Bus30	-10.914	-6.765	687.5	85.0	3.750
Bus33	11.000	100.463	-3.5	0	0	5.009	3.105	Bus31	-5.009	-3.105	307.9	85.0	3.750

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# indicates a bus with a load mismatch of more than 0.1 MVA

Bus Loading Summary Report

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent Loading
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	
Bus4	220.000										0	0.0	0.0	
Bus1	66.000		0	0	0	0	0	0	0	0	47.288	91.9	417.3	
Bus2	66.000		0	0	0	0	0	0	0	0	18.492	89.5	163.6	
Bus3	220.000		0	0	0	0	0	0	0	0	49.498	88.0	129.9	
Bus5	220.000		0	0	0	0	0	0	0	0	18.712	88.3	49.1	
Bus6	11.000		0	0.995	0	0.239	0	0	0	0	1.234	0.0	66.0	
Bus7	66.000		0	0	0	0	0	0	0	0	2.352	84.5	20.8	
Bus8	66.000		0	0	0	0	0	0	0	0	8.371	83.1	73.9	
Bus9	11.000		1.600	0.992	0.385	0.239	0	0	0	0	2.336	85.0	124.9	
Bus10	11.000		5.600	3.471	1.338	0.830	0	0	0	0	8.163	85.0	438.2	
Bus13	66.000		0	0	0	0	0	0	0	0	7.303	82.2	65.0	
Bus14	66.000		0	0	0	0	0	0	0	0	7.294	82.2	65.1	
Bus15	11.000		4.800	2.975	1.169	0.724	0	0	0	0	7.022	85.0	373.4	
Bus16	11.000		4.800	2.975	1.160	0.719	0	0	0	0	7.012	85.0	374.2	
Bus17	66.000		0	0	0	0	0	0	0	0	13.794	97.7	122.0	
Bus18	66.000		0	0	0	0	0	0	0	0	3.485	100.0	30.9	
Bus19	11.000		4.400	0	1.072	0	0	0	0	0	5.472	100.0	290.9	
Bus20	11.000		2.800	0	0.681	0	0	0	0	0	3.481	100.0	185.2	
Bus21	66.000		0	0	0	0	0	0	0	0	6.736	97.8	59.6	
Bus22	11.000		4.800	0	1.162	0	0	0	0	0	5.962	100.0	318.0	
Bus23	66.000		0	0	0	0	0	0	0	0	2.363	84.1	20.8	
Bus25	11.000		1.600	0.991	0.385	0.238	0	0	0	0	2.334	85.0	124.9	
Bus27	66.000		0	0	0	0	0	0	0	0	19.850	98.1	175.7	
Bus28	11.000		2.400	1.487	0.581	0.360	0	0	0	0	3.507	85.0	187.0	
Bus29	11.000		2.400	1.487	0.581	0.360	0	0	0	0	3.507	85.0	187.0	
Bus30	66.000		0	0	0	0	0	0	0	0	13.388	81.9	118.9	
Bus31	66.000		0	0	0	0	0	0	0	0	6.001	83.6	53.2	
Bus32	11.000		8.800	5.455	2.114	1.311	0	0	0	0	12.841	85.0	687.5	
Bus33	11.000		4.000	2.479	1.009	0.626	0	0	0	0	5.893	85.0	307.9	

* 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).

Project:	MASTER THESIS	**ETAP**	**Page:**	11
Location:	HOUN CITY - LIBYA	12.6.0H	**Date:**	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department		**SN:**	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case: LF	**Revision:**	Base
Filename:	HOUN SUBSTATION 220kV		**Config:**	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Branch Loading Summary Report

CKT / Branch		Cable & Reactor			Transformer				
						Loading (input)		Loading (output)	
ID	Type	Ampacity (Amp)	Loading Amp	%	Capability (MVA)	MVA	%	MVA	%
T1	Transformer				63.000	49.498	78.6	47.288	75.1
T3	Transformer				63.000	18.712	29.7	18.382	29.2
T4	Transformer				10.000	1.247	12.5	1.234	12.3
T5	Transformer				20.000	2.352	11.8	2.336	11.7
T6	Transformer				20.000	8.371	41.9	8.163	40.8
T9	Transformer				10.000	7.303	73.0	7.022	70.2
T10	Transformer				10.000	7.294	72.9	7.012	70.1
T11	Transformer				20.000	5.482	27.4	5.472	27.4
T12	Transformer				20.000	3.485	17.4	3.481	17.4
T13	Transformer				10.000	5.994	59.9	5.962	59.6
T14	Transformer				10.000	2.363	23.6	2.334	23.3
T16	Transformer				20.000	3.544	17.7	3.507	17.5
T17	Transformer				20.000	3.544	17.7	3.507	17.5
T18	Transformer				20.000	13.388	66.9	12.841	64.2
T19	Transformer				20.000	6.001	30.0	5.893	29.5

* Indicates a branch with operating load exceeding the branch capability.

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	6.017	3.963	-6.004	-4.158	13.4	-195.2	99.1	98.3	0.77
Line5	19.518	1.155	-19.478	-1.026	40.0	129.1	99.1	98.8	0.27
Line7	3.479	2.276	-3.478	-2.329	0.9	-52.3	99.1	99.0	0.09
Line9	3.479	2.276	-3.478	-2.329	0.9	-52.3	99.1	99.0	0.09
Line11	10.979	7.688	-10.961	-7.688	18.9	0.4	99.1	98.5	0.60
T1	-43.474	-18.606	43.582	23.466	108.0	4859.9	99.1	100.0	0.88
T4	0.001	1.247	0.000	-1.234	1.0	13.2	99.1	98.1	1.05
Line1	6.009	3.992	-5.996	-4.155	13.5	-162.6	98.9	98.0	0.84
Line3	3.488	-0.246	-3.484	-0.062	3.7	-308.2	98.9	98.8	0.09
Line6	0.994	0.572	-0.994	-0.629	0.1	-57.1	98.9	98.8	0.02
Line8	0.994	0.572	-0.994	-0.629	0.1	-57.1	98.9	98.8	0.02
Line10	5.022	3.198	-5.019	-3.290	3.8	-91.8	98.9	98.6	0.26
T3	-16.507	-8.089	16.522	8.783	15.4	694.5	98.9	100.0	1.15
T5	1.987	1.259	-1.986	-1.231	1.4	28.3	98.8	98.1	0.68
T6	6.956	4.657	-6.938	-4.301	17.8	356.9	99.0	97.8	1.26
T9	6.004	4.158	-5.968	-3.699	35.3	459.1	98.3	98.7	0.35
T10	5.996	4.155	-5.960	-3.694	35.5	461.1	98.0	98.3	0.32
Line4	-13.472	2.810	13.509	-2.797	37.4	12.8	98.9	98.8	0.07
Line12	6.602	-1.319	-6.590	1.092	12.4	-226.9	98.9	98.9	0.02
Line13	1.390	-1.644	-1.385	-0.656	4.6	-2300.1	98.9	99.3	0.35
T11	5.480	0.153	-5.472	0.000	7.7	153.4	98.9	98.7	0.18
T12	3.484	0.062	-3.481	0.000	3.1	62.2	98.8	98.7	0.10
Line14	0.604	-1.398	-0.603	-0.621	0.9	-2019.1	98.9	99.3	0.32
T13	5.986	0.306	-5.962	0.000	23.5	305.5	98.9	98.4	0.52
T14	1.988	1.277	-1.984	-1.230	3.6	47.2	99.3	98.1	1.19
T16	2.984	1.912	-2.981	-1.848	3.2	64.2	98.8	98.4	0.42
T17	2.984	1.912	-2.981	-1.848	3.2	64.2	98.8	98.4	0.42
T18	10.961	7.688	-10.914	-6.765	46.1	922.2	98.5	98.0	0.48
T19	5.019	3.290	-5.009	-3.105	9.2	185.0	98.6	100.5	1.87
					464.8	3296.6			

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 Report

Device ID	Type	Condition	Rating/Limit	Unit	Operating	% Operating	Phase Type
Bus10	Bus	Under Voltage	11.00	kV	10.75	97.8	3-Phase

SUMMARY OF TOTAL GENERATION, LOADING & DEMAND

	MW	Mvar	MVA	% PF
Source (Swing Buses):	60.104	32.249	68.209	88.12 Lagging
Source (Non-Swing Buses):	0.000	0.000	0.000	
Total Demand:	60.104	32.249	68.209	88.12 Lagging
Total Motor Load:	47.999	23.307	53.358	89.96 Lagging
Total Static Load:	11.640	5.646	12.937	89.97 Lagging
Total Constant I Load:	0.000	0.000	0.000	
Total Generic Load:	0.000	0.000	0.000	
Apparent Losses:	0.465	3.297		
System Mismatch:	0.000	0.000		

Number of Iterations: 2

APPENDIX 5
LOAD FLOW ANALYSIS WITH PV

Project:	MASTER THESIS	ETAP		Page:	1
Location:	HOUN CITY - LIBYA	12.6.0H		Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department			SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case:	LF	Revision:	Base
Filename:	HOUN SUBSTATION 220kV			Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Load Flow Analysis (With PV)

Loading Category (1): Design

Generation Category (1): Design

Load Diversity Factor: None

	Swing	V-Control	Load	Total
Number of Buses:	3	7	30	40

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of Branches:	24	0	0	16	0	0	40

Method of Solution:	Adaptive Newton-Raphson Method
Maximum No. of Iteration:	99
Precision of Solution:	0.0001000
System Frequency:	50.00 Hz
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus1	66.000	1	99.1	-5.1								
Bus2	66.000	2	98.9	-1.9								
Bus3	220.000	1	100.0	0.0								
Bus4	220.000	3	100.0	0.0								
Bus5	220.000	2	100.0	0.0								
Bus6	11.000	1	98.1	-5.1	0.000	0.995	0.000	0.249				
Bus7	66.000	2	98.8	-1.9								
Bus8	66.000	1	99.0	-5.2								
Bus9	11.000	2	98.1	-2.5	1.600	0.992	0.400	0.248				
Bus10	11.000	1	97.8	-7.2	5.600	3.471	1.400	0.868				
Bus11	66.000	2	99.1	-1.2								
Bus12	66.000	1	99.4	-4.2								
Bus13	66.000	1	98.3	-5.6								
Bus14	66.000	2	98.0	-2.4								
Bus15	11.000	1	98.7	-8.5	4.800	2.975	1.200	0.744				
Bus16	11.000	2	98.3	-5.4	4.800	2.975	1.200	0.744				
Bus17	66.000	1	98.9	-6.8								
Bus18	66.000	2	98.8	-2.3								
Bus19	11.000	1	98.7	-8.4	4.400	0.000	1.100	0.000				
Bus20	11.000	2	98.7	-3.3	2.800	0.000	0.700	0.000				
Bus21	66.000	1	98.9	-7.5								
Bus22	11.000	1	98.4	-10.4	4.800	0.000	1.200	0.000				
Bus23	66.000	1	99.3	-7.9								
Bus25	11.000	1	98.1	-8.8	1.600	0.991	0.400	0.248				
Bus27	66.000	1	98.8	-5.8								
Bus28	11.000	1	98.4	-6.7	2.400	1.487	0.600	0.372				
Bus29	11.000	1	98.4	-6.7	2.400	1.487	0.600	0.372				
Bus30	66.000	1	98.5	-5.5								
Bus31	66.000	2	98.6	-2.1								
Bus32	11.000	1	98.0	-8.7	8.800	5.455	2.200	1.364				
Bus33	11.000	2	100.5	-3.5	4.000	2.479	1.000	0.620				
Bus34	0.400	1	100.0	1.1								
Bus35	0.400	1	100.0	1.1								

Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus36	0.400	1	100.0	1.1								
Bus37	0.400	1	100.0	1.1								
Bus38	0.400	2	100.0	3.3								
Bus39	0.400	2	100.0	3.3								
Bus40	0.400	2	100.0	3.3								
Bus41	11.000	1	98.9	-1.2								
Bus42	11.000	2	98.6	1.0								
Total Number of Buses: 40					47.999	23.307	12.000	5.827	0.000	0.000	0.000	0.000

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus3	220.000	Swing	1	100.0	0.0					
Bus4	220.000	Swing	3	100.0	0.0					
Bus5	220.000	Swing	2	100.0	0.0					
Bus34	0.400	Voltage Control	1	100.0	1.1	1.960			0.899	0.000
Bus35	0.400	Voltage Control	1	100.0	1.1	1.960			0.899	0.000
Bus36	0.400	Voltage Control	1	100.0	1.1	1.960			0.899	0.000
Bus37	0.400	Voltage Control	1	100.0	1.1	1.960			0.899	0.000
Bus38	0.400	Voltage Control	2	100.0	3.3	1.960			0.899	0.000
Bus39	0.400	Voltage Control	2	100.0	3.3	1.960			0.899	0.000
Bus40	0.400	Voltage Control	2	100.0	3.3	1.960			0.899	0.000
						13.719	0.000			

Line/Cable Input Data

Line/Cable			Length				Ohms or Siemens/1000 m per Conductor (Cable) or per Phase (Line)		
ID	Library	Size	Adj. (m)	% Tol.	#Phase	T (°C)	R	X	Y
Cable1	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646
Cable2	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646
Line1		674	19300.0	0.0	1	75	0.056003	0.374255	0.0000031
Line2		674	19300.0	0.0	1	75	0.056001	0.342069	0.0000034
Line3		674	23000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line4		674	15000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line5		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line6		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line7		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line8		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line9		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line10		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line11		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line12		674	21000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line13		674	161000.0	0.0	1	75	0.056001	0.342069	0.0000034
Line14		674	140000.0	0.0	1	75	0.056001	0.342069	0.0000034

Line / Cable resistances are listed at the specified temperatures.

2-Winding Transformer Input Data

Transformer		Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	Phase	MVA	Prim. kV	Sec. kV	% Z1	X1/R1	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
T1	3-Phase	63.000	220.000	66.000	12.50	45.00	0	0	0	0	3.750	12.5000	Dyn	0.000
T3	3-Phase	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0.625	12.5000	Dyn	0.000
T4	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T5	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T6	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	1.250	10.0000	Dyn	0.000
T7	3-Phase	12.500	11.000	66.000	8.35	13.00	0	0	0	-1.250	0	8.3500	YNd	0.000
T8	3-Phase	12.500	11.000	66.000	8.35	13.00	0	0	0	-1.250	0	8.3500	YNd	0.000
T9	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500	Dyn	0.000
T10	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500	Dyn	0.000
T11	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T12	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T13	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T14	3-Phase	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T16	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000	Dyn	0.000
T17	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000	Dyn	0.000
T18	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000	Dyn	0.000
T19	3-Phase	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000	Dyn	0.000
T20	3-Phase	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T21	3-Phase	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T22	3-Phase	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T23	3-Phase	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T24	3-Phase	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T25	3-Phase	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T26	3-Phase	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.46	20.58	20.59	
T3	2W XFMR	Bus5	Bus2	0.44	19.96	19.97	
T4	2W XFMR	Bus1	Bus6	6.40	83.25	83.50	
T5	2W XFMR	Bus7	Bus9	2.50	49.94	50.00	
T6	2W XFMR	Bus8	Bus10	2.53	50.56	50.63	
T7	2W XFMR	Bus42	Bus11	5.06	65.77	65.97	
T8	2W XFMR	Bus41	Bus12	5.06	65.77	65.97	
T9	2W XFMR	Bus13	Bus15	6.68	86.90	87.15	
T10	2W XFMR	Bus14	Bus16	6.68	86.90	87.15	
T11	2W XFMR	Bus17	Bus19	2.50	49.94	50.00	
T12	2W XFMR	Bus18	Bus20	2.50	49.94	50.00	
T13	2W XFMR	Bus21	Bus22	6.40	83.25	83.50	
T14	2W XFMR	Bus23	Bus25	6.40	83.25	83.50	
T16	2W XFMR	Bus27	Bus28	2.51	50.25	50.31	
T17	2W XFMR	Bus27	Bus29	2.51	50.25	50.31	
T18	2W XFMR	Bus30	Bus32	2.59	51.81	51.88	
T19	2W XFMR	Bus31	Bus33	2.59	51.81	51.88	
T20	2W XFMR	Bus34	Bus41	34.25	205.50	208.33	
T21	2W XFMR	Bus35	Bus41	34.25	205.50	208.33	
T22	2W XFMR	Bus36	Bus41	34.25	205.50	208.33	
T23	2W XFMR	Bus37	Bus41	34.25	205.50	208.33	
T24	2W XFMR	Bus38	Bus42	34.25	205.50	208.33	
T25	2W XFMR	Bus39	Bus42	34.25	205.50	208.33	
T26	2W XFMR	Bus40	Bus42	34.25	205.50	208.33	
Cable1	Cable	Bus11	Bus2	0.02	0.02	0.03	0.0716998
Cable2	Cable	Bus12	Bus1	0.02	0.02	0.03	0.0716998
Line1	Line	Bus2	Bus14	2.48	16.58	16.77	0.2607629
Line2	Line	Bus1	Bus13	2.48	15.16	15.36	0.2842267
Line3	Line	Bus2	Bus18	2.96	18.06	18.30	0.3387157
Line4	Line	Bus27	Bus17	1.93	11.78	11.94	0.2209015
Line5	Line	Bus1	Bus27	1.03	6.28	6.37	0.1178142
Line6	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line7	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line8	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line9	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line10	Line	Bus2	Bus31	1.03	6.28	6.37	0.1178142
Line11	Line	Bus1	Bus30	1.03	6.28	6.37	0.1178142

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
ID	Type	From Bus	To Bus	R	X	Z	Y
Line12	Line	Bus17	Bus21	2.70	16.49	16.71	0.3092622
Line13	Line	Bus17	Bus23	20.70	126.43	128.11	2.3710100
Line14	Line	Bus21	Bus23	18.00	109.94	111.40	2.0617480

LOAD FLOW REPORT (With PV)

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
Bus1	66.000	99.388	-4.2	0	0	0	0	Bus12	-7.754	-0.376	68.3	99.9	
								Bus13	6.024	3.964	63.5	83.5	
								Bus27	19.539	1.129	172.3	99.8	
								Bus8	3.483	2.278	36.6	83.7	
								Bus8	3.483	2.278	36.6	83.7	
								Bus30	10.992	7.691	118.1	81.9	
								Bus3	-35.767	-18.211	353.3	89.1	3.750
								Bus6	0.001	1.248	11.0	0.1	
Bus2	66.000	99.061	-1.2	0	0	0	0	Bus11	-5.821	-0.725	51.8	99.2	
								Bus14	6.014	3.993	63.7	83.3	
								Bus18	3.491	-0.248	30.9	-99.7	
								Bus7	0.994	0.573	10.1	86.7	
								Bus7	0.994	0.573	10.1	86.7	
								Bus31	5.027	3.200	52.6	84.4	
								Bus5	-10.700	-7.365	114.7	82.4	0.625
* Bus3	220.000	100.000	0.0	35.844	21.694	0	0	Bus1	35.844	21.694	110.0	85.6	
* Bus5	220.000	100.000	0.0	10.708	7.711	0	0	Bus2	10.708	7.711	34.6	81.1	
Bus6	11.000	98.343	-4.2	0	0	0.000	1.235	Bus1	0.000	-1.235	65.9	0.0	
Bus7	66.000	99.036	-1.2	0	0	0	0	Bus2	-0.994	-0.630	10.4	84.5	
								Bus2	-0.994	-0.630	10.4	84.5	
								Bus9	1.989	1.260	20.8	84.5	
Bus8	66.000	99.297	-4.3	0	0	0	0	Bus1	-3.482	-2.330	36.9	83.1	
								Bus1	-3.482	-2.330	36.9	83.1	
								Bus10	6.964	4.661	73.8	83.1	
Bus9	11.000	98.356	-1.8	0	0	1.987	1.232	Bus7	-1.987	-1.232	124.8	85.0	
Bus10	11.000	98.048	-6.3	0	0	6.946	4.305	Bus8	-6.946	-4.305	437.5	85.0	1.250
Bus11	66.000	99.062	-1.2	0	0	0	0	Bus2	5.821	0.654	51.7	99.4	
								Bus42	-5.821	-0.654	51.7	99.4	
Bus12	66.000	99.390	-4.2	0	0	0	0	Bus1	7.754	0.306	68.3	99.9	
								Bus41	-7.754	-0.306	68.3	99.9	
Bus13	66.000	98.615	-4.7	0	0	0	0	Bus1	-6.011	-4.161	64.8	82.2	
								Bus15	6.011	4.161	64.8	82.2	
Bus14	66.000	98.224	-1.7	0	0	0	0	Bus2	-6.001	-4.157	65.0	82.2	
								Bus16	6.001	4.157	65.0	82.2	
Bus15	11.000	98.983	-7.6	0	0	5.975	3.703	Bus13	-5.975	-3.703	372.8	85.0	4.375
Bus16	11.000	98.564	-4.7	0	0	5.965	3.697	Bus14	-5.965	-3.697	373.7	85.0	4.375

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
Bus17	66.000	99.192	-5.9	0	0	0	0	Bus27	-13.487	2.837	121.5	-97.9	
								Bus21	6.609	-1.333	59.5	-98.0	
								Bus23	1.391	-1.657	19.1	-64.3	
								Bus19	5.486	0.153	48.4	100.0	
Bus18	66.000	98.973	-1.6	0	0	0	0	Bus2	-3.487	-0.062	30.8	100.0	
								Bus20	3.487	0.062	30.8	100.0	
Bus19	11.000	99.016	-7.5	0	0	5.478	0.000	Bus17	-5.478	0.000	290.4	100.0	
Bus20	11.000	98.870	-2.6	0	0	3.484	0.000	Bus18	-3.484	0.000	185.0	100.0	
Bus21	66.000	99.215	-6.5	0	0	0	0	Bus17	-6.597	1.104	59.0	-98.6	
								Bus23	0.604	-1.409	13.5	-39.4	
								Bus22	5.992	0.304	52.9	99.9	
Bus22	11.000	98.700	-9.4	0	0	5.969	0.000	Bus21	-5.969	0.000	317.4	100.0	
Bus23	66.000	99.545	-6.9	0	0	0	0	Bus17	-1.387	-0.656	13.5	90.4	
								Bus21	-0.603	-0.622	7.6	69.6	
								Bus25	1.990	1.278	20.8	84.1	
Bus25	11.000	95.360	-7.9	0	0	1.987	1.231	Bus23	-1.987	-1.231	124.7	85.0	
Bus27	66.000	99.119	-4.9	0	0	0	0	Bus17	13.524	-2.826	121.9	-97.9	
								Bus1	-19.499	-1.001	172.5	99.9	
								Bus28	2.988	1.914	31.3	84.2	
								Bus29	2.988	1.914	31.3	84.2	
Bus28	11.000	98.703	-5.8	0	0	2.984	1.850	Bus27	-2.984	-1.850	186.7	85.0	0.625
Bus29	11.000	98.703	-5.8	0	0	2.984	1.850	Bus27	-2.984	-1.850	186.7	85.0	0.625
Bus30	66.000	98.787	-4.6	0	0	0	0	Bus1	-10.973	-7.692	118.7	81.9	
								Bus32	10.973	7.692	118.7	81.9	
Bus31	66.000	98.802	-1.4	0	0	0	0	Bus2	-5.023	-3.292	53.2	83.6	
								Bus33	5.023	3.292	53.2	83.6	
Bus32	11.000	98.326	-7.8	0	0	10.927	6.773	Bus30	-10.927	-6.773	686.2	85.0	3.750
Bus33	11.000	100.682	-2.8	0	0	5.014	3.108	Bus31	-5.014	-3.108	307.5	85.0	3.750
* Bus34	0.400	100.000	1.1	1.960	0.258	0	0	Bus41	1.960	0.258	2853.2	99.1	
* Bus35	0.400	100.000	1.1	1.960	0.258	0	0	Bus41	1.960	0.258	2853.2	99.1	
* Bus36	0.400	100.000	1.1	1.960	0.258	0	0	Bus41	1.960	0.258	2853.2	99.1	
* Bus37	0.400	100.000	1.1	1.960	0.258	0	0	Bus41	1.960	0.258	2853.2	99.1	
* Bus38	0.400	100.000	3.3	1.960	0.378	0	0	Bus42	1.960	0.378	2880.8	98.2	
* Bus39	0.400	100.000	3.3	1.960	0.378	0	0	Bus42	1.960	0.378	2880.8	98.2	
* Bus40	0.400	100.000	3.3	1.960	0.378	0	0	Bus42	1.960	0.378	2880.8	98.2	
Bus41	11.000	98.877	-1.2	0	0	0	0	Bus12	7.786	0.712	415.0	99.6	-1.250
								Bus34	-1.946	-0.178	103.8	99.6	
								Bus35	-1.946	-0.178	103.8	99.6	
								Bus36	-1.946	-0.178	103.8	99.6	

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
								Bus37	-1.946	-0.178	103.8	99.6	
Bus42	11.000	98.630	1.0	0	0	0	0	Bus11	5.838	0.887	314.3	98.9	-1.250
								Bus38	-1.946	-0.296	104.8	98.9	
								Bus39	-1.946	-0.296	104.8	98.9	
								Bus40	-1.946	-0.296	104.8	98.9	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# indicates a bus with a load mismatch of more than 0.1 MVA

Bus Loading Summary Report

Bus			Directly Connected Load								Total Bus Load			
			Constant kVA		Constant Z		Constant I		Generic					Percent Loading
ID	kV	Rated Amp	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	MVA	% PF	Amp	
Bus4	220.000										0	0.0	0.0	
Bus1	66.000		0	0	0	0	0	0	0	0	47.324	92.0	416.5	
Bus2	66.000		0	0	0	0	0	0	0	0	18.506	89.3	163.4	
Bus3	220.000		0	0	0	0	0	0	0	0	41.898	85.6	110.0	
Bus5	220.000		0	0	0	0	0	0	0	0	13.195	81.1	34.6	
Bus6	11.000		0	0.995	0	0.240	0	0	0	0	1.235	0.0	65.9	
Bus7	66.000		0	0	0	0	0	0	0	0	2.354	84.5	20.8	
Bus8	66.000		0	0	0	0	0	0	0	0	8.380	83.1	73.8	
Bus9	11.000		1.600	0.992	0.387	0.240	0	0	0	0	2.338	85.0	124.8	
Bus10	11.000		5.600	3.471	1.346	0.834	0	0	0	0	8.172	85.0	437.5	
Bus11	66.000		0	0	0	0	0	0	0	0	5.857	99.4	51.7	
Bus12	66.000		0	0	0	0	0	0	0	0	7.760	99.9	68.3	
Bus13	66.000		0	0	0	0	0	0	0	0	7.310	82.2	64.8	
Bus14	66.000		0	0	0	0	0	0	0	0	7.300	82.2	65.0	
Bus15	11.000		4.800	2.975	1.176	0.729	0	0	0	0	7.030	85.0	372.8	
Bus16	11.000		4.800	2.975	1.166	0.722	0	0	0	0	7.018	85.0	373.7	
Bus17	66.000		0	0	0	0	0	0	0	0	13.814	97.6	121.8	
Bus18	66.000		0	0	0	0	0	0	0	0	3.488	100.0	30.8	
Bus19	11.000		4.400	0	1.078	0	0	0	0	0	5.478	100.0	290.4	
Bus20	11.000		2.800	0	0.684	0	0	0	0	0	3.484	100.0	185.0	
Bus21	66.000		0	0	0	0	0	0	0	0	6.745	97.8	59.5	
Bus22	11.000		4.800	0	1.169	0	0	0	0	0	5.969	100.0	317.4	
Bus23	66.000		0	0	0	0	0	0	0	0	2.365	84.1	20.8	
Bus25	11.000		1.600	0.991	0.387	0.240	0	0	0	0	2.337	85.0	124.7	
Bus27	66.000		0	0	0	0	0	0	0	0	19.871	98.1	175.4	
Bus28	11.000		2.400	1.487	0.585	0.362	0	0	0	0	3.511	85.0	186.7	
Bus29	11.000		2.400	1.487	0.585	0.362	0	0	0	0	3.511	85.0	186.7	
Bus30	66.000		0	0	0	0	0	0	0	0	13.400	81.9	118.7	
Bus31	66.000		0	0	0	0	0	0	0	0	6.006	83.6	53.2	
Bus32	11.000		8.800	5.455	2.127	1.318	0	0	0	0	12.856	85.0	686.2	
Bus33	11.000		4.000	2.479	1.014	0.628	0	0	0	0	5.899	85.0	307.5	
Bus34	0.400		0	0	0	0	0	0	0	0	1.977	99.1	2853.2	
Bus35	0.400		0	0	0	0	0	0	0	0	1.977	99.1	2853.2	
Bus36	0.400		0	0	0	0	0	0	0	0	1.977	99.1	2853.2	
Bus37	0.400		0	0	0	0	0	0	0	0	1.977	99.1	2853.2	
Bus38	0.400		0	0	0	0	0	0	0	0	1.996	98.2	2880.8	

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
Bus39	0.400		0	0	0	0	0	0	0	0	1.996	98.2	2880.8	
Bus40	0.400		0	0	0	0	0	0	0	0	1.996	98.2	2880.8	
Bus41	11.000		0	0	0	0	0	0	0	0	7.818	99.6	415.0	
Bus42	11.000		0	0	0	0	0	0	0	0	5.906	98.9	314.3	

* 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).

Branch Loading Summary Report

CKT / Branch		Cable & Reactor			Transformer				
					Capability (MVA)	Loading (input)		Loading (output)	
ID	Type	Ampacity (Amp)	Loading Amp	%		MVA	%	MVA	%
Cable1	Cable	423.67	51.80	12.23					
Cable2	Cable	423.67	68.33	16.13					
T1	Transformer				63.000	41.898	66.5	40.136	63.7
T3	Transformer				63.000	13.195	20.9	12.990	20.6
T4	Transformer				10.000	1.248	12.5	1.235	12.4
T5	Transformer				20.000	2.354	11.8	2.338	11.7
T6	Transformer				20.000	8.380	41.9	8.172	40.9
T7	Transformer				12.500	5.906	47.2	5.857	46.9
T8	Transformer				12.500	7.818	62.5	7.760	62.1
T9	Transformer				10.000	7.310	73.1	7.030	70.3
T10	Transformer				10.000	7.300	73.0	7.018	70.2
T11	Transformer				20.000	5.488	27.4	5.478	27.4
T12	Transformer				20.000	3.488	17.4	3.484	17.4
T13	Transformer				10.000	6.000	60.0	5.969	59.7
T14	Transformer				10.000	2.365	23.7	2.337	23.4
T16	Transformer				20.000	3.548	17.7	3.511	17.6
T17	Transformer				20.000	3.548	17.7	3.511	17.6
T18	Transformer				20.000	13.400	67.0	12.856	64.3
T19	Transformer				20.000	6.006	30.0	5.899	29.5
T20	Transformer				3.000	1.977	65.9	1.955	65.2
T21	Transformer				3.000	1.977	65.9	1.955	65.2
T22	Transformer				3.000	1.977	65.9	1.955	65.2
T23	Transformer				3.000	1.977	65.9	1.955	65.2
T24	Transformer				3.000	1.996	66.5	1.969	65.6
T25	Transformer				3.000	1.996	66.5	1.969	65.6
T26	Transformer				3.000	1.996	66.5	1.969	65.6

* Indicates a branch with operating load exceeding the branch capability.

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
Cable2	-7.754	-0.376	7.754	0.306	0.1	-70.7	99.4	99.4	0.00
Line2	6.024	3.964	-6.011	-4.161	13.3	-197.1	99.4	98.6	0.77
Line5	19.539	1.129	-19.499	-1.001	39.9	127.6	99.4	99.1	0.27
Line7	3.483	2.278	-3.482	-2.330	0.9	-52.6	99.4	99.3	0.09
Line9	3.483	2.278	-3.482	-2.330	0.9	-52.6	99.4	99.3	0.09
Line11	10.992	7.691	-10.973	-7.692	18.8	-0.6	99.4	98.8	0.60
T1	-35.767	-18.211	35.844	21.694	77.4	3482.1	99.4	100.0	0.61
T4	0.001	1.248	0.000	-1.235	1.0	13.1	99.4	98.3	1.05
Cable1	-5.821	-0.725	5.821	0.654	0.1	-70.3	99.1	99.1	0.00
Line1	6.014	3.993	-6.001	-4.157	13.4	-163.9	99.1	98.2	0.84
Line3	3.491	-0.248	-3.487	-0.062	3.7	-309.6	99.1	99.0	0.09
Line6	0.994	0.573	-0.994	-0.630	0.1	-57.4	99.1	99.0	0.02
Line8	0.994	0.573	-0.994	-0.630	0.1	-57.4	99.1	99.0	0.02
Line10	5.027	3.200	-5.023	-3.292	3.8	-92.3	99.1	98.8	0.26
T3	-10.700	-7.365	10.708	7.711	7.7	345.4	99.1	100.0	0.94
T5	1.989	1.260	-1.987	-1.232	1.4	28.2	99.0	98.4	0.68
T6	6.964	4.661	-6.946	-4.305	17.8	355.6	99.3	98.0	1.25
T7	-5.821	-0.654	5.838	0.887	17.9	232.8	99.1	98.6	0.43
T8	-7.754	-0.306	7.786	0.712	31.2	406.1	99.4	98.9	0.51
T9	6.011	4.161	-5.975	-3.703	35.2	457.5	98.6	99.0	0.37
T10	6.001	4.157	-5.965	-3.697	35.4	459.8	98.2	98.6	0.34
Line4	-13.487	2.837	13.524	-2.826	37.3	11.0	99.2	99.1	0.07
Line12	6.609	-1.333	-6.597	1.104	12.4	-228.8	99.2	99.2	0.02
Line13	1.391	-1.657	-1.387	-0.656	4.6	-2313.2	99.2	99.5	0.35
T11	5.486	0.153	-5.478	0.000	7.6	152.9	99.2	99.0	0.18
T12	3.487	0.062	-3.484	0.000	3.1	62.0	99.0	98.9	0.10
Line14	0.604	-1.409	-0.603	-0.622	1.0	-2030.5	99.2	99.5	0.33
T13	5.992	0.304	-5.969	0.000	23.4	304.5	99.2	98.7	0.52
T14	1.990	1.278	-1.987	-1.231	3.6	47.0	99.5	98.4	1.18
T16	2.988	1.914	-2.984	-1.850	3.2	64.0	99.1	98.7	0.42
T17	2.988	1.914	-2.984	-1.850	3.2	64.0	99.1	98.7	0.42
T18	10.973	7.692	-10.927	-6.773	45.9	918.9	98.8	98.3	0.46
T19	5.023	3.292	-5.014	-3.108	9.2	184.5	98.8	100.7	1.88
T20	1.960	0.258	-1.946	-0.178	13.4	80.3	100.0	98.9	1.12
T21	1.960	0.258	-1.946	-0.178	13.4	80.3	100.0	98.9	1.12

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
T22	1.960	0.258	-1.946	-0.178	13.4	80.3	100.0	98.9	1.12
T23	1.960	0.258	-1.946	-0.178	13.4	80.3	100.0	98.9	1.12
T24	1.960	0.378	-1.946	-0.296	13.6	81.9	100.0	98.6	1.37
T25	1.960	0.378	-1.946	-0.296	13.6	81.9	100.0	98.6	1.37
T26	1.960	0.378	-1.946	-0.296	13.6	81.9	100.0	98.6	1.37
					569.1	2586.8			

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	

SUMMARY OF TOTAL GENERATION, LOADING & DEMAND

	MW	Mvar	MVA	% PF
Source (Swing Buses):	46.552	29.404	55.061	84.55 Lagging
Source (Non-Swing Buses):	13.719	2.166	13.889	98.78 Lagging
Total Demand:	60.271	31.570	68.039	88.58 Lagging
Total Motor Load:	47.999	23.307	53.358	89.96 Lagging
Total Static Load:	11.703	5.677	13.007	89.97 Lagging
Total Constant I Load:	0.000	0.000	0.000	
Total Generic Load:	0.000	0.000	0.000	
Apparent Losses:	0.569	2.587		
System Mismatch:	0.000	0.000		

Number of Iterations: 3

APPENDIX 6

SHORT CIRCUIT ANALYSIS WITHOUT PV

		ETAP		
Project:	MASTER THESIS	12.6.0H	Page:	1
Location:	HOUN CITY - LIBYA		Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department		SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case: SC	Revision:	Base
Filename:	HOUN SUBSTATION 220kV		Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Short-Circuit Analysis (Without PV)

IEC 60909 Standard
3-Phase Fault Currents

	Swing	V-Control	Load	Total
Number of Buses:	3	0	26	29

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of Branches:	15	0	0	14	0	0	29

	Synchronous Generator	Power Grid	Synchronous Motor	Induction Machines	Lumped Load	Total
Number of Machines:	0	3	0	0	13	16

System Frequency:	50.00 Hz
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus					Initial Voltage	
ID	Type	Nom. kV	Base kV	Sub-sys	%Mag.	Ang.
Bus1	Load	66.000	68.475	1	99.12	-5.13
Bus2	Load	66.000	66.413	2	98.85	-1.89
Bus3	SWNG	220.000	220.000	1	100.00	0.00
Bus4	SWNG	220.000	220.000	3	100.00	0.00
Bus5	SWNG	220.000	220.000	2	100.00	0.00
Bus6	Load	11.000	11.413	1	98.07	-5.08
Bus7	Load	66.000	66.413	2	98.83	-1.91
Bus8	Load	66.000	68.475	1	99.03	-5.19
Bus9	Load	11.000	11.069	2	98.15	-2.47
Bus10	Load	11.000	11.555	1	97.77	-7.20
Bus13	Load	66.000	68.475	1	98.34	-5.61
Bus14	Load	66.000	66.413	2	98.01	-2.42
Bus15	Load	11.000	11.912	1	98.69	-8.52
Bus16	Load	11.000	11.553	2	98.34	-5.35
Bus17	Load	66.000	68.475	1	98.92	-6.80
Bus18	Load	66.000	66.413	2	98.76	-2.26
Bus19	Load	11.000	11.413	1	98.74	-8.41
Bus20	Load	11.000	11.069	2	98.66	-3.28
Bus21	Load	66.000	68.475	1	98.94	-7.46
Bus22	Load	11.000	11.413	1	98.42	-10.38
Bus23	Load	66.000	68.475	1	99.26	-7.89
Bus25	Load	11.000	11.413	1	98.08	-8.81
Bus27	Load	66.000	68.475	1	98.85	-5.84
Bus28	Load	11.000	11.484	1	98.43	-6.69
Bus29	Load	11.000	11.484	1	98.43	-6.69
Bus30	Load	66.000	68.475	1	98.52	-5.49
Bus31	Load	66.000	66.413	2	98.59	-2.06
Bus32	Load	11.000	11.840	1	98.04	-8.74
Bus33	Load	11.000	11.484	2	100.46	-3.51

29 Buses Total

All voltages reported by ETAP are in % of bus Nominal kV.
Base kV values of buses are calculated and used internally by ETAP.

Project: MASTER THESIS	ETAP	**Page:**	4
Location: HOUN CITY - LIBYA	12.6.0H	**Date:**	28-06-2016
Contract: NEAR EAST UNIVERSITY - EEE Department		**SN:**	
Engineer: SAND MUSTAFA AL-REFAI	**Study Case:** SC	**Revision:**	Base
Filename: HOUN SUBSTATION 220kV		**Config:**	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Line/Cable Input Data

Line/Cable	Ohms or Siemens/1000 m per Conductor (Cable) or per Phase (Line)								
			Length						
ID	Library	Size	Adj. (m)	% Tol.	#/Phase	T (°C)	R	X	Y
Line1		674	19300.0	0	1	75	0.05600	0.37425	0.0000031
Line2		674	19300.0	0	1	75	0.05600	0.34207	0.0000034
Line3		674	23000.0	0	1	75	0.05600	0.34207	0.0000034
Line4		674	15000.0	0	1	75	0.05600	0.34207	0.0000034
Line5		674	8000.0	0	1	75	0.05600	0.34207	0.0000034
Line6		674	4000.0	0	1	75	0.05600	0.34207	0.0000034
Line7		674	4000.0	0	1	75	0.05600	0.34207	0.0000034
Line8		674	4000.0	0	1	75	0.05600	0.34207	0.0000034
Line9		674	4000.0	0	1	75	0.05600	0.34207	0.0000034
Line10		674	8000.0	0	1	75	0.05600	0.34207	0.0000034
Line11		674	8000.0	0	1	75	0.05600	0.34207	0.0000034
Line12		674	21000.0	0	1	75	0.05600	0.34207	0.0000034
Line13		674	161000.0	0	1	75	0.05600	0.34207	0.0000034
Line14		674	140000.0	0	1	75	0.05600	0.34207	0.0000034

Line / Cable resistances are listed at the specified temperatures.

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z
T1	63.000	220.000	66.000	12.50	45.00	0	0	0	0	3.750	12.5000
T3	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0.625	12.5000
T4	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500
T5	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000
T6	20.000	66.000	11.000	10.00	20.00	0	0	0	0	1.250	10.0000
T9	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500
T10	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500
T11	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000
T12	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000
T13	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500
T14	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500
T16	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000
T17	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000
T18	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000
T19	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.43	19.28	19.29	
T3	2W XFMR	Bus5	Bus2	0.43	19.28	19.29	
T4	2W XFMR	Bus1	Bus6	5.92	76.98	77.21	
T5	2W XFMR	Bus7	Bus9	2.43	48.62	48.69	
T6	2W XFMR	Bus8	Bus10	2.29	45.74	45.80	
T9	2W XFMR	Bus13	Bus15	5.92	76.98	77.21	
T10	2W XFMR	Bus14	Bus16	6.30	81.84	82.08	
T11	2W XFMR	Bus17	Bus19	2.29	45.74	45.80	
T12	2W XFMR	Bus18	Bus20	2.43	48.62	48.69	
T13	2W XFMR	Bus21	Bus22	5.92	76.98	77.21	
T14	2W XFMR	Bus23	Bus25	5.92	76.98	77.21	
T16	2W XFMR	Bus27	Bus28	2.29	45.74	45.80	
T17	2W XFMR	Bus27	Bus29	2.29	45.74	45.80	
T18	2W XFMR	Bus30	Bus32	2.29	45.74	45.80	
T19	2W XFMR	Bus31	Bus33	2.43	48.62	48.69	
Line1	Line	Bus2	Bus14	2.45	16.38	16.56	
Line2	Line	Bus1	Bus13	2.31	14.08	14.27	
Line3	Line	Bus2	Bus18	2.92	17.84	18.08	
Line4	Line	Bus27	Bus17	1.79	10.94	11.09	
Line5	Line	Bus1	Bus27	0.96	5.84	5.91	
Line6	Line	Bus2	Bus7	0.51	3.10	3.14	
Line7	Line	Bus1	Bus8	0.48	2.92	2.96	
Line8	Line	Bus2	Bus7	0.51	3.10	3.14	
Line9	Line	Bus1	Bus8	0.48	2.92	2.96	
Line10	Line	Bus2	Bus31	1.02	6.20	6.29	
Line11	Line	Bus1	Bus30	0.96	5.84	5.91	
Line12	Line	Bus17	Bus21	2.51	15.32	15.52	
Line13	Line	Bus17	Bus23	19.23	117.46	119.02	
Line14	Line	Bus21	Bus23	16.72	102.14	103.50	

Power Grid Input Data

Power Grid	Connected Bus	Rating		% Impedance 100 MVA Base		
ID	ID	MVAsc	kV	R	X"	R/X
U1	Bus3	22.101	220.000	45.02233	450.22330	0.10
U2	Bus4	22.101	220.000	45.02233	450.22330	0.10
U3	Bus5	22.101	220.000	45.02233	450.22330	0.10

Total Connected Power Grids (= 3): 66.303 MVA

Lumped Load Input Data

Lumped Load								Motor Loads					
Lumped Load	Connected Bus	Rating				% Load		Loading		% Impedance Machine Base			m Fact.
ID	ID	kVA	kV	Amp	% PF	MTR	STAT	kW	kvar	R	X"	R/X"	MW/PP
Lump1	Bus6	1243.2	11.000	65.25	0.01	80	20	0.1	994.6	2.28	15.21	0.15	0.00
Lump2	Bus9	2353.5	11.000	123.53	85.00	80	20	1600.4	991.8	1.53	15.31	0.10	1.60
Lump3	Bus10	8235.7	11.000	432.26	85.00	80	20	5600.0	3471.1	1.53	15.31	0.10	5.60
Lump4	Bus15	7058.4	11.000	370.47	85.00	80	20	4799.7	2974.6	1.53	15.31	0.10	4.80
Lump5	Bus16	7058.4	11.000	370.47	85.00	80	20	4799.7	2974.6	1.53	15.31	0.10	4.80
Lump6	Bus19	5500.0	11.000	288.68	100.00	80	20	4400.0	0.0	1.53	15.31	0.10	4.40
Lump7	Bus20	3500.0	11.000	183.70	100.00	80	20	2800.0	0.0	1.53	15.31	0.10	2.80
Lump8	Bus22	6000.0	11.000	314.92	100.00	80	20	4800.0	0.0	1.53	15.31	0.10	4.80
Lump9	Bus25	2352.4	11.000	123.47	85.00	80	20	1599.6	991.4	1.53	15.31	0.10	1.60
Lump11	Bus28	3529.2	11.000	185.23	85.00	80	20	2399.8	1487.3	1.53	15.31	0.10	2.40
Lump12	Bus29	3529.2	11.000	185.23	85.00	80	20	2399.8	1487.3	1.53	15.31	0.10	2.40
Lump13	Bus32	12941.9	11.000	679.27	85.00	80	20	8800.0	5454.8	1.53	15.31	0.10	8.80
Lump14	Bus33	5882.5	11.000	308.75	85.00	80	20	4000.0	2479.2	1.53	15.31	0.10	4.00

Total Connected Lumped Loads (= 13): 69184.3 kVA

SHORT-CIRCUIT REPORT (Without PV)

3-Phase fault at bus: Bus1

Nominal kV	= 66.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 5.352	kA Method C
Steady State	= 0.173	kA rms

Contribution		Voltage & Initial Symmetrical Current (rms)				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus1	Total	0.00	0.211	-2.151	10.2	2.161
Bus13	Bus1	4.41	0.027	-0.275	10.3	0.276
Bus27	Bus1	5.37	0.083	-0.807	9.7	0.811
Bus8	Bus1	0.57	0.016	-0.172	10.9	0.173
Bus8	Bus1	0.57	0.016	-0.172	10.9	0.173
Bus30	Bus1	3.29	0.044	-0.495	11.2	0.497
Bus3	Bus1	3.60	0.017	-0.172	10.3	0.173
Bus6	Bus1	5.10	0.009	-0.058	6.8	0.059
Bus15	Bus13	29.48	0.027	-0.275	10.3	0.276
Bus17	Bus27	11.58	0.052	-0.498	9.5	0.501
Bus28	Bus27	13.37	0.015	-0.154	10.1	0.155
Bus29	Bus27	13.37	0.015	-0.154	10.1	0.155
Bus10	Bus8	18.49	0.031	-0.344	10.9	0.345
Bus32	Bus30	29.80	0.044	-0.495	11.2	0.497
U1	Bus3	96.39	0.005	-0.054	10.3	0.054
Lump1	Bus6	100.00	0.051	-0.351	6.8	0.354

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.01	2.029	3.029	2.249
0.02	1.996	2.595	1.658
0.03	1.960	2.309	1.221
0.04	1.911	2.112	0.900
0.05	1.857	1.954	0.666
0.06	1.784	1.850	0.491
0.07	1.721	1.759	0.362
0.08	1.657	1.678	0.267

(Cont.)

3-Phase fault at bus: Bus1

Nominal kV	= 66.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 5.352	kA Method C
Steady State	= 0.173	kA rms

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.09	1.594	1.606	0.197
0.10	1.532	1.539	0.147
0.15	1.388	1.389	0.032
0.20	1.250	1.250	0.007
0.25	1.118	1.118	0.002
0.30	1.106	1.106	0.000

3-Phase fault at bus: Bus2

Nominal kV	= 66.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 2.464	kA Method C
Steady State	= 0.184	kA rms

Contribution		Voltage & Initial Symmetrical Current (rms)				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus2	Total	0.00	0.095	-0.989	10.4	0.993
Bus14	Bus2	4.79	0.027	-0.274	10.3	0.275
Bus18	Bus2	2.97	0.015	-0.155	10.2	0.156
Bus7	Bus2	0.18	0.005	-0.055	10.3	0.055
Bus7	Bus2	0.18	0.005	-0.055	10.3	0.055
Bus31	Bus2	1.77	0.025	-0.267	10.6	0.268
Bus5	Bus2	3.71	0.018	-0.183	10.3	0.184
Bus16	Bus14	29.78	0.027	-0.274	10.3	0.275
Bus20	Bus18	10.94	0.015	-0.155	10.2	0.156
Bus9	Bus7	5.86	0.011	-0.110	10.3	0.111
Bus33	Bus31	16.06	0.025	-0.267	10.6	0.268
U3	Bus5	99.38	0.005	-0.055	10.3	0.055

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.01	0.952	1.408	1.038
0.02	0.937	1.211	0.767
0.03	0.920	1.080	0.566
0.04	0.894	0.987	0.418
0.05	0.848	0.902	0.309
0.06	0.817	0.849	0.228
0.07	0.788	0.806	0.169
0.08	0.759	0.769	0.125
0.09	0.730	0.736	0.092
0.10	0.702	0.705	0.068
0.15	0.638	0.638	0.015
0.20	0.577	0.577	0.003
0.25	0.518	0.518	0.001
0.30	0.512	0.512	0.000

3-Phase fault at bus: Bus9

Nominal kV	= 11.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 10.860	kA Method C
Steady State	= 1.005	kA rms

Contribution		Voltage & Initial Symmetrical Current (rms)				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus9	Total	0.00	0.368	-4.302	11.7	4.318
Bus7	Bus9	30.83	0.297	-3.599	12.1	3.611
Lump2	Bus9	100.00	0.070	-0.703	10.0	0.707
Bus2	Bus7	31.82	0.025	-0.300	12.1	0.301
Bus2	Bus7	31.82	0.025	-0.300	12.1	0.301

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.01	4.209	6.286	4.669
0.02	4.173	5.494	3.574
0.03	4.131	4.954	2.734
0.04	4.038	4.548	2.092
0.05	3.880	4.199	1.605
0.06	3.780	3.975	1.229
0.07	3.682	3.800	0.941
0.08	3.584	3.655	0.720
0.09	3.487	3.530	0.551
0.10	3.392	3.418	0.424
0.15	3.167	3.169	0.112
0.20	2.945	2.945	0.029
0.25	2.736	2.736	0.008
0.30	2.720	2.720	0.002

3-Phase fault at bus: Bus10

Nominal kV	= 11.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 19.898	kA Method C
Steady State	= 0.927	kA rms

Contribution		Voltage & Initial Symmetrical Current (rms)				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus10	Total	0.00	0.661	-7.868	11.9	7.896
Bus8	Bus10	46.89	0.415	-5.408	13.0	5.424
Lump3	Bus10	100.00	0.246	-2.460	10.0	2.473
Bus1	Bus8	48.39	0.035	-0.456	13.0	0.458
Bus1	Bus8	48.39	0.035	-0.456	13.0	0.458

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.01	7.621	11.480	8.584
0.02	7.552	10.044	6.622
0.03	7.472	9.046	5.099
0.04	7.367	8.348	3.926
0.05	7.210	7.831	3.056
0.06	7.047	7.432	2.359
0.07	6.889	7.125	1.820
0.08	6.716	6.861	1.405
0.09	6.544	6.633	1.084
0.10	6.375	6.432	0.855
0.15	5.975	5.980	0.237
0.20	5.586	5.586	0.065
0.25	5.208	5.208	0.018
0.30	5.180	5.180	0.005

Short-Circuit Summary Report (Without PV)

3-Phase Fault Currents

Bus		Device		Device Capacity (kA)				Short-Circuit Current (kA)					
ID	kV	ID	Type	Making Peak	Ib sym	Ib asym	Idc	I"k	ip	Ib sym	Ib asym	Idc	Ik
Bus1	66.000	Bus1	Bus					2.161	5.352				0.173
Bus2	66.000	Bus2	Bus					0.993	2.464				0.184
Bus9	11.000	Bus9	Bus					4.318	10.860				1.005
Bus10	11.000	Bus10	Bus					7.896	19.898				0.927

ip is calculated using method C
Ib does not include decay of non-terminal faulted induction motors
Ik is the maximum steady state fault current
Idc is based on X/R from Method C and Ib as specified above

LV CB duty determined based on service rating.
Total through current is used for device duty.

* Indicates a device with calculated duty exceeding the device capability.

# indicates a device with calculated duty exceeding the device marginal limit. (95 % times device capability)

APPENDIX 7
SHORT CIRCUIT ANALYSIS WITH PV

Project:	MASTER THESIS	ETAP	**Page:**	1
Location:	HOUN CITY - LIBYA	12.6.0H	**Date:**	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department		**SN:**	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case: SC	**Revision:**	Base
Filename:	HOUN SUBSTATION 220kV		**Config:**	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Short-Circuit Analysis (With PV)

IEC 60909 Standard
3-Phase Fault Currents

	Swing	V-Control	Load	Total
Number of Buses:	3	7	30	40

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of Branches:	24	0	0	16	0	0	40

	Synchronous Generator	Power Grid	Synchronous Motor	Induction Machines	Lumped Load	Total
Number of Machines:	0	3	0	0	13	16

System Frequency:	50.00 Hz
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus					Initial Voltage	
ID	Type	Nom. kV	Base kV	Sub-sys	%Mag.	Ang.
Bus1	Load	66.000	68.475	1	99.39	-4.20
Bus2	Load	66.000	66.413	2	99.06	-1.22
Bus3	SWNG	220.000	220.000	1	100.00	0.00
Bus4	SWNG	220.000	220.000	3	100.00	0.00
Bus5	SWNG	220.000	220.000	2	100.00	0.00
Bus6	Load	11.000	11.413	1	98.34	-4.15
Bus7	Load	66.000	66.413	2	99.04	-1.23
Bus8	Load	66.000	68.475	1	99.30	-4.26
Bus9	Load	11.000	11.069	2	98.36	-1.80
Bus10	Load	11.000	11.555	1	98.05	-6.26
Bus11	Load	66.000	66.413	2	99.06	-1.22
Bus12	Load	66.000	68.475	1	99.39	-4.20
Bus13	Load	66.000	68.475	1	98.62	-4.67
Bus14	Load	66.000	66.413	2	98.22	-1.74
Bus15	Load	11.000	11.912	1	98.98	-7.58
Bus16	Load	11.000	11.553	2	98.56	-4.67
Bus17	Load	66.000	68.475	1	99.19	-5.86
Bus18	Load	66.000	66.413	2	98.97	-1.59
Bus19	Load	11.000	11.413	1	99.02	-7.46
Bus20	Load	11.000	11.069	2	98.87	-2.61
Bus21	Load	66.000	68.475	1	99.22	-6.52
Bus22	Load	11.000	11.413	1	98.70	-9.43
Bus23	Load	66.000	68.475	1	99.54	-6.94
Bus25	Load	11.000	11.413	1	98.36	-7.87
Bus27	Load	66.000	68.475	1	99.12	-4.91
Bus28	Load	11.000	11.484	1	98.70	-5.76
Bus29	Load	11.000	11.484	1	98.70	-5.76
Bus30	Load	66.000	68.475	1	98.79	-4.56
Bus31	Load	66.000	66.413	2	98.80	-1.38
Bus32	Load	11.000	11.840	1	98.33	-7.79
Bus33	Load	11.000	11.484	2	100.68	-2.83
Bus34	Gen.	0.400	0.410	1	0.00	1.05
Bus35	Gen.	0.400	0.410	1	0.00	1.05
Bus36	Gen.	0.400	0.410	1	0.00	1.05
Bus37	Gen.	0.400	0.410	1	0.00	1.05

Bus					Initial Voltage	
ID	Type	Nom. kV	Base kV	Sub-sys	%Mag.	Ang.
Bus38	Gen.	0.400	0.397	2	0.00	3.28
Bus39	Gen.	0.400	0.397	2	0.00	3.28
Bus40	Gen.	0.400	0.397	2	0.00	3.28
Bus41	Load	11.000	11.270	1	98.88	-1.23
Bus42	Load	11.000	10.930	2	98.63	1.01

40 Buses Total

All voltages reported by ETAP are in % of bus Nominal kV.
Base kV values of buses are calculated and used internally by ETAP.

Line/Cable Input Data

Line/Cable	Ohms or Siemens/1000 m per Conductor (Cable) or per Phase (Line)								
			Length						
ID	Library	Size	Adj. (m)	% Tol.	#/Phase	T (°C)	R	X	Y
Cable1	11MCUS3	300	100.0	0	1	75	0.07630	0.08740	0.0001646
Cable2	11MCUS3	300	100.0	0	1	75	0.07630	0.08740	0.0001646
Line1		674	19300.0	0	1	75	0.05600	0.37425	0.0000031
Line2		674	19300.0	0	1	75	0.05600	0.34207	0.0000034
Line3		674	23000.0	0	1	75	0.05600	0.34207	0.0000034
Line4		674	15000.0	0	1	75	0.05600	0.34207	0.0000034
Line5		674	8000.0	0	1	75	0.05600	0.34207	0.0000034
Line6		674	4000.0	0	1	75	0.05600	0.34207	0.0000034
Line7		674	4000.0	0	1	75	0.05600	0.34207	0.0000034
Line8		674	4000.0	0	1	75	0.05600	0.34207	0.0000034
Line9		674	4000.0	0	1	75	0.05600	0.34207	0.0000034
Line10		674	8000.0	0	1	75	0.05600	0.34207	0.0000034
Line11		674	8000.0	0	1	75	0.05600	0.34207	0.0000034
Line12		674	21000.0	0	1	75	0.05600	0.34207	0.0000034
Line13		674	161000.0	0	1	75	0.05600	0.34207	0.0000034
Line14		674	140000.0	0	1	75	0.05600	0.34207	0.0000034

Line / Cable resistances are listed at the specified temperatures.

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z
T1	63.000	220.000	66.000	12.50	45.00	0	0	0	0	3.750	12.5000
T3	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0.625	12.5000
T4	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500
T5	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000
T6	20.000	66.000	11.000	10.00	20.00	0	0	0	0	1.250	10.0000
T7	12.500	11.000	66.000	8.35	13.00	0	0	0	-1.250	0	8.3500
T8	12.500	11.000	66.000	8.35	13.00	0	0	0	-1.250	0	8.3500
T9	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500
T10	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500
T11	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000
T12	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000
T13	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500
T14	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500
T16	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000
T17	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000
T18	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000
T19	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000
T20	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500
T21	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500
T22	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500
T23	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500
T24	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500
T25	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500
T26	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.43	19.28	19.29	
T3	2W XFMR	Bus5	Bus2	0.43	19.28	19.29	
T4	2W XFMR	Bus1	Bus6	5.92	76.98	77.21	
T5	2W XFMR	Bus7	Bus9	2.43	48.62	48.69	
T6	2W XFMR	Bus8	Bus10	2.29	45.74	45.80	
T7	2W XFMR	Bus42	Bus11	5.04	65.47	65.66	
T8	2W XFMR	Bus41	Bus12	4.74	61.58	61.77	
T9	2W XFMR	Bus13	Bus15	5.92	76.98	77.21	
T10	2W XFMR	Bus14	Bus16	6.30	81.84	82.08	
T11	2W XFMR	Bus17	Bus19	2.29	45.74	45.80	
T12	2W XFMR	Bus18	Bus20	2.43	48.62	48.69	
T13	2W XFMR	Bus21	Bus22	5.92	76.98	77.21	
T14	2W XFMR	Bus23	Bus25	5.92	76.98	77.21	
T16	2W XFMR	Bus27	Bus28	2.29	45.74	45.80	
T17	2W XFMR	Bus27	Bus29	2.29	45.74	45.80	
T18	2W XFMR	Bus30	Bus32	2.29	45.74	45.80	
T19	2W XFMR	Bus31	Bus33	2.43	48.62	48.69	
T20	2W XFMR	Bus34	Bus41	31.39	188.32	190.92	
T21	2W XFMR	Bus35	Bus41	31.39	188.32	190.92	
T22	2W XFMR	Bus36	Bus41	31.39	188.32	190.92	
T23	2W XFMR	Bus37	Bus41	31.39	188.32	190.92	
T24	2W XFMR	Bus38	Bus42	33.37	200.20	202.96	
T25	2W XFMR	Bus39	Bus42	33.37	200.20	202.96	
T26	2W XFMR	Bus40	Bus42	33.37	200.20	202.96	
Cable1	Cable	Bus11	Bus2	0.02	0.02	0.03	
Cable2	Cable	Bus12	Bus1	0.02	0.02	0.02	
Line1	Line	Bus2	Bus14	2.45	16.38	16.56	
Line2	Line	Bus1	Bus13	2.31	14.08	14.27	
Line3	Line	Bus2	Bus18	2.92	17.84	18.08	
Line4	Line	Bus27	Bus17	1.79	10.94	11.09	
Line5	Line	Bus1	Bus27	0.96	5.84	5.91	
Line6	Line	Bus2	Bus7	0.51	3.10	3.14	
Line7	Line	Bus1	Bus8	0.48	2.92	2.96	
Line8	Line	Bus2	Bus7	0.51	3.10	3.14	
Line9	Line	Bus1	Bus8	0.48	2.92	2.96	
Line10	Line	Bus2	Bus31	1.02	6.20	6.29	
Line11	Line	Bus1	Bus30	0.96	5.84	5.91	

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R	X	Z	Y
Line12	Line	Bus17	Bus21	2.51	15.32	15.52	
Line13	Line	Bus17	Bus23	19.23	117.46	119.02	
Line14	Line	Bus21	Bus23	16.72	102.14	103.50	

Power Grid Input Data

Power Grid	Connected Bus	Rating		% Impedance 100 MVA Base		
ID	ID	MVAsc	kV	R	X"	R/X
U1	Bus3	22.101	220.000	45.02233	450.22330	0.10
U2	Bus4	22.101	220.000	45.02233	450.22330	0.10
U3	Bus5	22.101	220.000	45.02233	450.22330	0.10

Total Connected Power Grids (= 3): 66.303 MVA

Lumped Load Input Data

Lumped Load		Lumped Load						Motor Loads					
Lumped Load	Connected Bus	Rating				% Load		Loading		% Impedance Machine Base			m Fact.
ID	ID	kVA	kV	Amp	% PF	MTR	STAT	kW	kvar	R	X"	R/X"	MW/PP
Lump1	Bus6	1243.2	11.000	65.25	0.01	80	20	0.1	994.6	2.28	15.21	0.15	0.00
Lump2	Bus9	2353.5	11.000	123.53	85.00	80	20	1600.4	991.8	1.53	15.31	0.10	1.60
Lump3	Bus10	8235.7	11.000	432.26	85.00	80	20	5600.0	3471.1	1.53	15.31	0.10	5.60
Lump4	Bus15	7058.4	11.000	370.47	85.00	80	20	4799.7	2974.6	1.53	15.31	0.10	4.80
Lump5	Bus16	7058.4	11.000	370.47	85.00	80	20	4799.7	2974.6	1.53	15.31	0.10	4.80
Lump6	Bus19	5500.0	11.000	288.68	100.00	80	20	4400.0	0.0	1.53	15.31	0.10	4.40
Lump7	Bus20	3500.0	11.000	183.70	100.00	80	20	2800.0	0.0	1.53	15.31	0.10	2.80
Lump8	Bus22	6000.0	11.000	314.92	100.00	80	20	4800.0	0.0	1.53	15.31	0.10	4.80
Lump9	Bus25	2352.4	11.000	123.47	85.00	80	20	1599.6	991.4	1.53	15.31	0.10	1.60
Lump11	Bus28	3529.2	11.000	185.23	85.00	80	20	2399.8	1487.3	1.53	15.31	0.10	2.40
Lump12	Bus29	3529.2	11.000	185.23	85.00	80	20	2399.8	1487.3	1.53	15.31	0.10	2.40
Lump13	Bus32	12941.9	11.000	679.27	85.00	80	20	8800.0	5454.8	1.53	15.31	0.10	8.80
Lump14	Bus33	5882.5	11.000	308.75	85.00	80	20	4000.0	2479.2	1.53	15.31	0.10	4.00

Total Connected Lumped Loads (= 13): 69184.3 kVA

SHORT-CIRCUIT REPORT (With PV)

3-Phase fault at bus: Bus1

Nominal kV	= 66.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 5.368	kA Method C
Steady State	= 0.232	kA rms

Contribution		Voltage & Initial Symmetrical Current (rms)				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus1	Total	0.00	0.327	-2.168	6.6	2.193
Bus12	Bus1	0.00	0.117	-0.017	0.1	0.118
Bus13	Bus1	4.41	0.027	-0.275	10.3	0.276
Bus27	Bus1	5.37	0.083	-0.807	9.7	0.811
Bus8	Bus1	0.57	0.016	-0.172	10.9	0.173
Bus8	Bus1	0.57	0.016	-0.172	10.9	0.173
Bus30	Bus1	3.29	0.044	-0.495	11.2	0.497
Bus3	Bus1	3.60	0.017	-0.172	10.3	0.173
Bus6	Bus1	5.10	0.009	-0.058	6.8	0.059
Bus41	Bus12	8.06	0.117	-0.017	0.1	0.118
Bus15	Bus13	29.48	0.027	-0.275	10.3	0.276
Bus17	Bus27	11.58	0.052	-0.498	9.5	0.501
Bus28	Bus27	13.37	0.015	-0.154	10.1	0.155
Bus29	Bus27	13.37	0.015	-0.154	10.1	0.155
Bus10	Bus8	18.49	0.031	-0.344	10.9	0.345
Bus32	Bus30	29.80	0.044	-0.495	11.2	0.497
U1	Bus3	96.39	0.005	-0.054	10.3	0.054
Lump1	Bus6	100.00	0.051	-0.351	6.8	0.354

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.01	2.059	3.050	2.250
0.02	2.026	2.622	1.664
0.03	1.990	2.334	1.219
0.04	1.941	2.137	0.893
0.05	1.867	1.982	0.666
0.06	1.813	1.878	0.489

(Cont.)

3-Phase fault at bus: Bus1

Nominal kV	= 66.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 5.368	kA Method C
Steady State	= 0.232	kA rms

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.07	1.750	1.786	0.360
0.08	1.685	1.706	0.264
0.09	1.622	1.633	0.194
0.10	1.559	1.566	0.146
0.15	1.415	1.415	0.032
0.20	1.275	1.275	0.007
0.25	1.141	1.141	0.001
0.30	1.129	1.129	0.000

3-Phase fault at bus: Bus2

Nominal kV	= 66.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 2.475	kA Method C
Steady State	= 0.221	kA rms

Contribution		Voltage & Initial Symmetrical Current (rms)				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus2	Total	0.00	0.184	-1.000	5.4	1.017
Bus11	Bus2	0.00	0.088	-0.011	0.1	0.089
Bus14	Bus2	4.79	0.027	-0.274	10.3	0.275
Bus18	Bus2	2.97	0.015	-0.155	10.2	0.156
Bus7	Bus2	0.18	0.005	-0.055	10.3	0.055
Bus7	Bus2	0.18	0.005	-0.055	10.3	0.055
Bus31	Bus2	1.77	0.025	-0.267	10.6	0.268
Bus5	Bus2	3.71	0.018	-0.183	10.3	0.184
Bus42	Bus11	6.07	0.088	-0.011	0.1	0.089
Bus16	Bus14	29.78	0.027	-0.274	10.3	0.275
Bus20	Bus18	10.94	0.015	-0.155	10.2	0.156
Bus9	Bus7	5.86	0.011	-0.110	10.3	0.111
Bus33	Bus31	16.06	0.025	-0.267	10.6	0.268
U3	Bus5	99.38	0.005	-0.055	10.3	0.055

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.01	0.975	1.424	1.038
0.02	0.960	1.231	0.771
0.03	0.943	1.099	0.564
0.04	0.917	1.006	0.413
0.05	0.870	0.923	0.309
0.06	0.840	0.870	0.227
0.07	0.810	0.827	0.167
0.08	0.780	0.790	0.123
0.09	0.752	0.757	0.090
0.10	0.723	0.726	0.067
0.15	0.659	0.659	0.015
0.20	0.596	0.596	0.003

(Cont.)

3-Phase fault at bus: Bus2

Nominal kV	= 66.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 2.475	kA Method C
Steady State	= 0.221	kA rms

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.25	0.537	0.537	0.001
0.30	0.531	0.531	0.000

3-Phase fault at bus: Bus9

Nominal kV	= 11.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 10.909	kA Method C
Steady State	= 1.199	kA rms

Contribution		Voltage & Initial Symmetrical Current (rms)				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus9	Total	0.00	0.610	-4.347	7.1	4.390
Bus7	Bus9	31.45	0.540	-3.644	6.7	3.684
Lump2	Bus9	100.00	0.070	-0.703	10.0	0.707
Bus2	Bus7	32.46	0.045	-0.304	6.7	0.307
Bus2	Bus7	32.46	0.045	-0.304	6.7	0.307

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.01	4.282	6.343	4.680
0.02	4.246	5.564	3.596
0.03	4.204	5.016	2.736
0.04	4.112	4.609	2.083
0.05	3.954	4.269	1.610
0.06	3.855	4.046	1.229
0.07	3.757	3.872	0.938
0.08	3.660	3.729	0.716
0.09	3.563	3.605	0.547
0.10	3.468	3.494	0.424
0.15	3.244	3.246	0.111
0.20	3.025	3.025	0.029
0.25	2.813	2.813	0.008
0.30	2.798	2.798	0.002

3-Phase fault at bus: Bus10

Nominal kV	= 11.000	
Voltage c Factor	= 1.10	(User-Defined)
Peak Value	= 19.943	kA Method C
Steady State	= 1.226	kA rms

Contribution		Voltage & Initial Symmetrical Current (rms)				
From Bus ID	To Bus ID	% V From Bus	kA Real	kA Imaginary	X/R Ratio	kA Magnitude
Bus10	Total	0.00	0.835	-7.907	9.5	7.951
Bus8	Bus10	47.36	0.589	-5.447	9.2	5.479
Lump3	Bus10	100.00	0.246	-2.460	10.0	2.473
Bus1	Bus8	48.88	0.050	-0.460	9.2	0.462
Bus1	Bus8	48.88	0.050	-0.460	9.2	0.462

Breaking and DC Fault Current (kA)

Based on Total Bus Fault Current

TD (S)	Ib sym	Ib asym	Idc
0.01	7.678	11.526	8.597
0.02	7.608	10.099	6.641
0.03	7.529	9.096	5.104
0.04	7.424	8.397	3.922
0.05	7.267	7.886	3.062
0.06	7.118	7.499	2.361
0.07	6.947	7.181	1.820
0.08	6.774	6.918	1.403
0.09	6.603	6.691	1.082
0.10	6.434	6.491	0.856
0.15	6.035	6.040	0.236
0.20	5.646	5.646	0.065
0.25	5.268	5.268	0.018
0.30	5.240	5.240	0.005

Project:	MASTER THESIS	ETAP	Page:	17
Location:	HOUN CITY - LIBYA	12.6.0H	Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department		SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case: SC	Revision:	Base
Filename:	HOUN SUBSTATION 220kV		Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Short-Circuit Summary Report (With PV)

3-Phase Fault Currents

Bus		Device		Device Capacity (kA)				Short-Circuit Current (kA)					
ID	kV	ID	Type	Making Peak	Ib sym	Ib asym	Idc	I"k	ip	Ib sym	Ib asym	Idc	Ik
Bus1	66.000	Bus1	Bus					2.193	5.368				0.232
Bus2	66.000	Bus2	Bus					1.017	2.475				0.221
Bus9	11.000	Bus9	Bus					4.390	10.909				1.199
Bus10	11.000	Bus10	Bus					7.951	19.945				1.226

ip is calculated using method C
Ib does not include decay of non-terminal faulted induction motors
Ik is the maximum steady state fault current
Idc is based on X/R from Method C and Ib as specified above

LV CB duty determined based on service rating.
Total through current is used for device duty.
* Indicates a device with calculated duty exceeding the device capability.
# indicates a device with calculated duty exceeding the device marginal limit. (95 % times device capability)

APPENDIX 8

HARMONICS ANALYSIS WITHOUT PV

Project:	MASTER THESIS	ETAP		Page:	1
Location:	HOUN CITY - LIBYA	12.6.0H		Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department			SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case:	HA	Revision:	Base
Filename:	HOUN SUBSTATION 220kV			Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Harmonic Load Flow (Without PV)

Loading: Operating P, Q

Generation: Operating P, Q, V

	Swing	V-Control	Load	Total
Number of Buses:	3	0	26	29

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of Branches:	15	0	0	14	0	0	29

	Current	Voltage
Number of Harm. Sources:	3	0

Number of Filters: 0

Method of Solution:	Adaptive Newton-Raphson
Maximum No. of Iteration:	99
Precision of Solution:	0.0001000000
System Frequency:	50.00 Hz
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus			Initial Voltage		Load: Constant kVA		Load: Constant Z		Load: Constant I		Load: Generic		% Limits	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	VTHD	VTHD
Bus1	66.000	1	99.1	-30.0									10.00	10.00
Bus2	66.000	2	98.9	30.0									10.00	10.00
Bus3	220.000	1	100.0	0.0									10.00	10.00
Bus4	220.000	3	100.0	0.0									10.00	10.00
Bus5	220.000	2	100.0	0.0									10.00	10.00
Bus6	11.000	1	98.1	-60.0	0.000	0.995	0.000	0.249					2.50	1.50
Bus7	66.000	2	98.8	30.0									10.00	10.00
Bus8	66.000	1	99.0	-30.0									10.00	10.00
Bus9	11.000	2	98.1	-2.5	1.600	0.992	0.400	0.248					10.00	10.00
Bus10	11.000	1	97.8	-60.0	5.600	3.471	1.400	0.868					10.00	10.00
Bus13	66.000	1	98.3	-30.0									10.00	10.00
Bus14	66.000	2	98.0	30.0									10.00	10.00
Bus15	11.000	1	98.7	-60.0	4.800	2.975	1.200	0.744					10.00	10.00
Bus16	11.000	2	98.3	-5.4	4.800	2.975	1.200	0.744					10.00	10.00
Bus17	66.000	1	98.9	-30.0									10.00	10.00
Bus18	66.000	2	98.8	30.0									10.00	10.00
Bus19	11.000	1	98.7	-60.0	4.400	0.000	1.100	0.000					10.00	10.00
Bus20	11.000	2	98.7	-3.3	2.800	0.000	0.700	0.000					10.00	10.00
Bus21	66.000	1	98.9	-30.0									10.00	10.00
Bus22	11.000	1	98.4	-60.0	4.800	0.000	1.200	0.000					10.00	10.00
Bus23	66.000	1	99.3	-30.0									10.00	10.00
Bus25	11.000	1	98.1	-60.0	1.600	0.991	0.400	0.248					10.00	10.00
Bus27	66.000	1	98.8	-30.0									10.00	10.00
Bus28	11.000	1	98.4	-60.0	2.400	1.487	0.600	0.372					10.00	10.00
Bus29	11.000	1	98.4	-60.0	2.400	1.487	0.600	0.372					10.00	10.00
Bus30	66.000	1	98.5	-30.0									10.00	10.00
Bus31	66.000	2	98.6	30.0									10.00	10.00
Bus32	11.000	1	98.0	-60.0	8.800	5.455	2.200	1.364					10.00	10.00
Bus33	11.000	2	100.5	-3.5	4.000	2.479	1.000	0.620					10.00	10.00
Total Number of Buses: 29					47.999	23.307	12.000	5.827	0.000	0.000	0.000	0.000		

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus3	220.000	Swing	1	100.0	0.0					

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus4	220.000	Swing	3	100.0	0.0					
Bus5	220.000	Swing	2	100.0	0.0					
						0.000	0.000			

Cable Input Data

Cable ID	Library	Size	Length	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0

Cable resistances are listed at the specified temperatures

Transmission Line Input Data

Line			Length				Ohms or Mhos / 1000 m per Phase					
ID	Library	Size	Adj. (m)	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Line1		674	19300.0	0.0	1	75	0.056003	0.374255	.0000031	0.200077	1.360791	.0000017
Line2		674	19300.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line3		674	23000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line4		674	15000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line5		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line6		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line7		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line8		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line9		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line10		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line11		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line12		674	21000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line13		674	161000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line14		674	140000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016

Line resistances are listed at the specified temperatures

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
T1	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0	12.5000	Dyn	30.000
T3	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0	12.5000	Dyn	-30.000
T4	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T5	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T6	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T9	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T10	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T11	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T12	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T13	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T14	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T16	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T17	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T18	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T19	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000

2-Winding Transformer Grounding Input Data

				Grounding								
Transformer	Rating			Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T1	63.000	220.000	66.000	D/Y					Solid			
T3	63.000	220.000	66.000	D/Y					Solid			
T4	10.000	66.000	11.000	D/Y					Solid			
T5	20.000	66.000	11.000	D/Y					Solid			
T6	20.000	66.000	11.000	D/Y					Solid			
T9	10.000	66.000	11.000	D/Y					Solid			
T10	10.000	66.000	11.000	D/Y					Solid			
T11	20.000	66.000	11.000	D/Y					Solid			
T12	20.000	66.000	11.000	D/Y					Solid			
T13	10.000	66.000	11.000	D/Y					Solid			
T14	10.000	66.000	11.000	D/Y					Solid			
T16	20.000	66.000	11.000	D/Y					Solid			

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T17	20.000	66.000	11.000	D/Y					Solid			
T18	20.000	66.000	11.000	D/Y					Solid			
T19	20.000	66.000	11.000	D/Y					Solid			

Branch Connections

CKT/Branch		Connected Bus ID		% Positive Sequence Impedance (100 MVA Base)			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.44	19.84	19.84	
T3	2W XFMR	Bus5	Bus2	0.44	19.84	19.84	
T4	2W XFMR	Bus1	Bus6	6.40	83.25	83.50	
T5	2W XFMR	Bus7	Bus9	2.50	49.94	50.00	
T6	2W XFMR	Bus8	Bus10	2.50	49.94	50.00	
T9	2W XFMR	Bus13	Bus15	6.40	83.25	83.50	
T10	2W XFMR	Bus14	Bus16	6.40	83.25	83.50	
T11	2W XFMR	Bus17	Bus19	2.50	49.94	50.00	
T12	2W XFMR	Bus18	Bus20	2.50	49.94	50.00	
T13	2W XFMR	Bus21	Bus22	6.40	83.25	83.50	
T14	2W XFMR	Bus23	Bus25	6.40	83.25	83.50	
T16	2W XFMR	Bus27	Bus28	2.50	49.94	50.00	
T17	2W XFMR	Bus27	Bus29	2.50	49.94	50.00	
T18	2W XFMR	Bus30	Bus32	2.50	49.94	50.00	
T19	2W XFMR	Bus31	Bus33	2.50	49.94	50.00	
Line1	Line	Bus2	Bus14	2.48	16.58	16.77	0.2607629
Line2	Line	Bus1	Bus13	2.48	15.16	15.36	0.2842266
Line3	Line	Bus2	Bus18	2.96	18.06	18.30	0.3387157
Line4	Line	Bus27	Bus17	1.93	11.78	11.94	0.2209015
Line5	Line	Bus1	Bus27	1.03	6.28	6.37	0.1178142
Line6	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line7	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line8	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line9	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line10	Line	Bus2	Bus31	1.03	6.28	6.37	0.1178142
Line11	Line	Bus1	Bus30	1.03	6.28	6.37	0.1178142
Line12	Line	Bus17	Bus21	2.70	16.49	16.71	0.3092622
Line13	Line	Bus17	Bus23	20.70	126.43	128.11	2.3710100
Line14	Line	Bus21	Bus23	18.00	109.94	111.40	2.0617480

Branch Connections
Zero Sequence Impedance

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
T1	2W Xfmr	Bus3	Bus1				
T3	2W Xfmr	Bus5	Bus2				
T4	2W Xfmr	Bus1	Bus6				
T5	2W Xfmr	Bus7	Bus9				
T6	2W Xfmr	Bus8	Bus10				
T9	2W Xfmr	Bus13	Bus15				
T10	2W Xfmr	Bus14	Bus16				
T11	2W Xfmr	Bus17	Bus19				
T12	2W Xfmr	Bus18	Bus20				
T13	2W Xfmr	Bus21	Bus22				
T14	2W Xfmr	Bus23	Bus25				
T16	2W Xfmr	Bus27	Bus28				
T17	2W Xfmr	Bus27	Bus29				
T18	2W Xfmr	Bus30	Bus32				
T19	2W Xfmr	Bus31	Bus33				
Line1	Line	Bus2	Bus14	8.86	60.29	60.94	0.1410145
Line2	Line	Bus1	Bus13	8.89	63.09	63.72	0.1341983
Line3	Line	Bus2	Bus18	10.59	75.19	75.93	0.1599255
Line4	Line	Bus27	Bus17	6.91	49.04	49.52	0.1042992
Line5	Line	Bus1	Bus27	3.68	26.15	26.41	0.0556262
Line6	Line	Bus2	Bus7	1.84	13.08	13.21	0.0278131
Line7	Line	Bus1	Bus8	1.84	13.08	13.21	0.0278131
Line8	Line	Bus2	Bus7	1.84	13.08	13.21	0.0278131
Line9	Line	Bus1	Bus8	1.84	13.08	13.21	0.0278131
Line10	Line	Bus2	Bus31	3.68	26.15	26.41	0.0556262
Line11	Line	Bus1	Bus30	3.68	26.15	26.41	0.0556262
Line12	Line	Bus17	Bus21	9.67	68.65	69.33	0.1460189
Line13	Line	Bus17	Bus23	74.16	526.33	531.53	1.1194780
Line14	Line	Bus21	Bus23	64.48	457.68	462.20	0.9734595

Machine Input Data

Machine		Connected Bus	Rating (Base)			% Negative Seq. Imp.			Grounding			% Zero Seq. Imp.		
ID	Type	ID	MVA	kV	RPM	X/R	R2	X2	Conn.	Type	Amp	X/R	R0	X0
U1	Grid	Bus3	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	35.648	356.48
U2	Grid	Bus4	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	17.738	177.38
U3	Grid	Bus5	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	17.738	177.38

Harmonic Library

Current Harmonic Source in %

Manufacturer: ABB
Model: ACS600 12P

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	5.00	250.00	2.60	7.00	350.00	1.50	11.00	550.00	3.70	13.00	650.00	3.70	17.00	850.00	0.50
19.00	950.00	0.30	23.00	1150.00	0.10	25.00	1250.00	0.50									

Manufacturer: ABB
Model: ACS600 12P

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	5.00	250.00	2.60	7.00	350.00	1.50	11.00	550.00	3.70	13.00	650.00	3.70	17.00	850.00	0.50
19.00	950.00	0.30	23.00	1150.00	0.10	25.00	1250.00	0.50									

Manufacturer: ABB
Model: ACS600 12P

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	5.00	250.00	2.60	7.00	350.00	1.50	11.00	550.00	3.70	13.00	650.00	3.70	17.00	850.00	0.50
19.00	950.00	0.30	23.00	1150.00	0.10	25.00	1250.00	0.50									

Harmonic Source from Library

		Harmonic Source Information				
Bus ID	Device ID	Type	Manufacturer	Model	Fund. Freq.	Mod. Freq.
Bus3	U1	Current	ABB	ACS600 12P	0.00	0.00
Bus4	U2	Current	ABB	ACS600 12P	0.00	0.00
Bus5	U3	Current	ABB	ACS600 12P	0.00	0.00

Fundamental Load Flow Report (Without PV)

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
Bus1	66.000	95.550	-35.0	0	0	0	0	Bus13	5.842	3.883	64.2	83.3	
								Bus27	19.234	1.494	176.6	99.7	
								Bus8	3.415	2.248	37.4	83.5	
								Bus8	3.415	2.248	37.4	83.5	
								Bus30	10.683	7.536	119.7	81.7	
								Bus3	-42.589	-18.638	425.6	91.6	
								Bus6	0.001	1.230	11.3	0.1	
Bus2	66.000	98.267	28.1	0	0	0	0	Bus14	5.901	3.915	63.0	83.3	
								Bus18	3.480	-0.241	31.1	-99.8	
								Bus7	0.991	0.572	10.2	86.6	
								Bus7	0.991	0.572	10.2	86.6	
								Bus31	4.939	3.144	52.1	84.4	
								Bus5	-16.303	-7.961	161.5	89.9	
* Bus3	220.000	100.000	0.0	42.694	23.334	0	0	Bus1	42.694	23.334	127.7	87.7	
* Bus5	220.000	100.000	0.0	16.318	8.637	0	0	Bus2	16.318	8.637	48.5	88.4	
Bus6	11.000	94.478	-65.0	0	0	0.000	1.217	Bus1	0.000	-1.217	67.6	0.0	
Bus7	66.000	98.242	28.1	0	0	0	0	Bus2	-0.991	-0.628	10.4	84.5	
								Bus2	-0.991	-0.628	10.4	84.5	
								Bus9	1.983	1.256	20.9	84.5	
Bus8	66.000	95.457	-35.1	0	0	0	0	Bus1	-3.414	-2.296	37.7	83.0	
								Bus1	-3.414	-2.296	37.7	83.0	
								Bus10	6.828	4.592	75.4	83.0	
Bus9	11.000	97.558	-2.5	0	0	1.981	1.228	Bus7	-1.981	-1.228	125.4	85.0	
Bus10	11.000	92.940	-67.2	0	0	6.809	4.221	Bus8	-6.809	-4.221	452.4	85.0	
Bus13	66.000	94.766	-35.5	0	0	0	0	Bus1	-5.828	-4.057	65.5	82.1	
								Bus15	5.828	4.057	65.5	82.1	
Bus14	66.000	97.440	27.6	0	0	0	0	Bus2	-5.888	-4.077	64.3	82.2	
								Bus16	5.888	4.077	64.3	82.2	
Bus15	11.000	90.937	-68.6	0	0	5.792	3.590	Bus13	-5.792	-3.590	393.3	85.0	
Bus16	11.000	93.691	-5.3	0	0	5.853	3.627	Bus14	-5.853	-3.627	385.8	85.0	
Bus17	66.000	95.282	-36.8	0	0	0	0	Bus27	-13.282	2.461	124.0	-98.3	
								Bus21	6.510	-1.140	60.7	-98.5	
								Bus23	1.370	-1.481	18.5	-67.9	
								Bus19	5.403	0.161	49.6	100.0	
Bus18	66.000	98.179	27.8	0	0	0	0	Bus2	-3.476	-0.063	31.0	100.0	
								Bus20	3.476	0.063	31.0	100.0	
Bus19	11.000	95.099	-68.5	0	0	5.395	0.000	Bus17	-5.395	0.000	297.7	100.0	

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
Bus20	11.000	98.074	-3.3	0	0	3.473	0.000	Bus18	-3.473	0.000	185.9	100.0	
Bus21	66.000	95.278	-37.5	0	0	0	0	Bus17	-6.497	0.938	60.3	-99.0	
								Bus23	0.595	-1.259	12.8	-42.7	
								Bus22	5.902	0.320	54.3	99.9	
Bus22	11.000	94.741	-70.6	0	0	5.877	0.000	Bus21	-5.877	0.000	325.6	100.0	
Bus23	66.000	95.541	-37.9	0	0	0	0	Bus17	-1.365	-0.649	13.8	90.3	
								Bus21	-0.594	-0.613	7.8	69.6	
								Bus25	1.959	1.261	21.3	84.1	
Bus25	11.000	94.324	-68.9	0	0	1.955	1.212	Bus23	-1.955	-1.212	128.0	85.0	
Bus27	66.000	95.250	-35.8	0	0	0	0	Bus17	13.321	-2.424	124.4	-98.4	
								Bus1	-19.192	-1.345	176.7	99.8	
								Bus28	2.936	1.884	32.0	84.2	
								Bus29	2.936	1.884	32.0	84.2	
Bus28	11.000	94.197	-66.7	0	0	2.932	1.817	Bus27	-2.932	-1.817	192.2	85.0	
Bus29	11.000	94.197	-66.7	0	0	2.932	1.817	Bus27	-2.932	-1.817	192.2	85.0	
Bus30	66.000	94.938	-35.4	0	0	0	0	Bus1	-10.663	-7.524	120.3	81.7	
								Bus32	10.663	7.524	120.3	81.7	
Bus31	66.000	98.011	28.0	0	0	0	0	Bus2	-4.936	-3.235	52.7	83.6	
								Bus33	4.936	3.235	52.7	83.6	
Bus32	11.000	90.861	-68.8	0	0	10.616	6.581	Bus30	-10.616	-6.581	721.5	85.0	
Bus33	11.000	96.268	-3.5	0	0	4.927	3.054	Bus31	-4.927	-3.054	316.0	85.0	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)
# indicates a bus with a load mismatch of more than 0.1 MVA

System Harmonics Bus Information

Bus		Voltage Distortion								
ID	kV	Fund. %	RMS %	ASUM %	THD %	TIF	TIHD %	TSHD %	THDG %	THDS %
Bus1	66.000	95.55	95.83	109.35	7.71	147.90	0.00	0.00	7.71	7.71
Bus2	66.000	98.27	98.55	113.93	7.66	131.63	0.00	0.00	7.66	7.66
* Bus3	220.000	100.00	100.61	121.75	11.08	229.91	0.00	0.00	11.08	11.08
Bus5	220.000	100.00	100.27	115.06	7.32	121.80	0.00	0.00	7.32	7.32
# * Bus6	11.000	94.48	94.76	108.14	7.71	148.04	0.00	0.00	7.71	7.71
Bus7	66.000	98.24	98.53	113.91	7.67	131.77	0.00	0.00	7.67	7.67
Bus8	66.000	95.46	95.74	109.22	7.69	147.52	0.00	0.00	7.69	7.69
Bus9	11.000	97.56	97.83	112.81	7.53	128.35	0.00	0.00	7.53	7.53
Bus10	11.000	92.94	93.16	104.87	6.88	126.99	0.00	0.00	6.88	6.88
Bus13	66.000	94.77	95.04	108.45	7.67	148.38	0.00	0.00	7.67	7.67
Bus14	66.000	97.44	97.72	112.89	7.60	131.01	0.00	0.00	7.60	7.60
Bus15	11.000	90.94	91.11	101.60	6.26	113.48	0.00	0.00	6.26	6.26
Bus16	11.000	93.69	93.88	106.01	6.36	101.97	0.00	0.00	6.36	6.36
Bus17	66.000	95.28	95.52	108.29	7.04	131.44	0.00	0.00	7.04	7.04
Bus18	66.000	98.18	98.48	114.22	7.83	136.15	0.00	0.00	7.83	7.83
Bus19	11.000	95.10	95.30	107.11	6.50	118.89	0.00	0.00	6.50	6.50
Bus20	11.000	98.07	98.35	113.42	7.53	128.54	0.00	0.00	7.53	7.53
Bus21	66.000	95.28	95.49	108.85	6.70	136.14	0.00	0.00	6.70	6.70
Bus22	11.000	94.74	94.88	105.56	5.48	99.22	0.00	0.00	5.48	5.48
Bus23	66.000	95.54	95.99	113.83	9.70	149.73	0.00	0.00	9.70	9.70
Bus25	11.000	94.32	94.73	111.68	9.32	141.77	0.00	0.00	9.32	9.32
Bus27	66.000	95.25	95.51	108.42	7.39	138.25	0.00	0.00	7.39	7.39
Bus28	11.000	94.20	94.44	106.78	7.15	132.37	0.00	0.00	7.15	7.15
Bus29	11.000	94.20	94.44	106.78	7.15	132.37	0.00	0.00	7.15	7.15
Bus30	66.000	94.94	95.21	108.38	7.54	144.38	0.00	0.00	7.54	7.54
Bus31	66.000	98.01	98.30	113.58	7.64	131.13	0.00	0.00	7.64	7.64
Bus32	11.000	90.86	91.03	101.33	6.16	110.97	0.00	0.00	6.16	6.16
Bus33	11.000	96.27	96.52	110.59	7.19	120.08	0.00	0.00	7.19	7.19

* Indicates THD (Total Harmonic Distortion) Exceeds the Limit.
# Indicates IHD (Individual Harmonic Distortion) Exceeds the Limit.

System Harmonics Branch Information

Bus		Current Distortion											
From Bus ID	To Bus ID	Fund. Amp	RMS Amp	ASUM Amp	THD %	TIF	IT Amp	ITB Amp	ITR Amp	TIHD %	TSHD %	THDG %	THDS %
Bus1	Bus13	64.22	64.27	69.43	4.15	80.84	5195.61	5195.61	0.00	0.00	0.00	4.15	4.15
	Bus27	176.62	177.29	211.58	8.70	143.72	25480.07	25480.07	0.00	0.00	0.00	8.70	8.70
	Bus8	37.43	37.47	40.83	4.88	88.47	3315.23	3315.23	0.00	0.00	0.00	4.88	4.88
	Bus8	37.43	37.47	40.83	4.88	88.47	3315.23	3315.23	0.00	0.00	0.00	4.88	4.88
	Bus30	119.69	119.79	128.95	4.15	72.87	8728.96	8728.96	0.00	0.00	0.00	4.15	4.15
	Bus3	425.61	426.32	477.79	5.76	97.57	41595.09	41595.09	0.00	0.00	0.00	5.76	5.76
	Bus6	11.26	11.26	11.41	0.69	10.37	116.81	116.81	0.00	0.00	0.00	0.69	0.69
Bus2	Bus14	63.04	63.10	68.91	4.38	70.90	4473.93	4473.93	0.00	0.00	0.00	4.38	4.38
	Bus18	31.05	31.20	37.41	9.70	185.14	5776.52	5776.52	0.00	0.00	0.00	9.70	9.70
	Bus7	10.19	10.21	11.69	7.03	127.52	1302.28	1302.28	0.00	0.00	0.00	7.03	7.03
	Bus7	10.19	10.21	11.69	7.03	127.52	1302.28	1302.28	0.00	0.00	0.00	7.03	7.03
	Bus31	52.12	52.20	58.08	5.53	91.14	4757.71	4757.71	0.00	0.00	0.00	5.53	5.53
	Bus5	161.51	161.79	181.75	5.93	102.60	16600.14	16600.14	0.00	0.00	0.00	5.93	5.93
Bus3	Bus1	127.68	127.90	143.34	5.76	97.57	12478.53	12478.53	0.00	0.00	0.00	5.76	5.76
Bus5	Bus2	48.45	48.54	54.52	5.93	102.60	4980.04	4980.04	0.00	0.00	0.00	5.93	5.93
Bus6	Bus1	67.58	67.58	68.47	0.69	10.37	700.87	700.87	0.00	0.00	0.00	0.69	0.69
Bus7	Bus2	10.45	10.47	11.79	6.17	105.07	1100.07	1100.07	0.00	0.00	0.00	6.17	6.17
	Bus2	10.45	10.47	11.79	6.17	105.07	1100.07	1100.07	0.00	0.00	0.00	6.17	6.17
	Bus9	20.90	20.94	23.58	6.17	105.07	2200.14	2200.14	0.00	0.00	0.00	6.17	6.17
Bus8	Bus1	37.70	37.75	41.36	5.21	96.06	3626.42	3626.42	0.00	0.00	0.00	5.21	5.21
	Bus1	37.70	37.75	41.36	5.21	96.06	3626.42	3626.42	0.00	0.00	0.00	5.21	5.21
	Bus10	75.40	75.51	82.73	5.21	96.06	7252.84	7252.84	0.00	0.00	0.00	5.21	5.21
Bus9	Bus7	125.40	125.63	141.46	6.17	105.07	13200.84	13200.84	0.00	0.00	0.00	6.17	6.17
Bus10	Bus8	452.42	453.04	496.35	5.21	96.06	43517.02	43517.02	0.00	0.00	0.00	5.21	5.21
Bus13	Bus1	65.55	65.62	71.16	4.57	82.80	5433.09	5433.09	0.00	0.00	0.00	4.57	4.57
	Bus15	65.55	65.62	71.16	4.57	82.80	5433.09	5433.09	0.00	0.00	0.00	4.57	4.57
Bus14	Bus2	64.29	64.37	70.78	4.87	78.15	5030.68	5030.68	0.00	0.00	0.00	4.87	4.87
	Bus16	64.29	64.37	70.78	4.87	78.15	5030.68	5030.68	0.00	0.00	0.00	4.87	4.87
Bus15	Bus13	393.29	393.70	426.94	4.57	82.80	32598.53	32598.53	0.00	0.00	0.00	4.57	4.57
Bus16	Bus14	385.75	386.21	424.66	4.87	78.15	30184.05	30184.05	0.00	0.00	0.00	4.87	4.87
Bus17	Bus27	124.02	124.75	154.73	10.86	177.19	22103.41	22103.41	0.00	0.00	0.00	10.86	10.86
	Bus21	60.67	61.09	77.48	11.75	239.40	14625.48	14625.48	0.00	0.00	0.00	11.75	11.75
	Bus23	18.52	19.23	29.66	27.97	320.45	6163.35	6163.35	0.00	0.00	0.00	27.97	27.97
	Bus19	49.62	49.71	55.40	5.99	109.65	5451.03	5451.03	0.00	0.00	0.00	5.99	5.99
Bus18	Bus2	30.98	31.06	35.68	7.30	124.61	3870.57	3870.57	0.00	0.00	0.00	7.30	7.30
	Bus20	30.98	31.06	35.68	7.30	124.61	3870.57	3870.57	0.00	0.00	0.00	7.30	7.30
Bus19	Bus17	297.75	298.28	332.41	5.99	109.65	32706.16	32706.16	0.00	0.00	0.00	5.99	5.99
Bus20	Bus18	185.88	186.37	214.08	7.30	124.61	23223.44	23223.44	0.00	0.00	0.00	7.30	7.30
Bus21	Bus17	60.27	60.74	77.14	12.55	230.64	14009.08	14009.08	0.00	0.00	0.00	12.55	12.55
	Bus23	12.78	14.26	27.11	49.54	879.24	12542.29	12542.29	0.00	0.00	0.00	49.54	49.54
	Bus22	54.27	54.33	59.95	5.02	90.95	4941.45	4941.45	0.00	0.00	0.00	5.02	5.02

Bus		Current Distortion											
From Bus ID	To Bus ID	Fund. Amp	RMS Amp	ASUM Amp	THD %	TIF	IT Amp	ITn Amp	ITn Amp	TIHD %	TSHD %	THDG %	THDS %
Bus22	Bus21	325.59	326.00	359.67	5.02	90.95	29648.68	29648.68	0.00	0.00	0.00	5.02	5.02
Bus23	Bus17	13.84	13.90	16.61	9.58	183.74	2554.54	2554.54	0.00	0.00	0.00	9.58	9.58
	Bus21	7.81	7.91	10.27	15.81	316.90	2506.68	2506.68	0.00	0.00	0.00	15.81	15.81
	Bus25	21.34	21.39	24.38	7.22	109.96	2352.16	2352.16	0.00	0.00	0.00	7.22	7.22
Bus25	Bus23	128.01	128.34	146.28	7.22	109.96	14112.98	14112.98	0.00	0.00	0.00	7.22	7.22
Bus27	Bus17	124.35	125.05	154.78	10.62	172.21	21535.02	21535.02	0.00	0.00	0.00	10.62	10.62
	Bus1	176.69	177.38	212.16	8.82	148.16	26280.37	26280.37	0.00	0.00	0.00	8.82	8.82
	Bus28	32.04	32.08	35.35	5.53	102.36	3284.20	3284.20	0.00	0.00	0.00	5.53	5.53
	Bus29	32.04	32.08	35.35	5.53	102.36	3284.20	3284.20	0.00	0.00	0.00	5.53	5.53
Bus28	Bus27	192.21	192.51	212.07	5.53	102.36	19705.18	19705.18	0.00	0.00	0.00	5.53	5.53
Bus29	Bus27	192.21	192.51	212.07	5.53	102.36	19705.18	19705.18	0.00	0.00	0.00	5.53	5.53
Bus30	Bus1	120.25	120.37	130.35	4.49	80.85	9732.70	9732.70	0.00	0.00	0.00	4.49	4.49
	Bus32	120.25	120.37	130.35	4.49	80.85	9732.70	9732.70	0.00	0.00	0.00	4.49	4.49
Bus31	Bus2	52.67	52.76	58.95	5.76	96.21	5075.57	5075.57	0.00	0.00	0.00	5.76	5.76
	Bus33	52.67	52.76	58.95	5.76	96.21	5075.57	5075.57	0.00	0.00	0.00	5.76	5.76
Bus32	Bus30	721.51	722.24	782.10	4.49	80.85	58396.22	58396.22	0.00	0.00	0.00	4.49	4.49
Bus33	Bus31	316.02	316.55	353.71	5.76	96.21	30453.45	30453.45	0.00	0.00	0.00	5.76	5.76

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus1
Fund. kV: 65.065

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	2.23	7.00	350.00	0.54	11.00	550.00	4.71	13.00	650.00	5.58	17.00	850.00	0.28	19.00	950.00	0.14
23.00	1150.00	0.12	25.00	1250.00	0.85												

Bus ID: Bus10
Fund. kV: 10.223

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	2.19	7.00	350.00	0.52	11.00	550.00	4.26	13.00	650.00	4.87	17.00	850.00	0.22	19.00	950.00	0.11
23.00	1150.00	0.09	25.00	1250.00	0.58												

Bus ID: Bus2
Fund. kV: 64.856

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	2.94	7.00	350.00	1.80	11.00	550.00	4.77	13.00	650.00	4.83	17.00	850.00	0.63	19.00	950.00	0.36
23.00	1150.00	0.11	25.00	1250.00	0.50												

Bus ID: Bus9
Fund. kV: 10.731

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	2.93	7.00	350.00	1.79	11.00	550.00	4.69	13.00	650.00	4.72	17.00	850.00	0.61	19.00	950.00	0.35
23.00	1150.00	0.10	25.00	1250.00	0.46												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus1
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	2.13	7.00	350.00	0.51	11.00	550.00	4.50	13.00	650.00	5.33	17.00	850.00	0.27	19.00	950.00	0.13
23.00	1150.00	0.12	25.00	1250.00	0.82												

Bus ID: Bus10
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	2.03	7.00	350.00	0.48	11.00	550.00	3.96	13.00	650.00	4.53	17.00	850.00	0.21	19.00	950.00	0.10
23.00	1150.00	0.08	25.00	1250.00	0.54												

Bus ID: Bus2
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	2.89	7.00	350.00	1.77	11.00	550.00	4.69	13.00	650.00	4.74	17.00	850.00	0.62	19.00	950.00	0.36
23.00	1150.00	0.11	25.00	1250.00	0.49												

Bus ID: Bus9
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	2.86	7.00	350.00	1.75	11.00	550.00	4.58	13.00	650.00	4.60	17.00	850.00	0.59	19.00	950.00	0.34
23.00	1150.00	0.10	25.00	1250.00	0.45												

VIHD (Individual Harmonic Distortion) Report

Bus		Voltage Distortion		
ID	kV	Fund. %	VIHD %	Order
Bus6	11.000	94.48	2.23	5.00
Bus6	11.000	94.48	4.71	11.00
Bus6	11.000	94.48	5.58	13.00

Indicates buses with IHD (Individual Harmonic Distortion) exceeding the limit

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

VTHD (Total Harmonic Distortion) Report

Bus		Voltage Distortion	
ID	kV	Fund. %	VTHD %
Bus3	220.000	100.00	11.08
Bus6	11.000	94.48	7.71

Indicates buses with THD (Total Harmonic Distortion) exceeding the limit

Alert Summary Report

	% Alert Settings	
	Critical	**Marginal**
Bus		
Individual Bus VTHD / VIHD values are used.		
Transformer		
Total I	100.0	95.0
Filter		
Capacitor kV	100.0	95.0
Inductor Amp	100.0	95.0
Capacitor		
Max kV	100.0	95.0
Cable		
Ampacity	100.0	95.0

APPENDIX 9
HARMONICS ANALYSIS WITH PV

Project:	MASTER THESIS	**ETAP**		**Page:**	1
Location:	HOUN CITY - LIBYA	12.6.0H		**Date:**	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department			**SN:**	
Engineer:	SAND MUSTAFA AL-REFAI	**Study Case:**	HA	**Revision:**	Base
Filename:	HOUN SUBSTATION 220kV			**Config:**	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Harmonic Load Flow (With PV)

Loading: Operating P, Q

Generation: Operating P, Q, V

	Swing	V-Control	Load	Total
Number of Buses:	3	7	30	40

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of Branches:	24	0	0	16	0	0	40

	Current	Voltage
Number of Harm. Sources:	4	0

Number of Filters: 0

Method of Solution:	Adaptive Newton-Raphson
Maximum No. of Iteration:	99
Precision of Solution:	0.0001000000
System Frequency:	50.00 Hz
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus			Initial Voltage		Load								% Limits	
					Constant kVA		Constant Z		Constant I		Generic			
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	VTHD	VIHD
Bus1	66.000	1	98.8	-30.0									10.00	10.00
Bus2	66.000	2	100.0	30.0									10.00	10.00
Bus3	220.000	1	100.0	0.0									5.00	5.00
Bus4	220.000	3	100.0	0.0									10.00	10.00
Bus5	220.000	2	100.0	0.0									10.00	10.00
Bus6	11.000	1	98.1	-60.0									5.00	5.00
Bus7	66.000	2	98.8	30.0									10.00	10.00
Bus8	66.000	1	99.0	-30.0									10.00	10.00
Bus9	11.000	2	98.1	0.0									10.00	10.00
Bus10	11.000	1	97.8	-60.0									10.00	10.00
Bus11	66.000	2	100.0	30.0									10.00	10.00
Bus12	66.000	1	100.0	-30.0									10.00	10.00
Bus13	66.000	1	98.3	-30.0									10.00	10.00
Bus14	66.000	2	98.0	30.0									10.00	10.00
Bus15	11.000	1	98.7	-60.0									10.00	10.00
Bus16	11.000	2	98.3	0.0									10.00	10.00
Bus17	66.000	1	98.9	-30.0									10.00	10.00
Bus18	66.000	2	98.8	30.0									10.00	10.00
Bus19	11.000	1	98.7	-60.0									10.00	10.00
Bus20	11.000	2	98.7	0.0									10.00	10.00
Bus21	66.000	1	98.9	-30.0									10.00	10.00
Bus22	11.000	1	98.4	-60.0									10.00	10.00
Bus23	66.000	1	99.3	-30.0									10.00	10.00
Bus25	11.000	1	98.1	-60.0									10.00	10.00
Bus27	66.000	1	98.8	-30.0									10.00	10.00
Bus28	11.000	1	98.4	-60.0									10.00	10.00
Bus29	11.000	1	98.4	-60.0									10.00	10.00
Bus30	66.000	1	98.5	-30.0									10.00	10.00
Bus31	66.000	2	98.6	30.0									10.00	10.00
Bus32	11.000	1	98.0	-60.0									10.00	10.00
Bus33	11.000	2	100.5	0.0									10.00	10.00
Bus34	0.400	1	100.0	-30.0									10.00	10.00
Bus35	0.400	1	100.0	-30.0									5.00	5.00
Bus36	0.400	1	100.0	-30.0									10.00	10.00

Bus			Initial Voltage		Load: Constant kVA		Load: Constant Z		Load: Constant I		Load: Generic		% Limits	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	VTHD	VIHD
Bus37	0.400	1	100.0	-30.0									10.00	10.00
Bus38	0.400	2	100.0	30.0									5.00	5.00
Bus39	0.400	2	100.0	30.0									5.00	5.00
Bus40	0.400	2	100.0	30.0									5.00	5.00
Bus41	11.000	1	120.5	-60.0									10.00	10.00
Bus42	11.000	2	98.9	0.0									10.00	10.00
Total Number of Buses: 40					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus3	220.000	Swing	1	100.0	0.0					
Bus4	220.000	Swing	3	100.0	0.0					
Bus5	220.000	Swing	2	100.0	0.0					
Bus34	0.400	Voltage Control	1	100.0	-30.0	1.952			0.000	0.000
Bus35	0.400	Voltage Control	1	100.0	-30.0	1.952			0.000	0.000
Bus36	0.400	Voltage Control	1	100.0	-30.0	1.952			0.000	0.000
Bus37	0.400	Voltage Control	1	100.0	-30.0	1.952			0.000	0.000
Bus38	0.400	Voltage Control	2	100.0	30.0	1.952			0.000	0.000
Bus39	0.400	Voltage Control	2	100.0	30.0	1.952			0.000	0.000
Bus40	0.400	Voltage Control	2	100.0	30.0	1.952			0.000	0.000
						13.662	0.000			

Cable Input Data

Cable			Length				Ohms or Mhos / 1000 m per Conductor					
ID	Library	Size	Adj. (m)	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Cable1	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646	0.240351	0.215000	
Cable2	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646	0.240351	0.215000	

Cable resistances are listed at the specified temperatures

Transmission Line Input Data

Line			Length				Ohms or Mhos / 1000 m per Phase					
ID	Library	Size	Adj. (m)	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Line1		674	19300.0	0.0	1	75	0.056003	0.374255	.0000031	0.200077	1.360791	.0000017
Line2		674	19300.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line3		674	23000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line4		674	15000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line5		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line6		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line7		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line8		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line9		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line10		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line11		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line12		674	21000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line13		674	161000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line14		674	140000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016

Line resistances are listed at the specified temperatures

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
T1	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0	12.5000	Dyn	30.000
T3	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0	12.5000	Dyn	-30.000
T4	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T5	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T6	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T7	12.500	11.000	66.000	8.35	13.00	0	0	0	0	0	8.3500	YNd	30.000
T8	12.500	11.000	66.000	8.35	13.00	0	0	0	0	0	8.3500	YNd	30.000
T9	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T10	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T11	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T12	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T13	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T14	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T16	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T17	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T18	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T19	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T20	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T21	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T22	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T23	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T24	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T25	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T26	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T1	63.000	220.000	66.000	D/Y					Solid			
T3	63.000	220.000	66.000	D/Y					Solid			
T4	10.000	66.000	11.000	D/Y					Solid			
T5	20.000	66.000	11.000	D/Y					Solid			

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T6	20.000	66.000	11.000	D/Y					Solid			
T7	12.500	11.000	66.000	D/Y					Solid			
T8	12.500	11.000	66.000	D/Y					Solid			
T9	10.000	66.000	11.000	D/Y					Solid			
T10	10.000	66.000	11.000	D/Y					Solid			
T11	20.000	66.000	11.000	D/Y					Solid			
T12	20.000	66.000	11.000	D/Y					Solid			
T13	10.000	66.000	11.000	D/Y					Solid			
T14	10.000	66.000	11.000	D/Y					Solid			
T16	20.000	66.000	11.000	D/Y					Solid			
T17	20.000	66.000	11.000	D/Y					Solid			
T18	20.000	66.000	11.000	D/Y					Solid			
T19	20.000	66.000	11.000	D/Y					Solid			
T20	3.000	0.400	11.000	D/Y					Solid			
T21	3.000	0.400	11.000	D/Y					Solid			
T22	3.000	0.400	11.000	D/Y					Solid			
T23	3.000	0.400	11.000	D/Y					Solid			
T24	3.000	0.400	11.000	D/Y					Solid			
T25	3.000	0.400	11.000	D/Y					Solid			
T26	3.000	0.400	11.000	D/Y					Solid			

Branch Connections

CKT/Branch		Connected Bus ID		% Positive Sequence Impedance (100 MVA Base)			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.44	19.84	19.84	
T3	2W XFMR	Bus5	Bus2	0.44	19.84	19.84	
T4	2W XFMR	Bus1	Bus6	6.40	83.25	83.50	
T5	2W XFMR	Bus7	Bus9	2.50	49.94	50.00	
T6	2W XFMR	Bus8	Bus10	2.50	49.94	50.00	
T7	2W XFMR	Bus42	Bus11	5.12	66.60	66.80	
T8	2W XFMR	Bus41	Bus12	5.12	66.60	66.80	
T9	2W XFMR	Bus13	Bus15	6.40	83.25	83.50	
T10	2W XFMR	Bus14	Bus16	6.40	83.25	83.50	
T11	2W XFMR	Bus17	Bus19	2.50	49.94	50.00	
T12	2W XFMR	Bus18	Bus20	2.50	49.94	50.00	
T13	2W XFMR	Bus21	Bus22	6.40	83.25	83.50	
T14	2W XFMR	Bus23	Bus25	6.40	83.25	83.50	
T16	2W XFMR	Bus27	Bus28	2.50	49.94	50.00	
T17	2W XFMR	Bus27	Bus29	2.50	49.94	50.00	
T18	2W XFMR	Bus30	Bus32	2.50	49.94	50.00	
T19	2W XFMR	Bus31	Bus33	2.50	49.94	50.00	
T20	2W XFMR	Bus34	Bus41	34.25	205.50	208.33	
T21	2W XFMR	Bus35	Bus41	34.25	205.50	208.33	
T22	2W XFMR	Bus36	Bus41	34.25	205.50	208.33	
T23	2W XFMR	Bus37	Bus41	34.25	205.50	208.33	
T24	2W XFMR	Bus38	Bus42	34.25	205.50	208.33	
T25	2W XFMR	Bus39	Bus42	34.25	205.50	208.33	
T26	2W XFMR	Bus40	Bus42	34.25	205.50	208.33	
Cable1	Cable	Bus11	Bus2	0.02	0.02	0.03	0.0716998
Cable2	Cable	Bus12	Bus1	0.02	0.02	0.03	0.0716998
Line1	Line	Bus2	Bus14	2.48	16.58	16.77	0.2607629
Line2	Line	Bus1	Bus13	2.48	15.16	15.36	0.2842266
Line3	Line	Bus2	Bus18	2.96	18.06	18.30	0.3387157
Line4	Line	Bus27	Bus17	1.93	11.78	11.94	0.2209015
Line5	Line	Bus1	Bus27	1.03	6.28	6.37	0.1178142
Line6	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line7	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line8	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line9	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line10	Line	Bus2	Bus31	1.03	6.28	6.37	0.1178142
Line11	Line	Bus1	Bus30	1.03	6.28	6.37	0.1178142

CKT/Branch		Connected Bus ID		% Positive Sequence Impedance (100 MVA Base)			
ID	Type	From Bus	To Bus	R	X	Z	Y
Line12	Line	Bus17	Bus21	2.70	16.49	16.71	0.3092622
Line13	Line	Bus17	Bus23	20.70	126.43	128.11	2.3710100
Line14	Line	Bus21	Bus23	18.00	109.94	111.40	2.0617480

Branch Connections
Zero Sequence Impedance

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
T1	2W Xfmr	Bus3	Bus1				
T3	2W Xfmr	Bus5	Bus2				
T4	2W Xfmr	Bus1	Bus6				
T5	2W Xfmr	Bus7	Bus9				
T6	2W Xfmr	Bus8	Bus10				
T7	2W Xfmr	Bus42	Bus11				
T8	2W Xfmr	Bus41	Bus12				
T9	2W Xfmr	Bus13	Bus15				
T10	2W Xfmr	Bus14	Bus16				
T11	2W Xfmr	Bus17	Bus19				
T12	2W Xfmr	Bus18	Bus20				
T13	2W Xfmr	Bus21	Bus22				
T14	2W Xfmr	Bus23	Bus25				
T16	2W Xfmr	Bus27	Bus28				
T17	2W Xfmr	Bus27	Bus29				
T18	2W Xfmr	Bus30	Bus32				
T19	2W Xfmr	Bus31	Bus33				
T20	2W Xfmr	Bus34	Bus41				
T21	2W Xfmr	Bus35	Bus41				
T22	2W Xfmr	Bus36	Bus41				
T23	2W Xfmr	Bus37	Bus41				
T24	2W Xfmr	Bus38	Bus42				
T25	2W Xfmr	Bus39	Bus42				
T26	2W Xfmr	Bus40	Bus42				
Cable1	Cable	Bus11	Bus2	0.06	0.05	0.07	
Cable2	Cable	Bus12	Bus1	0.06	0.05	0.07	
Line1	Line	Bus2	Bus14	8.86	60.29	60.94	0.1410145
Line2	Line	Bus1	Bus13	8.89	63.09	63.72	0.1341983
Line3	Line	Bus2	Bus18	10.59	75.19	75.93	0.1599255
Line4	Line	Bus27	Bus17	6.91	49.04	49.52	0.1042992
Line5	Line	Bus1	Bus27	3.68	26.15	26.41	0.0556262
Line6	Line	Bus2	Bus7	1.84	13.08	13.21	0.0278131
Line7	Line	Bus1	Bus8	1.84	13.08	13.21	0.0278131
Line8	Line	Bus2	Bus7	1.84	13.08	13.21	0.0278131
Line9	Line	Bus1	Bus8	1.84	13.08	13.21	0.0278131
Line10	Line	Bus2	Bus31	3.68	26.15	26.41	0.0556262

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
Line11	Line	Bus1	Bus30	3.68	26.15	26.41	0.0556262
Line12	Line	Bus17	Bus21	9.67	68.65	69.33	0.1460189
Line13	Line	Bus17	Bus23	74.16	526.33	531.53	1.1194780
Line14	Line	Bus21	Bus23	64.48	457.68	462.20	0.9734595

Machine Input Data

Machine		Connected Bus	Rating (Base)			% Negative Seq. Imp.			Grounding			% Zero Seq. Imp.		
ID	Type	ID	MVA	kV	RPM	X/R	R2	X2	Conn.	Type	Amp	X/R	R0	X0
U1	Grid	Bus3	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	35.648	356.48
U2	Grid	Bus4	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	17.738	177.38
U3	Grid	Bus5	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	17.738	177.38

Harmonic Library

Current Harmonic Source in %

Manufacturer: Typical-IEEE
Model: 12 Pulse2

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	11.00	550.00	8.30	13.00	650.00	6.70	23.00	1150.00	2.80	25.00	1250.00	2.30	35.00	1750.00	0.80
37.00	1850.00	0.60	47.00	2350.00	0.20	49.00	2450.00	0.20									

Manufacturer: Typical-IEEE
Model: 12 Pulse2

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	11.00	550.00	8.30	13.00	650.00	6.70	23.00	1150.00	2.80	25.00	1250.00	2.30	35.00	1750.00	0.80
37.00	1850.00	0.60	47.00	2350.00	0.20	49.00	2450.00	0.20									

Manufacturer: Typical-IEEE
Model: 12 Pulse2

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	11.00	550.00	8.30	13.00	650.00	6.70	23.00	1150.00	2.80	25.00	1250.00	2.30	35.00	1750.00	0.80
37.00	1850.00	0.60	47.00	2350.00	0.20	49.00	2450.00	0.20									

Manufacturer: Typical-IEEE
Model: 12 Pulse2

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	11.00	550.00	8.30	13.00	650.00	6.70	23.00	1150.00	2.80	25.00	1250.00	2.30	35.00	1750.00	0.80
37.00	1850.00	0.60	47.00	2350.00	0.20	49.00	2450.00	0.20									

Harmonic Source from Library

		Harmonic Source Information				
Bus ID	Device ID	Type	Manufacturer	Model	Fund. Freq.	Mod. Freq.
Bus34	Inv11	Current	Typical-IEEE	12 Pulse2	0.00	0.00
Bus36	Inv15	Current	Typical-IEEE	12 Pulse2	0.00	0.00
Bus37	Inv18	Current	Typical-IEEE	12 Pulse2	0.00	0.00
Bus39	Inv21	Current	Typical-IEEE	12 Pulse2	0.00	0.00

Project:	MASTER THESIS	**ETAP**		**Page:**	15
Location:	HOUN CITY - LIBYA	12.6.0H		**Date:**	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department			**SN:**	
Engineer:	SAND MUSTAFA AL-REFAI	**Study Case:**	HA	**Revision:**	Base
Filename:	HOUN SUBSTATION 220kV			**Config:**	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Fundamental Load Flow Report

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
Bus1	66.000	101.039	-29.1	0	0	0	0	Bus12	-7.726	0.622	67.1	-99.7	
								Bus13	0.000	-0.290	2.5	0.0	
								Bus27	0.014	-5.271	45.6	-0.3	
								Bus8	0.000	-0.060	0.5	0.0	
								Bus8	0.000	-0.060	0.5	0.0	
								Bus30	0.000	-0.120	1.0	0.0	
								Bus3	7.712	5.180	80.4	83.0	
								Bus6	0.000	0.000	0.0	0.0	
Bus2	66.000	100.109	30.7	0	0	0	0	Bus11	-5.799	0.384	50.8	-99.8	
								Bus14	0.000	-0.261	2.3	0.0	
								Bus18	0.000	-0.340	3.0	0.0	
								Bus7	0.000	-0.059	0.5	0.0	
								Bus7	0.000	-0.059	0.5	0.0	
								Bus31	0.000	-0.118	1.0	0.0	
								Bus5	5.799	0.453	50.8	99.7	
* Bus3	220.000	100.000	0.0	-7.708	-5.012	0	0	Bus1	-7.708	-5.012	24.1	83.8	
* Bus5	220.000	100.000	0.0	-5.798	-0.386	0	0	Bus2	-5.798	-0.386	15.2	99.8	
Bus6	11.000	101.039	-59.1	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
Bus7	66.000	100.110	30.7	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus2	0.000	0.000	0.0	0.0	
								Bus9	0.000	0.000	0.0	0.0	
Bus8	66.000	101.040	-29.1	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus1	0.000	0.000	0.0	0.0	
								Bus10	0.000	0.000	0.0	0.0	
Bus9	11.000	100.110	0.7	0	0	0	0	Bus7	0.000	0.000	0.0	0.0	
Bus10	11.000	101.040	-59.1	0	0	0	0	Bus8	0.000	0.000	0.0	0.0	
Bus11	66.000	100.110	30.7	0	0	0	0	Bus2	5.799	-0.456	50.8	-99.7	
								Bus42	-5.799	0.456	50.8	-99.7	
Bus12	66.000	101.041	-29.1	0	0	0	0	Bus1	7.726	-0.695	67.2	-99.6	
								Bus41	-7.726	0.695	67.2	-99.6	
Bus13	66.000	101.061	-29.1	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus15	0.000	0.000	0.0	0.0	
Bus14	66.000	100.130	30.7	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus16	0.000	0.000	0.0	0.0	
Bus15	11.000	101.061	-59.1	0	0	0	0	Bus13	0.000	0.000	0.0	0.0	
Bus16	11.000	100.130	0.7	0	0	0	0	Bus14	0.000	0.000	0.0	0.0	
Bus17	66.000	101.950	-29.2	0	0	0	0	Bus27	-0.007	4.968	42.6	-0.1	

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
								Bus21	0.004	-2.486	21.3	-0.1	
								Bus23	0.003	-2.482	21.3	-0.1	
								Bus19	0.000	0.000	0.0	0.0	
Bus18	66.000	100.139	30.7	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus20	0.000	0.000	0.0	0.0	
Bus19	11.000	101.950	-59.2	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
Bus20	11.000	100.139	0.7	0	0	0	0	Bus18	0.000	0.000	0.0	0.0	
Bus21	66.000	102.326	-29.3	0	0	0	0	Bus17	-0.002	2.172	18.6	-0.1	
								Bus23	0.002	-2.172	18.6	-0.1	
								Bus22	0.000	0.000	0.0	0.0	
Bus22	11.000	102.326	-59.3	0	0	0	0	Bus21	0.000	0.000	0.0	0.0	
Bus23	66.000	103.500	-29.4	0	0	0	0	Bus17	0.000	-0.001	0.0	-16.2	
								Bus21	0.000	0.001	0.0	-16.2	
								Bus25	0.000	0.000	0.0	0.0	
Bus25	11.000	103.500	-59.4	0	0	0	0	Bus23	0.000	0.000	0.0	0.0	
Bus27	66.000	101.363	-29.2	0	0	0	0	Bus17	0.011	-5.167	44.6	-0.2	
								Bus1	-0.011	5.167	44.6	-0.2	
								Bus28	0.000	0.000	0.0	0.0	
								Bus29	0.000	0.000	0.0	0.0	
Bus28	11.000	101.363	-59.2	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	
Bus29	11.000	101.363	-59.2	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	
Bus30	66.000	101.043	-29.1	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus32	0.000	0.000	0.0	0.0	
Bus31	66.000	100.112	30.7	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus33	0.000	0.000	0.0	0.0	
Bus32	11.000	101.043	-59.1	0	0	0	0	Bus30	0.000	0.000	0.0	0.0	
Bus33	11.000	100.112	0.7	0	0	0	0	Bus31	0.000	0.000	0.0	0.0	
Bus34	0.400	101.685	-24.0	1.952	0.000	0	0	Bus41	1.952	0.000	2770.4	100.0	
Bus35	0.400	101.685	-24.0	1.952	0.000	0	0	Bus41	1.952	0.000	2770.4	100.0	
Bus36	0.400	101.685	-24.0	1.952	0.000	0	0	Bus41	1.952	0.000	2770.4	100.0	
Bus37	0.400	101.685	-24.0	1.952	0.000	0	0	Bus41	1.952	0.000	2770.4	100.0	
Bus38	0.400	100.762	35.2	1.952	0.000	0	0	Bus42	1.952	0.000	2795.7	100.0	
Bus39	0.400	100.762	35.2	1.952	0.000	0	0	Bus42	1.952	0.000	2795.7	100.0	
Bus40	0.400	100.762	35.2	1.952	0.000	0	0	Bus42	1.952	0.000	2795.7	100.0	
Bus41	11.000	101.104	-56.2	0	0	0	0	Bus12	7.756	-0.303	403.0	-99.9	
								Bus34	-1.939	0.076	100.7	-99.9	
								Bus35	-1.939	0.076	100.7	-99.9	
								Bus36	-1.939	0.076	100.7	-99.9	
								Bus37	-1.939	0.076	100.7	-99.9	

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
Bus42	11.000	100.178	2.9	0	0	0	0	Bus11	5.817	-0.231	305.0	-99.9	
								Bus38	-1.939	0.077	101.7	-99.9	
								Bus39	-1.939	0.077	101.7	-99.9	
								Bus40	-1.939	0.077	101.7	-99.9	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# indicates a bus with a load mismatch of more than 0.1 MVA

System Harmonics Bus Information

Bus		Voltage Distortion								
ID	kV	Fund. %	RMS %	ASUM %	THD %	TIF	TIHD %	TSHD %	THDG %	THDS %
Bus1	66.000	101.04	101.07	105.13	2.32	53.04	0.00	0.00	2.32	2.32
Bus2	66.000	100.11	100.12	101.91	1.14	20.54	0.00	0.00	1.14	1.14
Bus3	220.000	100.00	100.03	103.92	2.25	51.33	0.00	0.00	2.25	2.25
Bus5	220.000	100.00	100.01	101.72	1.09	19.70	0.00	0.00	1.09	1.09
Bus6	11.000	101.04	101.07	105.13	2.32	53.04	0.00	0.00	2.32	2.32
Bus7	66.000	100.11	100.12	101.91	1.14	20.58	0.00	0.00	1.14	1.14
Bus8	66.000	101.04	101.07	105.14	2.32	53.21	0.00	0.00	2.32	2.32
Bus9	11.000	100.11	100.12	101.91	1.14	20.58	0.00	0.00	1.14	1.14
Bus10	11.000	101.04	101.07	105.14	2.32	53.21	0.00	0.00	2.32	2.32
Bus11	66.000	100.11	100.12	101.91	1.14	20.54	0.00	0.00	1.14	1.14
Bus12	66.000	101.04	101.07	105.13	2.32	53.05	0.00	0.00	2.32	2.32
Bus13	66.000	101.06	101.09	105.40	2.40	57.58	0.00	0.00	2.40	2.40
Bus14	66.000	100.13	100.14	102.01	1.17	21.51	0.00	0.00	1.17	1.17
Bus15	11.000	101.06	101.09	105.40	2.40	57.58	0.00	0.00	2.40	2.40
Bus16	11.000	100.13	100.14	102.01	1.17	21.51	0.00	0.00	1.17	1.17
Bus17	66.000	101.95	101.97	105.01	1.89	36.15	0.00	0.00	1.89	1.89
Bus18	66.000	100.14	100.15	102.06	1.19	21.99	0.00	0.00	1.19	1.19
Bus19	11.000	101.95	101.97	105.01	1.89	36.15	0.00	0.00	1.89	1.89
Bus20	11.000	100.14	100.15	102.06	1.19	21.99	0.00	0.00	1.19	1.19
Bus21	66.000	102.33	102.34	105.84	1.79	52.33	0.00	0.00	1.79	1.79
Bus22	11.000	102.33	102.34	105.84	1.79	52.33	0.00	0.00	1.79	1.79
Bus23	66.000	103.50	103.55	107.72	2.96	47.16	0.00	0.00	2.96	2.96
Bus25	11.000	103.50	103.55	107.72	2.96	47.16	0.00	0.00	2.96	2.96
Bus27	66.000	101.36	101.39	105.02	2.15	43.49	0.00	0.00	2.15	2.15
Bus28	11.000	101.36	101.39	105.02	2.15	43.49	0.00	0.00	2.15	2.15
Bus29	11.000	101.36	101.39	105.02	2.15	43.49	0.00	0.00	2.15	2.15
Bus30	66.000	101.04	101.07	105.17	2.33	53.73	0.00	0.00	2.33	2.33
Bus31	66.000	100.11	100.12	101.92	1.15	20.70	0.00	0.00	1.15	1.15
Bus32	11.000	101.04	101.07	105.17	2.33	53.73	0.00	0.00	2.33	2.33
Bus33	11.000	100.11	100.12	101.92	1.15	20.70	0.00	0.00	1.15	1.15
Bus34	0.400	101.68	101.91	117.50	6.73	273.30	0.00	0.00	6.73	6.73
Bus35	0.400	101.68	101.75	109.24	3.69	130.71	0.00	0.00	3.69	3.69
Bus36	0.400	101.68	101.91	117.50	6.73	273.30	0.00	0.00	6.73	6.73
Bus37	0.400	101.68	101.91	117.50	6.73	273.30	0.00	0.00	6.73	6.73
Bus38	0.400	100.76	100.76	102.19	0.58	28.34	0.00	0.00	0.58	0.58
Bus39	0.400	100.76	100.83	110.01	3.61	181.76	0.00	0.00	3.61	3.61
Bus40	0.400	100.76	100.76	102.19	0.58	28.34	0.00	0.00	0.58	0.58
Bus41	11.000	101.10	101.18	109.18	3.97	140.38	0.00	0.00	3.97	3.97
Bus42	11.000	100.18	100.18	101.70	0.62	30.46	0.00	0.00	0.63	0.63

* Indicates THD (Total Harmonic Distortion) Exceeds the Limit.
\# Indicates IHD (Individual Harmonic Distortion) Exceeds the Limit.

System Harmonics Branch Information

Bus		Current Distortion											
From Bus ID	To Bus ID	Fund. Amp	RMS Amp	ASUM Amp	THD %	TIF	IT Amp	ITB Amp	ITR Amp	TIHD %	TSHD %	THDG %	THDS %
Bus1	Bus12	67.11	67.15	71.91	3.66	98.65	6624.56	6624.56	0.00	0.00	0.00	3.66	3.66
	Bus13	2.51	2.63	4.13	31.18	1067.19	2808.61	2808.61	0.00	0.00	0.00	31.18	31.18
	Bus27	45.64	45.74	51.39	6.57	215.97	9877.82	9877.82	0.00	0.00	0.00	6.57	6.57
	Bus8	0.52	0.54	0.84	30.34	1005.48	547.08	547.08	0.00	0.00	0.00	30.34	30.34
	Bus8	0.52	0.54	0.84	30.34	1005.48	547.08	547.08	0.00	0.00	0.00	30.34	30.34
	Bus30	1.04	1.09	1.69	30.44	1012.47	1102.09	1102.09	0.00	0.00	0.00	30.44	30.44
	Bus3	80.43	80.43	81.00	0.46	8.15	655.68	655.68	0.00	0.00	0.00	0.46	0.46
	Bus6	0	0	0	0	0	0.00	655.68	0.00	0.00	0.00	0.00	0.00
Bus2	Bus11	50.79	50.79	52.38	1.64	41.16	2090.84	2090.84	0.00	0.00	0.00	1.64	1.64
	Bus14	2.28	2.31	2.86	13.81	316.86	730.51	730.51	0.00	0.00	0.00	13.81	13.81
	Bus18	2.97	3.00	3.73	13.92	323.86	970.03	970.03	0.00	0.00	0.00	13.92	13.92
	Bus7	0.52	0.52	0.64	13.58	304.59	158.57	158.57	0.00	0.00	0.00	13.58	13.58
	Bus7	0.52	0.52	0.64	13.58	304.59	158.57	158.57	0.00	0.00	0.00	13.58	13.58
	Bus31	1.03	1.04	1.29	13.61	306.03	318.66	318.66	0.00	0.00	0.00	13.61	13.61
	Bus5	50.83	50.83	51.09	0.36	5.95	302.37	302.37	0.00	0.00	0.00	0.36	0.36
Bus3	Bus1	24.13	24.13	24.30	0.46	8.15	196.70	196.70	0.00	0.00	0.00	0.46	0.46
Bus5	Bus2	15.25	15.25	15.33	0.36	5.95	90.71	90.71	0.00	0.00	0.00	0.36	0.36
Bus6	Bus1	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
Bus7	Bus2	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
	Bus2	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
	Bus9	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
Bus8	Bus1	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
	Bus1	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
	Bus10	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
Bus9	Bus7	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
Bus10	Bus8	0	0	0	0	0	0.00	90.71	0.00	0.00	0.00	0.00	0.00
Bus11	Bus2	50.83	50.84	52.58	1.80	44.89	2282.37	2282.37	0.00	0.00	0.00	1.80	1.80
	Bus42	50.83	50.84	52.58	1.80	44.89	2282.37	2282.37	0.00	0.00	0.00	1.80	1.80
Bus12	Bus1	67.16	67.20	71.82	3.57	93.57	6288.25	6288.25	0.00	0.00	0.00	3.57	3.57
	Bus41	67.16	67.20	71.82	3.57	93.57	6288.25	6288.25	0.00	0.00	0.00	3.57	3.57
Bus13	Bus1	0	0	0	0	0	0.00	6288.25	0.00	0.00	0.00	0.00	0.00
	Bus15	0	0	0	0	0	0.00	6288.25	0.00	0.00	0.00	0.00	0.00
Bus14	Bus2	0	0	0	0	0	0.00	6288.25	0.00	0.00	0.00	0.00	0.00
	Bus16	0	0	0	0	0	0.00	6288.25	0.00	0.00	0.00	0.00	0.00
Bus15	Bus13	0	0	0	0	0	0.00	6288.25	0.00	0.00	0.00	0.00	0.00
Bus16	Bus14	0	0	0	0	0	0.00	6288.25	0.00	0.00	0.00	0.00	0.00
Bus17	Bus27	42.63	42.77	48.61	8.07	258.04	11036.00	11036.00	0.00	0.00	0.00	8.07	8.07
	Bus21	21.33	21.45	25.79	10.66	448.69	9625.84	9625.84	0.00	0.00	0.00	10.66	10.66
	Bus23	21.30	21.34	23.80	6.56	181.12	3865.78	3865.78	0.00	0.00	0.00	6.56	6.56
	Bus19	0	0	0	0	0	0.00	3865.78	0.00	0.00	0.00	0.00	0.00

Bus		Current Distortion											
From Bus ID	To Bus ID	Fund. Amp	RMS Amp	ASUM Amp	THD %	TIF	IT Amp	ITB Amp	ITR Amp	TIHD %	TSHD %	THDG %	THDS %
Bus18	Bus2	0	0	0	0	0	0.00	3865.78	0.00	0.00	0.00	0.00	0.00
	Bus20	0	0	0	0	0	0.00	3865.78	0.00	0.00	0.00	0.00	0.00
Bus19	Bus17	0	0	0	0	0	0.00	3865.78	0.00	0.00	0.00	0.00	0.00
Bus20	Bus18	0	0	0	0	0	0.00	3865.78	0.00	0.00	0.00	0.00	0.00
Bus21	Bus17	18.57	18.72	23.08	12.90	445.83	8347.30	8347.30	0.00	0.00	0.00	12.90	12.90
	Bus23	18.57	18.72	23.08	12.90	445.83	8347.30	8347.30	0.00	0.00	0.00	12.90	12.90
	Bus22	0	0	0	0	0	0.00	8347.30	0.00	0.00	0.00	0.00	0.00
Bus22	Bus21	0	0	0	0	0	0.00	8347.30	0.00	0.00	0.00	0.00	0.00
Bus23	Bus17	0.01	0.39	0.75	4850.20	2613.08	1019.93	1019.93	0.00	0.00	0.00	4850.20	4850.20
	Bus21	0.01	0.39	0.75	4850.20	2613.08	1019.93	1019.93	0.00	0.00	0.00	4850.20	4850.20
	Bus25	0	0	0	0	0	0.00	1019.93	0.00	0.00	0.00	0.00	0.00
Bus25	Bus23	0	0	0	0	0	0.00	1019.93	0.00	0.00	0.00	0.00	0.00
Bus27	Bus17	44.59	44.71	50.56	7.15	237.32	10610.28	10610.28	0.00	0.00	0.00	7.15	7.15
	Bus1	44.59	44.71	50.56	7.15	237.32	10610.28	10610.28	0.00	0.00	0.00	7.15	7.15
	Bus28	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
	Bus29	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
Bus28	Bus27	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
Bus29	Bus27	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
Bus30	Bus1	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
	Bus32	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
Bus31	Bus2	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
	Bus33	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
Bus32	Bus30	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
Bus33	Bus31	0	0	0	0	0	0.00	10610.28	0.00	0.00	0.00	0.00	0.00
Bus34	Bus41	2770.37	2773.68	3033.78	4.89	127.69	354180.40	354180.40	0.00	0.00	0.00	4.89	4.89
Bus35	Bus41	2770.37	2770.40	2792.18	0.50	10.76	29801.97	29801.97	0.00	0.00	0.00	0.50	0.50
Bus36	Bus41	2770.37	2773.68	3033.78	4.89	127.69	354180.40	354180.40	0.00	0.00	0.00	4.89	4.89
Bus37	Bus41	2770.37	2773.68	3033.78	4.89	127.69	354180.40	354180.40	0.00	0.00	0.00	4.89	4.89
Bus38	Bus42	2795.72	2795.72	2799.27	0.07	1.98	5530.49	5530.49	0.00	0.00	0.00	0.07	0.07
Bus39	Bus42	2795.72	2799.70	3082.91	5.34	136.04	380861.50	380861.50	0.00	0.00	0.00	5.34	5.34
Bus40	Bus42	2795.72	2795.72	2799.27	0.07	1.98	5530.49	5530.49	0.00	0.00	0.00	0.07	0.07
Bus41	Bus12	402.96	403.22	430.94	3.57	93.57	37729.53	37729.53	0.00	0.00	0.00	3.57	3.57
	Bus34	100.74	100.86	110.32	4.89	127.69	12879.29	12879.29	0.00	0.00	0.00	4.89	4.89
	Bus35	100.74	100.74	101.53	0.50	10.76	1083.71	1083.71	0.00	0.00	0.00	0.50	0.50
	Bus36	100.74	100.86	110.32	4.89	127.69	12879.29	12879.29	0.00	0.00	0.00	4.89	4.89
	Bus37	100.74	100.86	110.32	4.89	127.69	12879.29	12879.29	0.00	0.00	0.00	4.89	4.89
Bus42	Bus11	304.99	305.04	315.46	1.80	44.89	13694.22	13694.22	0.00	0.00	0.00	1.80	1.80
	Bus38	101.66	101.66	101.79	0.07	1.98	201.11	201.11	0.00	0.00	0.00	0.07	0.07
	Bus39	101.66	101.81	112.11	5.34	136.04	13849.50	13849.50	0.00	0.00	0.00	5.34	5.34
	Bus40	101.66	101.66	101.79	0.07	1.98	201.11	201.11	0.00	0.00	0.00	0.07	0.07

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus1
Fund. kV: 66.686

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.89	13.00	650.00	1.18	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus10
Fund. kV: 11.114

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.89	13.00	650.00	1.18	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus11
Fund. kV: 66.072

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.96	13.00	650.00	0.59	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus12
Fund. kV: 66.687

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.89	13.00	650.00	1.18	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus13
Fund. kV: 66.700

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.94	13.00	650.00	1.22	23.00	1150.00	0.37	25.00	1250.00	0.62	35.00	1750.00	0.06	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.04												

Bus ID: Bus14
Fund. kV: 66.086

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.99	13.00	650.00	0.61	23.00	1150.00	0.13	25.00	1250.00	0.10	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus15
Fund. kV: 11.117

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.94	13.00	650.00	1.22	23.00	1150.00	0.37	25.00	1250.00	0.62	35.00	1750.00	0.06	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.04												

Bus ID: Bus16
Fund. kV: 11.014

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.99	13.00	650.00	0.61	23.00	1150.00	0.13	25.00	1250.00	0.10	35.00	1750.00	0.03	37.00	1850.00	0.02

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus16
Fund. kV: 11.014

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus17
Fund. kV: 67.287

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.33	13.00	650.00	1.33	23.00	1150.00	0.11	25.00	1250.00	0.05	35.00	1750.00	0.08	37.00	1850.00	0.08
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus18
Fund. kV: 66.092

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.00	13.00	650.00	0.62	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus19
Fund. kV: 11.215

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.33	13.00	650.00	1.33	23.00	1150.00	0.11	25.00	1250.00	0.05	35.00	1750.00	0.08	37.00	1850.00	0.08
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus2
Fund. kV: 66.072

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.96	13.00	650.00	0.59	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus20
Fund. kV: 11.015

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.00	13.00	650.00	0.62	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus21
Fund. kV: 67.536

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.99	13.00	650.00	1.32	23.00	1150.00	0.41	25.00	1250.00	0.55	35.00	1750.00	0.09	37.00	1850.00	0.07
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus22
Fund. kV: 11.256

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.99	13.00	650.00	1.32	23.00	1150.00	0.41	25.00	1250.00	0.55	35.00	1750.00	0.09	37.00	1850.00	0.07
47.00	2350.00	0.01	49.00	2450.00	0.00												

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus23
Fund. kV: 68.310

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	2.65	13.00	650.00	1.33	23.00	1150.00	0.05	25.00	1250.00	0.05	35.00	1750.00	0.00	37.00	1850.00	0.00
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus25
Fund. kV: 11.385

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	2.65	13.00	650.00	1.33	23.00	1150.00	0.05	25.00	1250.00	0.05	35.00	1750.00	0.00	37.00	1850.00	0.00
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus27
Fund. kV: 66.900

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.71	13.00	650.00	1.25	23.00	1150.00	0.18	25.00	1250.00	0.35	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus28
Fund. kV: 11.150

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.71	13.00	650.00	1.25	23.00	1150.00	0.18	25.00	1250.00	0.35	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus29
Fund. kV: 11.150

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.71	13.00	650.00	1.25	23.00	1150.00	0.18	25.00	1250.00	0.35	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus3
Fund. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.83	13.00	650.00	1.14	23.00	1150.00	0.32	25.00	1250.00	0.53	35.00	1750.00	0.04	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus30
Fund. kV: 66.688

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.90	13.00	650.00	1.19	23.00	1150.00	0.34	25.00	1250.00	0.56	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus31
Fund. kV: 66.074

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.97	13.00	650.00	0.60	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus31
Fund. kV: 66.074

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus32
Fund. kV: 11.115

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.90	13.00	650.00	1.19	23.00	1150.00	0.34	25.00	1250.00	0.56	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus33
Fund. kV: 11.012

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.97	13.00	650.00	0.60	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus34
Fund. kV: 0.407

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	4.79	13.00	650.00	2.20	23.00	1150.00	2.72	25.00	1250.00	2.67	35.00	1750.00	1.21	37.00	1850.00	1.00
47.00	2350.00	0.46	49.00	2450.00	0.50												

Bus ID: Bus35
Fund. kV: 0.407

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.05	13.00	650.00	0.50	23.00	1150.00	1.32	25.00	1250.00	1.39	35.00	1750.00	0.45	37.00	1850.00	0.39
47.00	2350.00	0.16	49.00	2450.00	0.17												

Bus ID: Bus36
Fund. kV: 0.407

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	4.79	13.00	650.00	2.20	23.00	1150.00	2.72	25.00	1250.00	2.67	35.00	1750.00	1.21	37.00	1850.00	1.00
47.00	2350.00	0.46	49.00	2450.00	0.50												

Bus ID: Bus37
Fund. kV: 0.407

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	4.79	13.00	650.00	2.20	23.00	1150.00	2.72	25.00	1250.00	2.67	35.00	1750.00	1.21	37.00	1850.00	1.00
47.00	2350.00	0.46	49.00	2450.00	0.50												

Bus ID: Bus38
Fund. kV: 0.403

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.37	13.00	650.00	0.12	23.00	1150.00	0.27	25.00	1250.00	0.26	35.00	1750.00	0.15	37.00	1850.00	0.12
47.00	2350.00	0.06	49.00	2450.00	0.06												

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus39
Fund. kV: 0.403

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.53	13.00	650.00	1.76	23.00	1150.00	1.77	25.00	1250.00	1.64	35.00	1750.00	0.94	37.00	1850.00	0.77
47.00	2350.00	0.38	49.00	2450.00	0.40												

Bus ID: Bus4
Fund. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %

Bus ID: Bus40
Fund. kV: 0.403

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.37	13.00	650.00	0.12	23.00	1150.00	0.27	25.00	1250.00	0.26	35.00	1750.00	0.15	37.00	1850.00	0.12
47.00	2350.00	0.06	49.00	2450.00	0.06												

Bus ID: Bus41
Fund. kV: 11.121

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.27	13.00	650.00	0.54	23.00	1150.00	1.41	25.00	1250.00	1.50	35.00	1750.00	0.49	37.00	1850.00	0.42
47.00	2350.00	0.17	49.00	2450.00	0.18												

Bus ID: Bus42
Fund. kV: 11.020

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.40	13.00	650.00	0.13	23.00	1150.00	0.29	25.00	1250.00	0.28	35.00	1750.00	0.16	37.00	1850.00	0.13
47.00	2350.00	0.06	49.00	2450.00	0.07												

Bus ID: Bus5
Fund. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.92	13.00	650.00	0.57	23.00	1150.00	0.11	25.00	1250.00	0.08	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus6
Fund. kV: 11.114

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.89	13.00	650.00	1.18	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus7
Fund. kV: 66.072

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.96	13.00	650.00	0.59	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Project:	MASTER THESIS	ETAP		Page:	26
Location:	HOUN CITY - LIBYA	12.6.0H		Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department			SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case:	HA	Revision:	Base
Filename:	HOUN SUBSTATION 220kV			Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus8
Fund. kV: 66.687

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.89	13.00	650.00	1.18	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus9
Fund. kV: 11.012

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.96	13.00	650.00	0.59	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus1
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.91	13.00	650.00	1.19	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus10
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.91	13.00	650.00	1.19	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus11
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.96	13.00	650.00	0.59	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus12
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.91	13.00	650.00	1.19	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus13
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.96	13.00	650.00	1.23	23.00	1150.00	0.37	25.00	1250.00	0.63	35.00	1750.00	0.06	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.04												

Bus ID: Bus14
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.99	13.00	650.00	0.61	23.00	1150.00	0.13	25.00	1250.00	0.10	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus15
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.96	13.00	650.00	1.23	23.00	1150.00	0.37	25.00	1250.00	0.63	35.00	1750.00	0.06	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.04												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus16
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.99	13.00	650.00	0.61	23.00	1150.00	0.13	25.00	1250.00	0.10	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus17
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.36	13.00	650.00	1.35	23.00	1150.00	0.11	25.00	1250.00	0.05	35.00	1750.00	0.08	37.00	1850.00	0.08
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus18
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.00	13.00	650.00	0.62	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus19
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.36	13.00	650.00	1.35	23.00	1150.00	0.11	25.00	1250.00	0.05	35.00	1750.00	0.08	37.00	1850.00	0.08
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus2
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.96	13.00	650.00	0.59	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus20
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.00	13.00	650.00	0.62	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus21
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.01	13.00	650.00	1.35	23.00	1150.00	0.42	25.00	1250.00	0.57	35.00	1750.00	0.09	37.00	1850.00	0.07
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus22
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.01	13.00	650.00	1.35	23.00	1150.00	0.42	25.00	1250.00	0.57	35.00	1750.00	0.09	37.00	1850.00	0.07
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus23
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	2.74	13.00	650.00	1.37	23.00	1150.00	0.05	25.00	1250.00	0.05	35.00	1750.00	0.00	37.00	1850.00	0.00
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus25
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	2.74	13.00	650.00	1.37	23.00	1150.00	0.05	25.00	1250.00	0.05	35.00	1750.00	0.00	37.00	1850.00	0.00
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus27
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.73	13.00	650.00	1.26	23.00	1150.00	0.19	25.00	1250.00	0.35	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus28
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.73	13.00	650.00	1.26	23.00	1150.00	0.19	25.00	1250.00	0.35	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus29
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.73	13.00	650.00	1.26	23.00	1150.00	0.19	25.00	1250.00	0.35	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus3
Nom. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.83	13.00	650.00	1.14	23.00	1150.00	0.32	25.00	1250.00	0.53	35.00	1750.00	0.04	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.02												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus30
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.92	13.00	650.00	1.20	23.00	1150.00	0.34	25.00	1250.00	0.56	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus31
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.97	13.00	650.00	0.60	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus32
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.92	13.00	650.00	1.20	23.00	1150.00	0.34	25.00	1250.00	0.56	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus33
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.97	13.00	650.00	0.60	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus34
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	4.87	13.00	650.00	2.24	23.00	1150.00	2.77	25.00	1250.00	2.71	35.00	1750.00	1.23	37.00	1850.00	1.02
47.00	2350.00	0.47	49.00	2450.00	0.51												

Bus ID: Bus35
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.10	13.00	650.00	0.51	23.00	1150.00	1.34	25.00	1250.00	1.42	35.00	1750.00	0.46	37.00	1850.00	0.39
47.00	2350.00	0.16	49.00	2450.00	0.17												

Bus ID: Bus36
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	4.87	13.00	650.00	2.24	23.00	1150.00	2.77	25.00	1250.00	2.71	35.00	1750.00	1.23	37.00	1850.00	1.02
47.00	2350.00	0.47	49.00	2450.00	0.51												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus37
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	4.87	13.00	650.00	2.24	23.00	1150.00	2.77	25.00	1250.00	2.71	35.00	1750.00	1.23	37.00	1850.00	1.02
47.00	2350.00	0.47	49.00	2450.00	0.51												

Bus ID: Bus38
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.38	13.00	650.00	0.12	23.00	1150.00	0.27	25.00	1250.00	0.26	35.00	1750.00	0.15	37.00	1850.00	0.13
47.00	2350.00	0.06	49.00	2450.00	0.06												

Bus ID: Bus39
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.54	13.00	650.00	1.77	23.00	1150.00	1.78	25.00	1250.00	1.65	35.00	1750.00	0.95	37.00	1850.00	0.77
47.00	2350.00	0.38	49.00	2450.00	0.41												

Bus ID: Bus4
Nom. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %

Bus ID: Bus40
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.38	13.00	650.00	0.12	23.00	1150.00	0.27	25.00	1250.00	0.26	35.00	1750.00	0.15	37.00	1850.00	0.13
47.00	2350.00	0.06	49.00	2450.00	0.06												

Bus ID: Bus41
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.31	13.00	650.00	0.55	23.00	1150.00	1.43	25.00	1250.00	1.51	35.00	1750.00	0.49	37.00	1850.00	0.42
47.00	2350.00	0.17	49.00	2450.00	0.19												

Bus ID: Bus42
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.40	13.00	650.00	0.13	23.00	1150.00	0.29	25.00	1250.00	0.28	35.00	1750.00	0.17	37.00	1850.00	0.13
47.00	2350.00	0.06	49.00	2450.00	0.07												

Bus ID: Bus5
Nom. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.92	13.00	650.00	0.57	23.00	1150.00	0.11	25.00	1250.00	0.08	35.00	1750.00	0.02	37.00	1850.00	0.01

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus5
Nom. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus6
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.91	13.00	650.00	1.19	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus7
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.97	13.00	650.00	0.59	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus8
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.91	13.00	650.00	1.19	23.00	1150.00	0.33	25.00	1250.00	0.55	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus9
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.97	13.00	650.00	0.59	23.00	1150.00	0.12	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Alert Summary Report

	% Alert Settings	
	Critical	Marginal
Bus		
Individual Bus VTHD / VIHD values are used.		
Transformer		
Total I	100.0	95.0
Filter		
Capacitor kV	100.0	95.0
Inductor Amp	100.0	95.0
Capacitor		
Max kV	100.0	95.0
Cable		
Ampacity	100.0	95.0

APPENDIX 10

HARMONICS ANALYSIS WITH FILTERS AND NO PV CONNECTION

Project:	MASTER THESIS	ETAP		Page:	1
Location:	HOUN CITY - LIBYA	12.6.0H		Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department			SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case:	HA	Revision:	Base
Filename:	HOUN SUBSTATION 220kV			Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Harmonic study with filters and no PV connection

Loading: Operating P, Q

Generation: Operating P, Q, V

	Swing	V-Control	Load	Total
Number of Buses:	3	0	26	29

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of Branches:	15	0	0	14	0	0	29

	Current	Voltage
Number of Harm. Sources:	3	0

Number of Filters: 2

Method of Solution:	Adaptive Newton-Raphson
Maximum No. of Iteration:	99
Precision of Solution:	0.0001000000
System Frequency:	50.00 Hz
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus			Initial Voltage		Load: Constant kVA		Constant Z		Constant I		Generic		% Limits	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	VTHD	VIHD
Bus1	66.000	1	98.8	-30.0									10.00	10.00
Bus2	66.000	2	100.0	30.0									10.00	10.00
Bus3	220.000	1	100.0	0.0									10.00	10.00
Bus4	220.000	3	100.0	0.0									10.00	10.00
Bus5	220.000	2	100.0	0.0									10.00	10.00
Bus6	11.000	1	98.1	-60.0									2.50	1.50
Bus7	66.000	2	98.8	30.0									10.00	10.00
Bus8	66.000	1	99.0	-30.0									10.00	10.00
Bus9	11.000	2	98.1	0.0									10.00	10.00
Bus10	11.000	1	97.8	-60.0									10.00	10.00
Bus13	66.000	1	98.3	-30.0									10.00	10.00
Bus14	66.000	2	98.0	30.0									10.00	10.00
Bus15	11.000	1	98.7	-60.0									10.00	10.00
Bus16	11.000	2	98.3	0.0									10.00	10.00
Bus17	66.000	1	98.9	-30.0									10.00	10.00
Bus18	66.000	2	98.8	30.0									10.00	10.00
Bus19	11.000	1	98.7	-60.0									10.00	10.00
Bus20	11.000	2	98.7	0.0									10.00	10.00
Bus21	66.000	1	98.9	-30.0									10.00	10.00
Bus22	11.000	1	98.4	-60.0									10.00	10.00
Bus23	66.000	1	99.3	-30.0									10.00	10.00
Bus25	11.000	1	98.1	-60.0									10.00	10.00
Bus27	66.000	1	98.8	-30.0									10.00	10.00
Bus28	11.000	1	98.4	-60.0									10.00	10.00
Bus29	11.000	1	98.4	-60.0									10.00	10.00
Bus30	66.000	1	98.5	-30.0									10.00	10.00
Bus31	66.000	2	98.6	30.0									10.00	10.00
Bus32	11.000	1	98.0	-60.0									10.00	10.00
Bus33	11.000	2	100.5	0.0									10.00	10.00
Total Number of Buses: 29					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus3	220.000	Swing	1	100.0	0.0					

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus4	220.000	Swing	3	100.0	0.0					
Bus5	220.000	Swing	2	100.0	0.0					
						0.000	0.000			

Cable Input Data

Cable			Length									
ID	Library	Size	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0

Cable resistances are listed at the specified temperatures

Transmission Line Input Data

Line			Length				Ohms or Mhos / 1000 m per Phase					
ID	Library	Size	Adj. (m)	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Line1		674	19300.0	0.0	1	75	0.056003	0.374255	.0000031	0.200077	1.360791	.0000017
Line2		674	19300.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line3		674	23000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line4		674	15000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line5		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line6		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line7		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line8		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line9		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line10		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line11		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line12		674	21000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line13		674	161000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line14		674	140000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016

Line resistances are listed at the specified temperatures

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
T1	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0	12.5000	Dyn	30.000
T3	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0	12.5000	Dyn	-30.000
T4	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T5	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T6	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T9	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T10	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T11	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T12	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T13	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T14	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T16	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T17	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T18	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T19	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T1	63.000	220.000	66.000	D/Y					Solid			
T3	63.000	220.000	66.000	D/Y					Solid			
T4	10.000	66.000	11.000	D/Y					Solid			
T5	20.000	66.000	11.000	D/Y					Solid			
T6	20.000	66.000	11.000	D/Y					Solid			
T9	10.000	66.000	11.000	D/Y					Solid			
T10	10.000	66.000	11.000	D/Y					Solid			
T11	20.000	66.000	11.000	D/Y					Solid			
T12	20.000	66.000	11.000	D/Y					Solid			
T13	10.000	66.000	11.000	D/Y					Solid			
T14	10.000	66.000	11.000	D/Y					Solid			
T16	20.000	66.000	11.000	D/Y					Solid			

2-Winding Transformer Grounding Input Data

Transformer	Rating			Conn.	Grounding: Primary				Grounding: Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T17	20.000	66.000	11.000	D/Y					Solid			
T18	20.000	66.000	11.000	D/Y					Solid			
T19	20.000	66.000	11.000	D/Y					Solid			

Branch Connections

CKT/Branch		Connected Bus ID		% Positive Sequence Impedance (100 MVA Base)			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.44	19.84	19.84	
T3	2W XFMR	Bus5	Bus2	0.44	19.84	19.84	
T4	2W XFMR	Bus1	Bus6	6.40	83.25	83.50	
T5	2W XFMR	Bus7	Bus9	2.50	49.94	50.00	
T6	2W XFMR	Bus8	Bus10	2.50	49.94	50.00	
T9	2W XFMR	Bus13	Bus15	6.40	83.25	83.50	
T10	2W XFMR	Bus14	Bus16	6.40	83.25	83.50	
T11	2W XFMR	Bus17	Bus19	2.50	49.94	50.00	
T12	2W XFMR	Bus18	Bus20	2.50	49.94	50.00	
T13	2W XFMR	Bus21	Bus22	6.40	83.25	83.50	
T14	2W XFMR	Bus23	Bus25	6.40	83.25	83.50	
T16	2W XFMR	Bus27	Bus28	2.50	49.94	50.00	
T17	2W XFMR	Bus27	Bus29	2.50	49.94	50.00	
T18	2W XFMR	Bus30	Bus32	2.50	49.94	50.00	
T19	2W XFMR	Bus31	Bus33	2.50	49.94	50.00	
Line1	Line	Bus2	Bus14	2.48	16.58	16.77	0.2607629
Line2	Line	Bus1	Bus13	2.48	15.16	15.36	0.2842266
Line3	Line	Bus2	Bus18	2.96	18.06	18.30	0.3387157
Line4	Line	Bus27	Bus17	1.93	11.78	11.94	0.2209015
Line5	Line	Bus1	Bus27	1.03	6.28	6.37	0.1178142
Line6	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line7	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line8	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line9	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line10	Line	Bus2	Bus31	1.03	6.28	6.37	0.1178142
Line11	Line	Bus1	Bus30	1.03	6.28	6.37	0.1178142
Line12	Line	Bus17	Bus21	2.70	16.49	16.71	0.3092622
Line13	Line	Bus17	Bus23	20.70	126.43	128.11	2.3710100
Line14	Line	Bus21	Bus23	18.00	109.94	111.40	2.0617480

Branch Connections
Zero Sequence Impedance

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
T1	2W Xfmr	Bus3	Bus1				
T3	2W Xfmr	Bus5	Bus2				
T4	2W Xfmr	Bus1	Bus6				
T5	2W Xfmr	Bus7	Bus9				
T6	2W Xfmr	Bus8	Bus10				
T9	2W Xfmr	Bus13	Bus15				
T10	2W Xfmr	Bus14	Bus16				
T11	2W Xfmr	Bus17	Bus19				
T12	2W Xfmr	Bus18	Bus20				
T13	2W Xfmr	Bus21	Bus22				
T14	2W Xfmr	Bus23	Bus25				
T16	2W Xfmr	Bus27	Bus28				
T17	2W Xfmr	Bus27	Bus29				
T18	2W Xfmr	Bus30	Bus32				
T19	2W Xfmr	Bus31	Bus33				
Line1	Line	Bus2	Bus14	8.86	60.29	60.94	0.1410145
Line2	Line	Bus1	Bus13	8.89	63.09	63.72	0.1341983
Line3	Line	Bus2	Bus18	10.59	75.19	75.93	0.1599255
Line4	Line	Bus27	Bus17	6.91	49.04	49.52	0.1042992
Line5	Line	Bus1	Bus27	3.68	26.15	26.41	0.0556262
Line6	Line	Bus2	Bus7	1.84	13.08	13.21	0.0278131
Line7	Line	Bus1	Bus8	1.84	13.08	15.21	0.0278131
Line8	Line	Bus2	Bus7	1.84	13.08	13.21	0.0278131
Line9	Line	Bus1	Bus8	1.84	13.08	13.21	0.0278131
Line10	Line	Bus2	Bus31	3.68	26.15	26.41	0.0556262
Line11	Line	Bus1	Bus30	3.68	26.15	26.41	0.0556262
Line12	Line	Bus17	Bus21	9.67	68.65	69.33	0.1460189
Line13	Line	Bus17	Bus23	74.16	526.33	531.53	1.1194780
Line14	Line	Bus21	Bus23	64.48	457.68	462.20	0.9734595

Machine Input Data

Machine		Connected Bus	Rating (Base)			% Negative Seq. Imp.			Grounding			% Zero Seq. Imp.		
ID	Type	ID	MVA	kV	RPM	X/R	R2	X2	Conn.	Type	Amp	X/R	R0	X0
U1	Grid	Bus3	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	35.648	356.48
U2	Grid	Bus4	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	17.738	177.38
U3	Grid	Bus5	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	17.738	177.38

Harmonic Library

Current Harmonic Source in %

Manufacturer: ABB
Model: ACS600 12P

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	5.00	250.00	2.60	7.00	350.00	1.50	11.00	550.00	3.70	13.00	650.00	3.70	17.00	850.00	0.50
19.00	950.00	0.30	23.00	1150.00	0.10	25.00	1250.00	0.50									

Manufacturer: ABB
Model: ACS600 12P

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	5.00	250.00	2.60	7.00	350.00	1.50	11.00	550.00	3.70	13.00	650.00	3.70	17.00	850.00	0.50
19.00	950.00	0.30	23.00	1150.00	0.10	25.00	1250.00	0.50									

Manufacturer: ABB
Model: ACS600 12P

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	5.00	250.00	2.60	7.00	350.00	1.50	11.00	550.00	3.70	13.00	650.00	3.70	17.00	850.00	0.50
19.00	950.00	0.30	23.00	1150.00	0.10	25.00	1250.00	0.50									

Harmonic Source from Library

		Harmonic Source Information				
Bus ID	Device ID	Type	Manufacturer	Model	Fund. Freq.	Mod. Freq.
Bus3	U1	Current	ABB	ACS600 12P	0.00	0.00
Bus4	U2	Current	ABB	ACS600 12P	0.00	0.00
Bus5	U3	Current	ABB	ACS600 12P	0.00	0.00

Filter Input Data

Filter Type: Single-Tuned

Filter	Connected Bus	Capacitor C1			Inductor L1			R
ID	ID	kV	Max kV	kvar	Xl	Q Fact.	Max I	Ohm
HF2	Bus2	66.000	0.000	62000.0	0.0000	0.00	0.0	0.0000
HF1	Bus1	66.000	0.000	62000.0	0.0000	0.00	0.0	0.0000

Fundamental Load Flow Report study with filters and no PV connection

Bus	Bus	Voltage	Voltage	Generation	Generation	Load	Load	Load Flow	Load Flow	Load Flow	Load Flow	Load Flow	XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
Bus1	66.000	115.507	-30.2	0	0	0.000	-82.720	Bus13	0.000	-0.379	2.9	0.0	
								Bus27	0.018	-6.889	52.2	-0.3	
								Bus8	0.000	-0.079	0.6	0.0	
								Bus8	0.000	-0.079	0.6	0.0	
								Bus30	0.000	-0.157	1.2	0.0	
								Bus3	-0.018	90.303	683.9	0.0	
								Bus6	0.000	0.000	0.0	0.0	
Bus2	66.000	114.238	29.8	0	0	0.000	-80.913	Bus14	0.000	-0.340	2.6	0.0	
								Bus18	0.000	-0.442	3.4	0.0	
								Bus7	0.000	-0.077	0.6	0.0	
								Bus7	0.000	-0.077	0.6	0.0	
								Bus31	0.000	-0.154	1.2	0.0	
								Bus5	0.000	82.003	627.9	0.0	
* Bus3	220.000	100.000	0.0	0.288	-78.179	0	0	Bus1	0.288	-78.179	205.2	-0.4	
* Bus5	220.000	100.000	0.0	0.227	-71.782	0	0	Bus2	0.227	-71.782	188.4	-0.3	
Bus6	11.000	115.507	-60.2	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
Bus7	66.000	114.240	29.8	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus2	0.000	0.000	0.0	0.0	
								Bus9	0.000	0.000	0.0	0.0	
Bus8	66.000	115.508	-30.2	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus1	0.000	0.000	0.0	0.0	
								Bus10	0.000	0.000	0.0	0.0	
Bus9	11.000	114.240	-0.2	0	0	0	0	Bus7	0.000	0.000	0.0	0.0	
Bus10	11.000	115.508	-60.2	0	0	0	0	Bus8	0.000	0.000	0.0	0.0	
Bus13	66.000	115.532	-30.2	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus15	0.000	0.000	0.0	0.0	
Bus14	66.000	114.263	29.8	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus16	0.000	0.000	0.0	0.0	
Bus15	11.000	115.532	-60.2	0	0	0	0	Bus13	0.000	0.000	0.0	0.0	
Bus16	11.000	114.263	-0.2	0	0	0	0	Bus14	0.000	0.000	0.0	0.0	
Bus17	66.000	116.549	-30.3	0	0	0	0	Bus27	-0.009	6.493	48.7	-0.1	
								Bus21	0.005	-3.249	24.4	-0.1	
								Bus23	0.004	-3.244	24.3	-0.1	
								Bus19	0.000	0.000	0.0	0.0	
Bus18	66.000	114.273	29.8	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus20	0.000	0.000	0.0	0.0	
Bus19	11.000	116.549	-60.3	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
Bus20	11.000	114.273	-0.2	0	0	0	0	Bus18	0.000	0.000	0.0	0.0	
Bus21	66.000	116.979	-30.3	0	0	0	0	Bus17	-0.003	2.839	21.2	-0.1	
								Bus23	0.003	-2.839	21.2	-0.1	
								Bus22	0.000	0.000	0.0	0.0	
Bus22	11.000	116.979	-60.3	0	0	0	0	Bus21	0.000	0.000	0.0	0.0	
Bus23	66.000	118.320	-30.4	0	0	0	0	Bus17	0.000	-0.001	0.0	-16.2	
								Bus21	0.000	0.001	0.0	-16.2	
								Bus25	0.000	0.000	0.0	0.0	
Bus25	11.000	118.320	-60.4	0	0	0	0	Bus23	0.000	0.000	0.0	0.0	
Bus27	66.000	115.878	-30.2	0	0	0	0	Bus17	0.015	-6.753	51.0	-0.2	
								Bus1	-0.015	6.753	51.0	-0.2	
								Bus28	0.000	0.000	0.0	0.0	
								Bus29	0.000	0.000	0.0	0.0	
Bus28	11.000	115.878	-60.2	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	
Bus29	11.000	115.878	-60.2	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	
Bus30	66.000	115.511	-30.2	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus32	0.000	0.000	0.0	0.0	
Bus31	66.000	114.243	29.8	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus33	0.000	0.000	0.0	0.0	
Bus32	11.000	115.511	-60.2	0	0	0	0	Bus30	0.000	0.000	0.0	0.0	
Bus33	11.000	114.243	-0.2	0	0	0	0	Bus31	0.000	0.000	0.0	0.0	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)
# indicates a bus with a load mismatch of more than 0.1 MVA

System Harmonics Bus Information

Bus		Voltage Distortion								
ID	kV	Fund. %	RMS %	ASUM %	THD %	TIF	TIHD %	TSHD %	THDG %	THDS %
Bus1	66.000	115.51	115.51	117.04	0.68	8.34	0.00	0.00	0.68	0.68
Bus2	66.000	114.24	114.24	115.81	0.69	7.76	0.00	0.00	0.69	0.69
Bus3	220.000	100.00	100.44	119.56	9.40	211.39	0.00	0.00	9.40	9.40
Bus5	220.000	100.00	100.37	117.81	8.62	194.19	0.00	0.00	8.62	8.62
Bus6	11.000	115.51	115.51	117.04	0.68	8.34	0.00	0.00	0.68	0.68
Bus7	66.000	114.24	114.24	115.81	0.69	7.77	0.00	0.00	0.69	0.69
Bus8	66.000	115.51	115.51	117.05	0.68	8.35	0.00	0.00	0.68	0.68
Bus9	11.000	114.24	114.24	115.81	0.69	7.77	0.00	0.00	0.69	0.69
Bus10	11.000	115.51	115.51	117.05	0.68	8.35	0.00	0.00	0.68	0.68
Bus13	66.000	115.53	115.53	117.10	0.69	8.61	0.00	0.00	0.69	0.69
Bus14	66.000	114.26	114.27	115.86	0.70	8.01	0.00	0.00	0.70	0.70
Bus15	11.000	115.53	115.53	117.10	0.69	8.61	0.00	0.00	0.69	0.69
Bus16	11.000	114.26	114.27	115.86	0.70	8.01	0.00	0.00	0.70	0.70
Bus17	66.000	116.55	116.55	119.03	1.00	14.26	0.00	0.00	1.00	1.00
Bus18	66.000	114.27	114.28	115.89	0.71	8.13	0.00	0.00	0.71	0.71
Bus19	11.000	116.55	116.55	119.03	1.00	14.26	0.00	0.00	1.00	1.00
Bus20	11.000	114.27	114.28	115.89	0.71	8.13	0.00	0.00	0.71	0.71
Bus21	66.000	116.98	116.99	119.91	1.19	18.49	0.00	0.00	1.19	1.19
Bus22	11.000	116.98	116.99	119.91	1.19	18.49	0.00	0.00	1.19	1.19
Bus23	66.000	118.32	118.34	122.58	2.00	13.18	0.00	0.00	2.00	2.00
Bus25	11.000	118.32	118.34	122.58	2.00	13.18	0.00	0.00	2.00	2.00
Bus27	66.000	115.88	115.88	117.72	0.77	9.45	0.00	0.00	0.77	0.77
Bus28	11.000	115.88	115.88	117.72	0.77	9.45	0.00	0.00	0.77	0.77
Bus29	11.000	115.88	115.88	117.72	0.77	9.45	0.00	0.00	0.77	0.77
Bus30	66.000	115.51	115.51	117.05	0.68	8.38	0.00	0.00	0.68	0.68
Bus31	66.000	114.24	114.25	115.82	0.69	7.80	0.00	0.00	0.69	0.69
Bus32	11.000	115.51	115.51	117.05	0.68	8.38	0.00	0.00	0.68	0.68
Bus33	11.000	114.24	114.25	115.82	0.69	7.80	0.00	0.00	0.69	0.69

* Indicates THD (Total Harmonic Distortion) Exceeds the Limit.
# Indicates IHD (Individual Harmonic Distortion) Exceeds the Limit.

System Harmonics Branch Information

Bus		Current Distortion											
From Bus ID	To Bus ID	Fund. Amp	RMS Amp	ASUM Amp	THD %	TIF	IT Amp	ITn Amp	ITn Amp	TIHD %	TSHD %	THDG %	THDS %
Bus1	Bus13	2.87	2.88	3.23	6.17	108.88	313.31	313.31	0.00	0.00	0.00	6.17	6.17
	Bus27	52.17	52.37	60.24	8.81	86.43	4526.66	4526.66	0.00	0.00	0.00	8.81	8.81
	Bus8	0.60	0.60	0.67	6.09	106.75	63.66	63.66	0.00	0.00	0.00	6.09	6.09
	Bus8	0.60	0.60	0.67	6.09	106.75	63.66	63.66	0.00	0.00	0.00	6.09	6.09
	Bus30	1.19	1.19	1.34	6.10	107.02	127.64	127.64	0.00	0.00	0.00	6.10	6.10
	Bus3	683.89	685.06	768.76	5.85	99.34	68057.16	68057.16	0.00	0.00	0.00	5.85	5.85
	Bus6	0	0	0	0	0	0.00	68057.16	0.00	0.00	0.00	0.00	0.00
Bus2	Bus14	2.61	2.61	2.93	5.92	101.39	264.70	264.70	0.00	0.00	0.00	5.92	5.92
	Bus18	3.39	3.39	3.81	5.95	102.34	347.06	347.06	0.00	0.00	0.00	5.95	5.95
	Bus7	0.59	0.59	0.66	5.85	99.40	58.62	58.62	0.00	0.00	0.00	5.85	5.85
	Bus7	0.59	0.59	0.66	5.85	99.40	58.62	58.62	0.00	0.00	0.00	5.85	5.85
	Bus31	1.18	1.18	1.32	5.86	99.66	117.53	117.53	0.00	0.00	0.00	5.86	5.86
	Bus5	627.93	629.00	705.90	5.85	99.35	62488.71	62488.71	0.00	0.00	0.00	5.85	5.85
Bus3	Bus1	205.17	205.52	230.63	5.85	99.34	20417.15	20417.15	0.00	0.00	0.00	5.85	5.85
Bus5	Bus2	188.38	188.70	211.77	5.85	99.35	18746.62	18746.62	0.00	0.00	0.00	5.85	5.85
Bus6	Bus1	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus7	Bus2	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
	Bus2	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
	Bus9	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus8	Bus1	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
	Bus1	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
	Bus10	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus9	Bus7	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus10	Bus8	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus13	Bus1	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
	Bus15	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus14	Bus2	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
	Bus16	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus15	Bus13	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus16	Bus14	0	0	0	0	0	0.00	18746.62	0.00	0.00	0.00	0.00	0.00
Bus17	Bus27	48.73	48.94	56.50	9.17	85.66	4192.34	4192.34	0.00	0.00	0.00	9.17	9.17
	Bus21	24.39	24.50	28.57	9.59	104.05	2548.96	2548.96	0.00	0.00	0.00	9.59	9.59
	Bus23	24.35	24.44	27.93	8.77	67.97	1661.37	1661.37	0.00	0.00	0.00	8.77	8.77
	Bus19	0	0	0	0	0	0.00	1661.37	0.00	0.00	0.00	0.00	0.00
Bus18	Bus2	0	0	0	0	0	0.00	1661.37	0.00	0.00	0.00	0.00	0.00
	Bus20	0	0	0	0	0	0.00	1661.37	0.00	0.00	0.00	0.00	0.00
Bus19	Bus17	0	0	0	0	0	0.00	1661.37	0.00	0.00	0.00	0.00	0.00
Bus20	Bus18	0	0	0	0	0	0.00	1661.37	0.00	0.00	0.00	0.00	0.00
Bus21	Bus17	21.23	21.34	25.02	10.06	87.86	1874.43	1874.43	0.00	0.00	0.00	10.06	10.06
	Bus23	21.23	21.34	25.02	10.06	87.86	1874.43	1874.43	0.00	0.00	0.00	10.06	10.06
	Bus22	0	0	0	0	0	0.00	1874.43	0.00	0.00	0.00	0.00	0.00

Bus	Current Distortion												
From Bus ID	To Bus ID	Fund. Amp	RMS Amp	ASUM Amp	THD %	TIF	IT Amp	ITb Amp	ITr Amp	TIHD %	TSHD %	THDG %	THDS %
Bus22	Bus21	0	0	0	0	0	0.00	1874.43	0.00	0.00	0.00	0.00	0.00
Bus23	Bus17	0.01	0.13	0.29	1404.38	2702.48	349.97	349.97	0.00	0.00	0.00	1404.38	1404.38
	Bus21	0.01	0.13	0.29	1404.38	2702.48	349.97	349.97	0.00	0.00	0.00	1404.38	1404.38
	Bus25	0	0	0	0	0	0.00	349.97	0.00	0.00	0.00	0.00	0.00
Bus25	Bus23	0	0	0	0	0	0.00	349.97	0.00	0.00	0.00	0.00	0.00
Bus27	Bus17	50.98	51.18	58.99	8.96	87.49	4478.34	4478.34	0.00	0.00	0.00	8.96	8.96
	Bus1	50.98	51.18	58.99	8.96	87.49	4478.34	4478.34	0.00	0.00	0.00	8.96	8.96
	Bus28	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
	Bus29	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
Bus28	Bus27	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
Bus29	Bus27	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
Bus30	Bus1	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
	Bus32	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
Bus31	Bus2	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
	Bus33	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
Bus32	Bus30	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00
Bus33	Bus31	0	0	0	0	0	0.00	4478.34	0.00	0.00	0.00	0.00	0.00

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus1
Fund. kV: 76.235

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	0.48	7.00	350.00	0.14	11.00	550.00	0.36	13.00	650.00	0.29	17.00	850.00	0.02	19.00	950.00	0.02
23.00	1150.00	0.00	25.00	1250.00	0.02												

Bus ID: Bus10
Fund. kV: 12.706

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	0.48	7.00	350.00	0.14	11.00	550.00	0.36	13.00	650.00	0.29	17.00	850.00	0.02	19.00	950.00	0.02
23.00	1150.00	0.00	25.00	1250.00	0.02												

Bus ID: Bus2
Fund. kV: 75.397

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	0.50	7.00	350.00	0.21	11.00	550.00	0.32	13.00	650.00	0.27	17.00	850.00	0.03	19.00	950.00	0.02
23.00	1150.00	0.00	25.00	1250.00	0.02												

Bus ID: Bus9
Fund. kV: 12.566

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	0.50	7.00	350.00	0.21	11.00	550.00	0.32	13.00	650.00	0.27	17.00	850.00	0.03	19.00	950.00	0.02
23.00	1150.00	0.00	25.00	1250.00	0.02												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus1
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	0.55	7.00	350.00	0.16	11.00	550.00	0.41	13.00	650.00	0.34	17.00	850.00	0.02	19.00	950.00	0.02
23.00	1150.00	0.01	25.00	1250.00	0.02												

Bus ID: Bus10
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	0.55	7.00	350.00	0.16	11.00	550.00	0.41	13.00	650.00	0.34	17.00	850.00	0.02	19.00	950.00	0.02
23.00	1150.00	0.01	25.00	1250.00	0.02												

Bus ID: Bus2
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	0.58	7.00	350.00	0.24	11.00	550.00	0.37	13.00	650.00	0.31	17.00	850.00	0.03	19.00	950.00	0.02
23.00	1150.00	0.00	25.00	1250.00	0.02												

Bus ID: Bus9
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
5.00	250.00	0.58	7.00	350.00	0.24	11.00	550.00	0.37	13.00	650.00	0.31	17.00	850.00	0.03	19.00	950.00	0.02
23.00	1150.00	0.00	25.00	1250.00	0.02												

Filter Overloading

Filter			Capacitor C1			Inductor L1			Capacitor C2			Inductor L2		
ID	Type	Connection	Max. kV	Opr. kV	% OverVolt	Max. Amp	Opr. Amp	% Overload	Max. kV	Opr. kV	% OverVolt	Max. Amp	Opr. Amp	% Overload
HF1	3	Wye	0.000	63.074	N/A	0.00	627.63	N/A						
HF2	3	Wye	0.000	62.408	N/A	0.00	620.64	N/A						

Filter Types: 0 = By-Pass, 1 = High-Pass (Damped), 2 = High-Pass (Undamped), 3 = Single Tuned, 4 = 3rd Order Damped, 5 = 3rd Order C-Type

Alert Summary Report

	% Alert Settings	
	Critical	Marginal
Bus		
Individual Bus VTHD / VIHD values are used.		
Transformer		
Total I	100.0	95.0
Filter		
Capacitor kV	100.0	95.0
Inductor Amp	100.0	95.0
Capacitor		
Max kV	100.0	95.0
Cable		
Ampacity	100.0	95.0

APPENDIX 11

HARMONICS ANALYSIS WITH FILTERS AND PV

Project:	MASTER THESIS	ETAP	Page:	1
Location:	HOUN CITY - LIBYA	12.6.0H	Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department		SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case: HA	Revision:	Base
Filename:	HOUN SUBSTATION 220kV		Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Harmonic study with filters and PV connection

Loading: Operating P, Q

Generation: Operating P, Q, V

	Swing	V-Control	Load	Total
Number of Buses:	3	7	30	40

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	Total
Number of Branches:	24	0	0	16	0	0	40

	Current	Voltage
Number of Harm. Sources:	4	0

Number of Filters:	2
Method of Solution:	Adaptive Newton-Raphson
Maximum No. of Iteration:	99
Precision of Solution:	0.0001000000
System Frequency:	50.00 Hz
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus			Initial Voltage		Load: Constant kVA		Load: Constant Z		Load: Constant I		Load: Generic		% Limits	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	VTHD	VIHD
Bus1	66.000	1	98.8	-30.0									10.00	10.00
Bus2	66.000	2	100.0	30.0									10.00	10.00
Bus3	220.000	1	100.0	0.0									5.00	5.00
Bus4	220.000	3	100.0	0.0									10.00	10.00
Bus5	220.000	2	100.0	0.0									10.00	10.00
Bus6	11.000	1	98.1	-60.0									5.00	5.00
Bus7	66.000	2	98.8	30.0									10.00	10.00
Bus8	66.000	1	99.0	-30.0									10.00	10.00
Bus9	11.000	2	98.1	0.0									10.00	10.00
Bus10	11.000	1	97.8	-60.0									10.00	10.00
Bus11	66.000	2	100.0	30.0									10.00	10.00
Bus12	66.000	1	100.0	-30.0									10.00	10.00
Bus13	66.000	1	98.3	-30.0									10.00	10.00
Bus14	66.000	2	98.0	30.0									10.00	10.00
Bus15	11.000	1	98.7	-60.0									10.00	10.00
Bus16	11.000	2	98.3	0.0									10.00	10.00
Bus17	66.000	1	98.9	-30.0									10.00	10.00
Bus18	66.000	2	98.8	30.0									10.00	10.00
Bus19	11.000	1	98.7	-60.0									10.00	10.00
Bus20	11.000	2	98.7	0.0									10.00	10.00
Bus21	66.000	1	98.9	-30.0									10.00	10.00
Bus22	11.000	1	98.4	-60.0									10.00	10.00
Bus23	66.000	1	99.3	-30.0									10.00	10.00
Bus25	11.000	1	98.1	-60.0									10.00	10.00
Bus27	66.000	1	98.8	-30.0									10.00	10.00
Bus28	11.000	1	98.4	-60.0									10.00	10.00
Bus29	11.000	1	98.4	-60.0									10.00	10.00
Bus30	66.000	1	98.5	-30.0									10.00	10.00
Bus31	66.000	2	98.6	30.0									10.00	10.00
Bus32	11.000	1	98.0	-60.0									10.00	10.00
Bus33	11.000	2	100.5	0.0									10.00	10.00
Bus34	0.400	1	100.0	-30.0									10.00	10.00
Bus35	0.400	1	100.0	-30.0									5.00	5.00
Bus36	0.400	1	100.0	-30.0									10.00	10.00

Bus			Initial Voltage		Load: Constant kVA		Load: Constant Z		Load: Constant I		Load: Generic		% Limits	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar	VTHD	VIHD
Bus37	0.400	1	100.0	-30.0									10.00	10.00
Bus38	0.400	2	100.0	30.0									5.00	5.00
Bus39	0.400	2	100.0	30.0									5.00	5.00
Bus40	0.400	2	100.0	30.0									5.00	5.00
Bus41	11.000	1	120.8	-60.0									10.00	10.00
Bus42	11.000	2	98.9	0.0									10.00	10.00
Total Number of Buses: 40					0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus3	220.000	Swing	1	100.0	0.0					
Bus4	220.000	Swing	3	100.0	0.0					
Bus5	220.000	Swing	2	100.0	0.0					
Bus34	0.400	Voltage Control	1	100.0	-30.0	1.952			0.000	0.000
Bus35	0.400	Voltage Control	1	100.0	-30.0	1.952			0.000	0.000
Bus36	0.400	Voltage Control	1	100.0	-30.0	1.952			0.000	0.000
Bus37	0.400	Voltage Control	1	100.0	-30.0	1.952			0.000	0.000
Bus38	0.400	Voltage Control	2	100.0	30.0	1.952			0.000	0.000
Bus39	0.400	Voltage Control	2	100.0	30.0	1.952			0.000	0.000
Bus40	0.400	Voltage Control	2	100.0	30.0	1.952			0.000	0.000
						13.662	0.000			

Cable Input Data

Cable			Length				Ohms or Mhos / 1000 m per Conductor					
ID	Library	Size	Adj. (m)	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Cable1	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646	0.240351	0.215000	
Cable2	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646	0.240351	0.215000	

Cable resistances are listed at the specified temperatures

Transmission Line Input Data

Line			Length				Ohms or Mhos / 1000 m per Phase					
ID	Library	Size	Adj. (m)	% Tol.	#Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Line1		674	19300.0	0.0	1	75	0.056003	0.374255	.0000031	0.200077	1.360791	.0000017
Line2		674	19300.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line3		674	23000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line4		674	15000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line5		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line6		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line7		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line8		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line9		674	4000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line10		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line11		674	8000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line12		674	21000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line13		674	161000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016
Line14		674	140000.0	0.0	1	75	0.056001	0.342069	.0000034	0.200637	1.424041	.0000016

Line resistances are listed at the specified temperatures

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
T1	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0	12.5000	Dyn	30.000
T3	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0	12.5000	Dyn	-30.000
T4	10.000	66.000	11.000	8.35	15.00	0	0	0	0	0	8.3500	Dyn	30.000
T5	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T6	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T7	12.500	11.000	66.000	8.35	13.00	0	0	0	0	0	8.3500	YNd	30.000
T8	12.500	11.000	66.000	8.35	13.00	0	0	0	0	0	8.3500	YNd	30.000
T9	10.000	66.000	11.000	8.35	15.00	0	0	0	0	0	8.3500	Dyn	30.000
T10	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T11	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T12	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T13	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T14	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	30.000
T16	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T17	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T18	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T19	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	30.000
T20	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T21	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T22	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T23	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T24	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T25	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000
T26	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	-30.000

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T1	63.000	220.000	66.000	D/Y					Solid			
T3	63.000	220.000	66.000	D/Y					Solid			
T4	10.000	66.000	11.000	D/Y					Solid			
T5	20.000	66.000	11.000	D/Y					Solid			

2-Winding Transformer Grounding Input Data

Transformer	Rating			Conn.	Grounding							
					Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T6	20.000	66.000	11.000	D/Y					Solid			
T7	12.500	11.000	66.000	D/Y					Solid			
T8	12.500	11.000	66.000	D/Y					Solid			
T9	10.000	66.000	11.000	D/Y					Solid			
T10	10.000	66.000	11.000	D/Y					Solid			
T11	20.000	66.000	11.000	D/Y					Solid			
T12	20.000	66.000	11.000	D/Y					Solid			
T13	10.000	66.000	11.000	D/Y					Solid			
T14	10.000	66.000	11.000	D/Y					Solid			
T16	20.000	66.000	11.000	D/Y					Solid			
T17	20.000	66.000	11.000	D/Y					Solid			
T18	20.000	66.000	11.000	D/Y					Solid			
T19	20.000	66.000	11.000	D/Y					Solid			
T20	3.000	0.400	11.000	D/Y					Solid			
T21	3.000	0.400	11.000	D/Y					Solid			
T22	3.000	0.400	11.000	D/Y					Solid			
T23	3.000	0.400	11.000	D/Y					Solid			
T24	3.000	0.400	11.000	D/Y					Solid			
T25	3.000	0.400	11.000	D/Y					Solid			
T26	3.000	0.400	11.000	D/Y					Solid			

Branch Connections

CKT/Branch		Connected Bus ID		% Positive Sequence Impedance (100 MVA Base)			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.44	19.84	19.84	
T3	2W XFMR	Bus5	Bus2	0.44	19.84	19.84	
T4	2W XFMR	Bus1	Bus6	6.40	83.25	83.50	
T5	2W XFMR	Bus7	Bus9	2.50	49.94	50.00	
T6	2W XFMR	Bus8	Bus10	2.50	49.94	50.00	
T7	2W XFMR	Bus42	Bus11	5.12	66.60	66.80	
T8	2W XFMR	Bus41	Bus12	5.12	66.60	66.80	
T9	2W XFMR	Bus13	Bus15	6.40	83.25	83.50	
T10	2W XFMR	Bus14	Bus16	6.40	83.25	83.50	
T11	2W XFMR	Bus17	Bus19	2.50	49.94	50.00	
T12	2W XFMR	Bus18	Bus20	2.50	49.94	50.00	
T13	2W XFMR	Bus21	Bus22	6.40	83.25	83.50	
T14	2W XFMR	Bus23	Bus25	6.40	83.25	83.50	
T16	2W XFMR	Bus27	Bus28	2.50	49.94	50.00	
T17	2W XFMR	Bus27	Bus29	2.50	49.94	50.00	
T18	2W XFMR	Bus30	Bus32	2.50	49.94	50.00	
T19	2W XFMR	Bus31	Bus33	2.50	49.94	50.00	
T20	2W XFMR	Bus34	Bus41	34.25	205.50	208.33	
T21	2W XFMR	Bus35	Bus41	34.25	205.50	208.33	
T22	2W XFMR	Bus36	Bus41	34.25	205.50	208.33	
T23	2W XFMR	Bus37	Bus41	34.25	205.50	208.33	
T24	2W XFMR	Bus38	Bus42	34.25	205.50	208.33	
T25	2W XFMR	Bus39	Bus42	34.25	205.50	208.33	
T26	2W XFMR	Bus40	Bus42	34.25	205.50	208.33	
Cable1	Cable	Bus11	Bus2	0.02	0.02	0.03	0.0716998
Cable2	Cable	Bus12	Bus1	0.02	0.02	0.03	0.0716998
Line1	Line	Bus2	Bus14	2.48	16.58	16.77	0.2607629
Line2	Line	Bus1	Bus13	2.48	15.16	15.36	0.2842266
Line3	Line	Bus2	Bus18	2.96	18.06	18.30	0.3387157
Line4	Line	Bus27	Bus17	1.93	11.78	11.94	0.2209015
Line5	Line	Bus1	Bus27	1.03	6.28	6.37	0.1178142
Line6	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line7	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line8	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line9	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line10	Line	Bus2	Bus31	1.03	6.28	6.37	0.1178142
Line11	Line	Bus1	Bus30	1.03	6.28	6.37	0.1178142

CKT/Branch		Connected Bus ID		% Positive Sequence Impedance (100 MVA Base)			
ID	Type	From Bus	To Bus	R	X	Z	Y
Line12	Line	Bus17	Bus21	2.70	16.49	16.71	0.3092622
Line13	Line	Bus17	Bus23	20.70	126.43	128.11	2.3710100
Line14	Line	Bus21	Bus23	18.00	109.94	111.40	2.0617480

Branch Connections
Zero Sequence Impedance

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
T1	2W Xfmr	Bus3	Bus1				
T3	2W Xfmr	Bus5	Bus2				
T4	2W Xfmr	Bus1	Bus6				
T5	2W Xfmr	Bus7	Bus9				
T6	2W Xfmr	Bus8	Bus10				
T7	2W Xfmr	Bus42	Bus11				
T8	2W Xfmr	Bus41	Bus12				
T9	2W Xfmr	Bus13	Bus15				
T10	2W Xfmr	Bus14	Bus16				
T11	2W Xfmr	Bus17	Bus19				
T12	2W Xfmr	Bus18	Bus20				
T13	2W Xfmr	Bus21	Bus22				
T14	2W Xfmr	Bus23	Bus25				
T16	2W Xfmr	Bus27	Bus28				
T17	2W Xfmr	Bus27	Bus29				
T18	2W Xfmr	Bus30	Bus32				
T19	2W Xfmr	Bus31	Bus33				
T20	2W Xfmr	Bus34	Bus41				
T21	2W Xfmr	Bus35	Bus41				
T22	2W Xfmr	Bus36	Bus41				
T23	2W Xfmr	Bus37	Bus41				
T24	2W Xfmr	Bus38	Bus42				
T25	2W Xfmr	Bus39	Bus42				
T26	2W Xfmr	Bus40	Bus42				
Cable1	Cable	Bus11	Bus2	0.06	0.05	0.07	
Cable2	Cable	Bus12	Bus1	0.06	0.05	0.07	
Line1	Line	Bus2	Bus14	8.86	60.29	60.94	0.1410145
Line2	Line	Bus1	Bus13	8.89	63.09	63.72	0.1341983
Line3	Line	Bus2	Bus18	10.59	75.19	75.93	0.1599255
Line4	Line	Bus27	Bus17	6.91	49.04	49.52	0.1042992
Line5	Line	Bus1	Bus27	3.68	26.15	26.41	0.0556262
Line6	Line	Bus2	Bus7	1.84	13.08	13.21	0.0278131
Line7	Line	Bus1	Bus8	1.84	13.08	13.21	0.0278131
Line8	Line	Bus2	Bus7	1.84	13.08	13.21	0.0278131
Line9	Line	Bus1	Bus8	1.84	13.08	13.21	0.0278131
Line10	Line	Bus2	Bus31	3.68	26.15	26.41	0.0556262

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
Line11	Line	Bus1	Bus30	3.68	26.15	26.41	0.0556262
Line12	Line	Bus17	Bus21	9.67	68.65	69.33	0.1460189
Line13	Line	Bus17	Bus23	74.16	526.33	531.53	1.1194780
Line14	Line	Bus21	Bus23	64.48	457.68	462.20	0.9734595

Machine Input Data

Machine		Connected Bus	Rating (Base)			% Negative Seq. Imp.			Grounding			% Zero Seq. Imp.		
ID	Type	ID	MVA	kV	RPM	X/R	R2	X2	Conn.	Type	Amp	X/R	R0	X0
U1	Grid	Bus3	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	35.648	356.48
U2	Grid	Bus4	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	17.738	177.38
U3	Grid	Bus5	22.101	220.000		10.00	9.950	99.50	Wye	Solid		10.00	17.738	177.38

Harmonic Library

Current Harmonic Source in %

Manufacturer: Typical-IEEE
Model: 12 Pulse2

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	11.00	550.00	8.30	13.00	650.00	6.70	23.00	1150.00	2.80	25.00	1250.00	2.30	35.00	1750.00	0.80
37.00	1850.00	0.60	47.00	2350.00	0.20	49.00	2450.00	0.20									

Manufacturer: Typical-IEEE
Model: 12 Pulse2

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	11.00	550.00	8.30	13.00	650.00	6.70	23.00	1150.00	2.80	25.00	1250.00	2.30	35.00	1750.00	0.80
37.00	1850.00	0.60	47.00	2350.00	0.20	49.00	2450.00	0.20									

Manufacturer: Typical-IEEE
Model: 12 Pulse2

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	11.00	550.00	8.30	13.00	650.00	6.70	23.00	1150.00	2.80	25.00	1250.00	2.30	35.00	1750.00	0.80
37.00	1850.00	0.60	47.00	2350.00	0.20	49.00	2450.00	0.20									

Manufacturer: Typical-IEEE
Model: 12 Pulse2

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
1.00	50.00	100.00	11.00	550.00	8.30	13.00	650.00	6.70	23.00	1150.00	2.80	25.00	1250.00	2.30	35.00	1750.00	0.80
37.00	1850.00	0.60	47.00	2350.00	0.20	49.00	2450.00	0.20									

Harmonic Source from Library

		Harmonic Source Information				
Bus ID	Device ID	Type	Manufacturer	Model	Fund. Freq.	Mod. Freq.
Bus34	Inv11	Current	Typical-IEEE	12 Pulse2	0.00	0.00
Bus36	Inv15	Current	Typical-IEEE	12 Pulse2	0.00	0.00
Bus37	Inv18	Current	Typical-IEEE	12 Pulse2	0.00	0.00
Bus39	Inv21	Current	Typical-IEEE	12 Pulse2	0.00	0.00

Filter Input Data

Filter Type: Single-Tuned

Filter	Connected Bus	Capacitor C1			Inductor L1			R
ID	ID	kV	Max kV	kvar	Xl	Q Fact.	Max I	Ohm
HF2	Bus2	66.000	100.000	420.7	85.5804	90.00	100.0	0.0000
HF1	Bus1	66.000	100.000	140.1	257.0066	70.00	100.0	0.0000

Fundamental Load Flow Report

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus1	66.000	101.068	-29.1	0	0	0.000	-0.144	Bus12	-7.726	0.622	67.1	-99.7	
								Bus13	0.000	-0.290	2.5	0.0	
								Bus27	0.014	-5.274	45.7	-0.3	
								Bus8	0.000	-0.060	0.5	0.0	
								Bus8	0.000	-0.060	0.5	0.0	
								Bus30	0.000	-0.120	1.0	0.0	
								Bus3	7.712	5.328	81.1	82.3	
								Bus6	0.000	0.000	0.0	0.0	
Bus2	66.000	100.193	30.7	0	0	0.000	-0.426	Bus11	-5.799	0.384	50.7	-99.8	
								Bus14	0.000	-0.262	2.3	0.0	
								Bus18	0.000	-0.340	3.0	0.0	
								Bus7	0.000	-0.059	0.5	0.0	
								Bus7	0.000	-0.059	0.5	0.0	
								Bus31	0.000	-0.118	1.0	0.0	
								Bus5	5.799	0.881	51.2	98.9	
* Bus3	220.000	100.000	0.0	-7.708	-5.157	0	0	Bus1	-7.708	-5.157	24.3	83.1	
* Bus5	220.000	100.000	0.0	-5.798	-0.813	0	0	Bus2	-5.798	-0.813	15.4	99.0	
Bus6	11.000	101.068	-59.1	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
Bus7	66.000	100.194	30.7	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus2	0.000	0.000	0.0	0.0	
								Bus9	0.000	0.000	0.0	0.0	
Bus8	66.000	101.069	-29.1	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus1	0.000	0.000	0.0	0.0	
								Bus10	0.000	0.000	0.0	0.0	
Bus9	11.000	100.194	0.7	0	0	0	0	Bus7	0.000	0.000	0.0	0.0	
Bus10	11.000	101.069	-59.1	0	0	0	0	Bus8	0.000	0.000	0.0	0.0	
Bus11	66.000	100.194	30.7	0	0	0	0	Bus2	5.799	-0.455	50.8	-99.7	
								Bus42	-5.799	0.455	50.8	-99.7	
Bus12	66.000	101.069	-29.1	0	0	0	0	Bus1	7.726	-0.695	67.1	-99.6	
								Bus41	-7.726	0.695	67.1	-99.6	
Bus13	66.000	101.090	-29.1	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus15	0.000	0.000	0.0	0.0	
Bus14	66.000	100.215	30.7	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus16	0.000	0.000	0.0	0.0	
Bus15	11.000	101.090	-59.1	0	0	0	0	Bus13	0.000	0.000	0.0	0.0	
Bus16	11.000	100.215	0.7	0	0	0	0	Bus14	0.000	0.000	0.0	0.0	
Bus17	66.000	101.980	-29.2	0	0	0	0	Bus27	-0.007	4.971	42.6	-0.1	

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
								Bus21	0.004	-2.488	21.3	-0.1	
								Bus23	0.003	-2.484	21.3	-0.1	
								Bus19	0.000	0.000	0.0	0.0	
Bus18	66.000	100.224	30.7	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus20	0.000	0.000	0.0	0.0	
Bus19	11.000	101.980	-59.2	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
Bus20	11.000	100.224	0.7	0	0	0	0	Bus18	0.000	0.000	0.0	0.0	
Bus21	66.000	102.356	-29.3	0	0	0	0	Bus17	-0.002	2.173	18.6	-0.1	
								Bus23	0.002	-2.173	18.6	-0.1	
								Bus22	0.000	0.000	0.0	0.0	
Bus22	11.000	102.356	-59.3	0	0	0	0	Bus21	0.000	0.000	0.0	0.0	
Bus23	66.000	103.530	-29.4	0	0	0	0	Bus17	0.000	-0.001	0.0	-16.2	
								Bus21	0.000	0.001	0.0	-16.2	
								Bus25	0.000	0.000	0.0	0.0	
Bus25	11.000	103.530	-59.4	0	0	0	0	Bus23	0.000	0.000	0.0	0.0	
Bus27	66.000	101.392	-29.2	0	0	0	0	Bus17	0.011	-5.170	44.6	-0.2	
								Bus1	-0.011	5.170	44.6	-0.2	
								Bus28	0.000	0.000	0.0	0.0	
								Bus29	0.000	0.000	0.0	0.0	
Bus28	11.000	101.392	-59.2	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	
Bus29	11.000	101.392	-59.2	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	
Bus30	66.000	101.072	-29.1	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus32	0.000	0.000	0.0	0.0	
Bus31	66.000	100.197	30.7	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus33	0.000	0.000	0.0	0.0	
Bus32	11.000	101.072	-59.1	0	0	0	0	Bus30	0.000	0.000	0.0	0.0	
Bus33	11.000	100.197	0.7	0	0	0	0	Bus31	0.000	0.000	0.0	0.0	
Bus34	0.400	101.713	-24.0	1.952	0.000	0	0	Bus41	1.952	0.000	2769.6	100.0	
Bus35	0.400	101.713	-24.0	1.952	0.000	0	0	Bus41	1.952	0.000	2769.6	100.0	
Bus36	0.400	101.713	-24.0	1.952	0.000	0	0	Bus41	1.952	0.000	2769.6	100.0	
Bus37	0.400	101.713	-24.0	1.952	0.000	0	0	Bus41	1.952	0.000	2769.6	100.0	
Bus38	0.400	100.847	35.1	1.952	0.000	0	0	Bus42	1.952	0.000	2793.4	100.0	
Bus39	0.400	100.847	35.1	1.952	0.000	0	0	Bus42	1.952	0.000	2793.4	100.0	
Bus40	0.400	100.847	35.1	1.952	0.000	0	0	Bus42	1.952	0.000	2793.4	100.0	
Bus41	11.000	101.133	-56.2	0	0	0	0	Bus12	7.756	-0.303	402.8	-99.9	
								Bus34	-1.939	0.076	100.7	-99.9	
								Bus35	-1.939	0.076	100.7	-99.9	
								Bus36	-1.939	0.076	100.7	-99.9	
								Bus37	-1.939	0.076	100.7	-99.9	

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	%Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	% PF	% Tap
Bus42	11.000	100.263	2.9	0	0	0	0	Bus11	5.817	-0.231	304.7	-99.9	
								Bus38	-1.939	0.077	101.6	-99.9	
								Bus39	-1.939	0.077	101.6	-99.9	
								Bus40	-1.939	0.077	101.6	-99.9	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

# indicates a bus with a load mismatch of more than 0.1 MVA

System Harmonics Bus Information

Bus		Voltage Distortion								
ID	kV	Fund. %	RMS %	ASUM %	THD %	TIF	TIHD %	TSHD %	THDG %	THDS %
Bus1	66.000	101.07	101.09	103.78	1.85	52.15	0.00	0.00	1.85	1.85
Bus2	66.000	100.19	100.20	101.86	1.40	31.80	0.00	0.00	1.40	1.40
Bus3	220.000	100.00	100.02	102.60	1.79	50.48	0.00	0.00	1.79	1.79
Bus5	220.000	100.00	100.01	101.59	1.34	30.51	0.00	0.00	1.34	1.34
Bus6	11.000	101.07	101.09	103.78	1.85	52.15	0.00	0.00	1.85	1.85
Bus7	66.000	100.19	100.20	101.86	1.40	31.85	0.00	0.00	1.40	1.40
Bus8	66.000	101.07	101.09	103.79	1.85	52.31	0.00	0.00	1.85	1.85
Bus9	11.000	100.19	100.20	101.86	1.40	31.85	0.00	0.00	1.40	1.40
Bus10	11.000	101.07	101.09	103.79	1.85	52.31	0.00	0.00	1.85	1.85
Bus11	66.000	100.19	100.20	101.86	1.40	31.80	0.00	0.00	1.40	1.40
Bus12	66.000	101.07	101.09	103.78	1.85	52.15	0.00	0.00	1.85	1.85
Bus13	66.000	101.09	101.11	104.02	1.93	56.50	0.00	0.00	1.93	1.93
Bus14	66.000	100.22	100.23	101.97	1.45	33.17	0.00	0.00	1.45	1.45
Bus15	11.000	101.09	101.11	104.02	1.93	56.50	0.00	0.00	1.93	1.93
Bus16	11.000	100.22	100.23	101.97	1.45	33.17	0.00	0.00	1.45	1.45
Bus17	66.000	101.98	102.00	104.34	1.97	44.24	0.00	0.00	1.97	1.97
Bus18	66.000	100.22	100.23	102.02	1.47	33.81	0.00	0.00	1.47	1.47
Bus19	11.000	101.98	102.00	104.34	1.97	44.24	0.00	0.00	1.97	1.97
Bus20	11.000	100.22	100.23	102.02	1.47	33.81	0.00	0.00	1.47	1.47
Bus21	66.000	102.36	102.38	105.45	2.06	57.63	0.00	0.00	2.06	2.06
Bus22	11.000	102.36	102.38	105.45	2.06	57.63	0.00	0.00	2.06	2.06
Bus23	66.000	103.53	103.55	105.69	1.97	43.08	0.00	0.00	1.97	1.97
Bus25	11.000	103.53	103.55	105.69	1.97	43.08	0.00	0.00	1.97	1.97
Bus27	66.000	101.39	101.41	103.91	1.88	46.12	0.00	0.00	1.88	1.88
Bus28	11.000	101.39	101.41	103.91	1.88	46.12	0.00	0.00	1.88	1.88
Bus29	11.000	101.39	101.41	103.91	1.88	46.12	0.00	0.00	1.88	1.88
Bus30	66.000	101.07	101.09	103.82	1.86	52.81	0.00	0.00	1.86	1.86
Bus31	66.000	100.20	100.21	101.87	1.40	32.02	0.00	0.00	1.41	1.41
Bus32	11.000	101.07	101.09	103.82	1.86	52.81	0.00	0.00	1.86	1.86
Bus33	11.000	100.20	100.21	101.87	1.40	32.02	0.00	0.00	1.41	1.41
Bus34	0.400	101.71	101.87	115.53	5.56	266.09	0.00	0.00	5.56	5.56
Bus35	0.400	101.71	101.75	107.60	2.50	123.38	0.00	0.00	2.50	2.50
Bus36	0.400	101.71	101.87	115.53	5.56	266.09	0.00	0.00	5.56	5.56
Bus37	0.400	101.71	101.87	115.53	5.56	266.09	0.00	0.00	5.56	5.56
Bus38	0.400	100.85	100.86	103.95	1.80	46.03	0.00	0.00	1.80	1.80
Bus39	0.400	100.85	100.97	112.47	4.91	192.81	0.00	0.00	4.91	4.91
Bus40	0.400	100.85	100.86	103.95	1.80	46.03	0.00	0.00	1.80	1.80
Bus41	11.000	101.13	101.17	107.42	2.69	132.53	0.00	0.00	2.69	2.69
Bus42	11.000	100.26	100.28	103.57	1.93	49.42	0.00	0.00	1.93	1.93

* Indicates THD (Total Harmonic Distortion) Exceeds the Limit.
\# Indicates IHD (Individual Harmonic Distortion) Exceeds the Limit.

System Harmonics Branch Information

Bus		Current Distortion											
From Bus ID	To Bus ID	Fund. Amp	RMS Amp	ASUM Amp	THD %	TIF	IT Amp	ITB Amp	ITR Amp	TIHD %	TSHD %	THDG %	THDS %
Bus1	Bus12	67.09	67.13	71.92	3.70	98.60	6619.51	6619.51	0.00	0.00	0.00	3.70	3.70
	Bus13	2.51	2.61	3.76	27.98	1043.89	2724.26	2724.26	0.00	0.00	0.00	27.98	27.98
	Bus27	45.65	45.69	49.33	4.34	197.18	9010.11	9010.11	0.00	0.00	0.00	4.34	4.34
	Bus8	0.52	0.54	0.77	27.13	984.55	531.29	531.29	0.00	0.00	0.00	27.13	27.13
	Bus8	0.52	0.54	0.77	27.13	984.55	531.29	531.29	0.00	0.00	0.00	27.13	27.13
	Bus30	1.04	1.08	1.54	27.23	991.21	1070.07	1070.07	0.00	0.00	0.00	27.23	27.23
	Bus3	81.13	81.13	81.45	0.32	7.60	616.61	616.61	0.00	0.00	0.00	0.32	0.32
	Bus6	0	0	0	0	0	0.00	616.61	0.00	0.00	0.00	0.00	0.00
Bus2	Bus11	50.74	50.75	52.38	1.69	42.04	2133.63	2133.63	0.00	0.00	0.00	1.69	1.69
	Bus14	2.29	2.33	2.88	18.83	466.02	1083.93	1083.93	0.00	0.00	0.00	18.83	18.83
	Bus18	2.97	3.02	3.76	18.99	473.23	1430.20	1430.20	0.00	0.00	0.00	18.99	18.99
	Bus7	0.52	0.53	0.65	18.49	452.59	237.64	237.64	0.00	0.00	0.00	18.49	18.49
	Bus7	0.52	0.53	0.65	18.49	452.59	237.64	237.64	0.00	0.00	0.00	18.49	18.49
	Bus31	1.03	1.05	1.29	18.53	454.22	477.02	477.02	0.00	0.00	0.00	18.53	18.53
	Bus5	51.21	51.21	51.43	0.39	8.62	441.31	441.31	0.00	0.00	0.00	0.39	0.39
Bus3	Bus1	24.34	24.34	24.44	0.32	7.60	184.98	184.98	0.00	0.00	0.00	0.32	0.32
Bus5	Bus2	15.36	15.36	15.43	0.39	8.62	132.39	132.39	0.00	0.00	0.00	0.39	0.39
Bus6	Bus1	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
Bus7	Bus2	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
	Bus2	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
	Bus9	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
Bus8	Bus1	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
	Bus1	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
	Bus10	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
Bus9	Bus7	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
Bus10	Bus8	0	0	0	0	0	0.00	132.39	0.00	0.00	0.00	0.00	0.00
Bus11	Bus2	50.79	50.80	52.35	1.58	41.88	2127.24	2127.24	0.00	0.00	0.00	1.58	1.58
	Bus42	50.79	50.80	52.35	1.58	41.88	2127.24	2127.24	0.00	0.00	0.00	1.58	1.58
Bus12	Bus1	67.14	67.19	72.02	3.79	95.73	6432.11	6432.11	0.00	0.00	0.00	3.79	3.79
	Bus41	67.14	67.19	72.02	3.79	95.73	6432.11	6432.11	0.00	0.00	0.00	3.79	3.79
Bus13	Bus1	0	0	0	0	0	0.00	6432.11	0.00	0.00	0.00	0.00	0.00
	Bus15	0	0	0	0	0	0.00	6432.11	0.00	0.00	0.00	0.00	0.00
Bus14	Bus2	0	0	0	0	0	0.00	6432.11	0.00	0.00	0.00	0.00	0.00
	Bus16	0	0	0	0	0	0.00	6432.11	0.00	0.00	0.00	0.00	0.00
Bus15	Bus13	0	0	0	0	0	0.00	6432.11	0.00	0.00	0.00	0.00	0.00
Bus16	Bus14	0	0	0	0	0	0.00	6432.11	0.00	0.00	0.00	0.00	0.00
Bus17	Bus27	42.64	42.68	45.77	4.09	226.17	9652.35	9652.35	0.00	0.00	0.00	4.09	4.09
	Bus21	21.34	21.39	24.15	7.01	411.32	8798.41	8798.41	0.00	0.00	0.00	7.01	7.01
	Bus23	21.30	21.31	22.61	2.65	161.77	3447.68	3447.68	0.00	0.00	0.00	2.65	2.65
	Bus19	0	0	0	0	0	0.00	3447.68	0.00	0.00	0.00	0.00	0.00

Bus		Current Distortion											
From Bus ID	To Bus ID	Fund. Amp	RMS Amp	ASUM Amp	THD %	TIF	IT Amp	ITb Amp	ITr Amp	TIHD %	TSHD %	THDG %	THDS %
Bus18	Bus2	0	0	0	0	0	0.00	3447.68	0.00	0.00	0.00	0.00	0.00
	Bus20	0	0	0	0	0	0.00	3447.68	0.00	0.00	0.00	0.00	0.00
Bus19	Bus17	0	0	0	0	0	0.00	3447.68	0.00	0.00	0.00	0.00	0.00
Bus20	Bus18	0	0	0	0	0	0.00	3447.68	0.00	0.00	0.00	0.00	0.00
Bus21	Bus17	18.57	18.62	21.14	6.94	399.58	7439.84	7439.84	0.00	0.00	0.00	6.94	6.94
	Bus23	18.57	18.62	21.14	6.94	399.58	7439.84	7439.84	0.00	0.00	0.00	6.94	6.94
	Bus22	0	0	0	0	0	0.00	7439.84	0.00	0.00	0.00	0.00	0.00
Bus22	Bus21	0	0	0	0	0	0.00	7439.84	0.00	0.00	0.00	0.00	0.00
Bus23	Bus17	0.01	0.38	0.57	4660.62	2847.38	1068.26	1068.26	0.00	0.00	0.00	4660.62	4660.62
	Bus21	0.01	0.38	0.57	4660.62	2847.38	1068.26	1068.26	0.00	0.00	0.00	4660.62	4660.62
	Bus25	0	0	0	0	0	0.00	1068.26	0.00	0.00	0.00	0.00	0.00
Bus25	Bus23	0	0	0	0	0	0.00	1068.26	0.00	0.00	0.00	0.00	0.00
Bus27	Bus17	44.61	44.65	48.21	4.30	213.40	9528.12	9528.12	0.00	0.00	0.00	4.30	4.30
	Bus1	44.61	44.65	48.21	4.30	213.40	9528.12	9528.12	0.00	0.00	0.00	4.30	4.30
	Bus28	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
	Bus29	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
Bus28	Bus27	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
Bus29	Bus27	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
Bus30	Bus1	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
	Bus32	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
Bus31	Bus2	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
	Bus33	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
Bus32	Bus30	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
Bus33	Bus31	0	0	0	0	0	0.00	9528.12	0.00	0.00	0.00	0.00	0.00
Bus34	Bus41	2769.58	2773.20	3041.73	5.11	129.85	360095.00	360095.00	0.00	0.00	0.00	5.11	5.11
Bus35	Bus41	2769.58	2769.59	2784.30	0.27	8.90	24656.24	24656.24	0.00	0.00	0.00	0.27	0.27
Bus36	Bus41	2769.58	2773.20	3041.73	5.11	129.85	360095.00	360095.00	0.00	0.00	0.00	5.11	5.11
Bus37	Bus41	2769.58	2773.20	3041.73	5.11	129.85	360095.00	360095.00	0.00	0.00	0.00	5.11	5.11
Bus38	Bus42	2793.38	2793.38	2803.04	0.23	5.17	14430.58	14430.58	0.00	0.00	0.00	0.23	0.23
Bus39	Bus42	2793.38	2797.02	3070.48	5.11	132.97	371924.50	371924.50	0.00	0.00	0.00	5.11	5.11
Bus40	Bus42	2793.38	2793.38	2803.04	0.23	5.17	14430.58	14430.58	0.00	0.00	0.00	0.23	0.23
Bus41	Bus12	402.85	403.14	432.10	3.79	95.73	38592.68	38592.68	0.00	0.00	0.00	3.79	3.79
	Bus34	100.71	100.84	110.61	5.11	129.85	13094.37	13094.37	0.00	0.00	0.00	5.11	5.11
	Bus35	100.71	100.71	101.25	0.27	8.90	896.59	896.59	0.00	0.00	0.00	0.27	0.27
	Bus36	100.71	100.84	110.61	5.11	129.85	13094.37	13094.37	0.00	0.00	0.00	5.11	5.11
	Bus37	100.71	100.84	110.61	5.11	129.85	13094.37	13094.37	0.00	0.00	0.00	5.11	5.11
Bus42	Bus11	304.73	304.77	314.12	1.58	41.88	12763.43	12763.43	0.00	0.00	0.00	1.58	1.58
	Bus38	101.58	101.58	101.93	0.23	5.17	524.75	524.75	0.00	0.00	0.00	0.23	0.23
	Bus39	101.58	101.71	111.65	5.11	132.97	13524.53	13524.53	0.00	0.00	0.00	5.11	5.11
	Bus40	101.58	101.58	101.93	0.23	5.17	524.75	524.75	0.00	0.00	0.00	0.23	0.23

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus1
Fund. kV: 66.705

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.75	23.00	1150.00	0.31	25.00	1250.00	0.50	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus10
Fund. kV: 11.118

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.75	23.00	1150.00	0.32	25.00	1250.00	0.51	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus11
Fund. kV: 66.128

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.13	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus12
Fund. kV: 66.706

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.75	23.00	1150.00	0.32	25.00	1250.00	0.50	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus13
Fund. kV: 66.719

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.81	23.00	1150.00	0.35	25.00	1250.00	0.57	35.00	1750.00	0.06	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.04												

Bus ID: Bus14
Fund. kV: 66.142

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.43	23.00	1150.00	0.15	25.00	1250.00	0.11	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus15
Fund. kV: 11.128

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.81	23.00	1150.00	0.35	25.00	1250.00	0.57	35.00	1750.00	0.06	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.04												

Bus ID: Bus16
Fund. kV: 11.024

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.43	23.00	1150.00	0.15	25.00	1250.00	0.11	35.00	1750.00	0.03	37.00	1850.00	0.02

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus16
Fund. kV: 11.024

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus17
Fund. kV: 67.306

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.01	13.00	650.00	1.97	23.00	1150.00	0.10	25.00	1250.00	0.05	35.00	1750.00	0.08	37.00	1850.00	0.08
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus18
Fund. kV: 66.148

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.45	23.00	1150.00	0.16	25.00	1250.00	0.12	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus19
Fund. kV: 11.218

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.01	13.00	650.00	1.97	23.00	1150.00	0.10	25.00	1250.00	0.05	35.00	1750.00	0.08	37.00	1850.00	0.08
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus2
Fund. kV: 66.128

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.13	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus20
Fund. kV: 11.025

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.45	23.00	1150.00	0.16	25.00	1250.00	0.12	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus21
Fund. kV: 67.555

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.01	13.00	650.00	1.95	23.00	1150.00	0.39	25.00	1250.00	0.51	35.00	1750.00	0.09	37.00	1850.00	0.07
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus22
Fund. kV: 11.259

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.01	13.00	650.00	1.95	23.00	1150.00	0.39	25.00	1250.00	0.51	35.00	1750.00	0.09	37.00	1850.00	0.07
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus23
Fund. kV: 68.330

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.97	23.00	1150.00	0.05	25.00	1250.00	0.05	35.00	1750.00	0.00	37.00	1850.00	0.00
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus25
Fund. kV: 11.388

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.97	23.00	1150.00	0.05	25.00	1250.00	0.05	35.00	1750.00	0.00	37.00	1850.00	0.00
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus27
Fund. kV: 66.919

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.84	23.00	1150.00	0.17	25.00	1250.00	0.32	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus28
Fund. kV: 11.153

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.84	23.00	1150.00	0.17	25.00	1250.00	0.32	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus29
Fund. kV: 11.153

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.84	23.00	1150.00	0.17	25.00	1250.00	0.32	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus3
Fund. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.69	23.00	1150.00	0.30	25.00	1250.00	0.49	35.00	1750.00	0.04	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus30
Fund. kV: 66.707

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.76	23.00	1150.00	0.32	25.00	1250.00	0.52	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus31
Fund. kV: 66.130

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus31
Fund. kV: 66.130

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus32
Fund. kV: 11.118

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.76	23.00	1150.00	0.32	25.00	1250.00	0.52	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus33
Fund. kV: 11.022

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus34
Fund. kV: 0.407

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.18	13.00	650.00	1.90	23.00	1150.00	2.71	25.00	1250.00	2.63	35.00	1750.00	1.21	37.00	1850.00	1.00
47.00	2350.00	0.46	49.00	2450.00	0.50												

Bus ID: Bus35
Fund. kV: 0.407

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.42	13.00	650.00	0.54	23.00	1150.00	1.30	25.00	1250.00	1.36	35.00	1750.00	0.45	37.00	1850.00	0.39
47.00	2350.00	0.16	49.00	2450.00	0.17												

Bus ID: Bus36
Fund. kV: 0.407

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.18	13.00	650.00	1.90	23.00	1150.00	2.71	25.00	1250.00	2.63	35.00	1750.00	1.21	37.00	1850.00	1.00
47.00	2350.00	0.46	49.00	2450.00	0.50												

Bus ID: Bus37
Fund. kV: 0.407

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.18	13.00	650.00	1.90	23.00	1150.00	2.71	25.00	1250.00	2.63	35.00	1750.00	1.21	37.00	1850.00	1.00
47.00	2350.00	0.46	49.00	2450.00	0.50												

Bus ID: Bus38
Fund. kV: 0.403

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.49	13.00	650.00	1.68	23.00	1150.00	0.25	25.00	1250.00	0.25	35.00	1750.00	0.15	37.00	1850.00	0.12
47.00	2350.00	0.06	49.00	2450.00	0.06												

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus39
Fund. kV: 0.403

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	2.29	13.00	650.00	3.38	23.00	1150.00	1.75	25.00	1250.00	1.63	35.00	1750.00	0.94	37.00	1850.00	0.77
47.00	2350.00	0.37	49.00	2450.00	0.40												

Bus ID: Bus4
Fund. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %

Bus ID: Bus40
Fund. kV: 0.403

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.49	13.00	650.00	1.68	23.00	1150.00	0.25	25.00	1250.00	0.25	35.00	1750.00	0.15	37.00	1850.00	0.12
47.00	2350.00	0.06	49.00	2450.00	0.06												

Bus ID: Bus41
Fund. kV: 11.125

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.53	13.00	650.00	0.57	23.00	1150.00	1.40	25.00	1250.00	1.46	35.00	1750.00	0.49	37.00	1850.00	0.42
47.00	2350.00	0.17	49.00	2450.00	0.18												

Bus ID: Bus42
Fund. kV: 11.029

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.53	13.00	650.00	1.80	23.00	1150.00	0.27	25.00	1250.00	0.27	35.00	1750.00	0.16	37.00	1850.00	0.13
47.00	2350.00	0.06	49.00	2450.00	0.07												

Bus ID: Bus5
Fund. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.33	23.00	1150.00	0.13	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus6
Fund. kV: 11.118

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.75	23.00	1150.00	0.31	25.00	1250.00	0.50	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus7
Fund. kV: 66.128

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus Tabulation

Harmonic Voltages (% of Fundamental Voltage)

Bus ID: Bus8
Fund. kV: 66.706

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.75	23.00	1150.00	0.32	25.00	1250.00	0.51	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus9
Fund. kV: 11.021

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus1
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.77	23.00	1150.00	0.32	25.00	1250.00	0.51	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus10
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.77	23.00	1150.00	0.32	25.00	1250.00	0.51	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus11
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.13	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus12
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.77	23.00	1150.00	0.32	25.00	1250.00	0.51	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus13
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.83	23.00	1150.00	0.35	25.00	1250.00	0.58	35.00	1750.00	0.06	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.04												

Bus ID: Bus14
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.44	23.00	1150.00	0.15	25.00	1250.00	0.11	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus15
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.83	23.00	1150.00	0.35	25.00	1250.00	0.58	35.00	1750.00	0.06	37.00	1850.00	0.00
47.00	2350.00	0.05	49.00	2450.00	0.04												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus16
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.44	23.00	1150.00	0.15	25.00	1250.00	0.11	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus17
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.01	13.00	650.00	2.01	23.00	1150.00	0.10	25.00	1250.00	0.05	35.00	1750.00	0.08	37.00	1850.00	0.08
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus18
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.46	23.00	1150.00	0.16	25.00	1250.00	0.12	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus19
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.01	13.00	650.00	2.01	23.00	1150.00	0.10	25.00	1250.00	0.05	35.00	1750.00	0.08	37.00	1850.00	0.08
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus2
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus20
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.46	23.00	1150.00	0.16	25.00	1250.00	0.12	35.00	1750.00	0.03	37.00	1850.00	0.02
47.00	2350.00	0.01	49.00	2450.00	0.01												

Bus ID: Bus21
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.01	13.00	650.00	1.99	23.00	1150.00	0.40	25.00	1250.00	0.52	35.00	1750.00	0.09	37.00	1850.00	0.07
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus22
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.01	13.00	650.00	1.99	23.00	1150.00	0.40	25.00	1250.00	0.52	35.00	1750.00	0.09	37.00	1850.00	0.07
47.00	2350.00	0.01	49.00	2450.00	0.00												

Bus ID: Bus23
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	2.04	23.00	1150.00	0.05	25.00	1250.00	0.05	35.00	1750.00	0.00	37.00	1850.00	0.00
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus25
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	2.04	23.00	1150.00	0.05	25.00	1250.00	0.05	35.00	1750.00	0.00	37.00	1850.00	0.00
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus27
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.87	23.00	1150.00	0.18	25.00	1250.00	0.33	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus28
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.87	23.00	1150.00	0.18	25.00	1250.00	0.33	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus29
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.87	23.00	1150.00	0.18	25.00	1250.00	0.33	35.00	1750.00	0.06	37.00	1850.00	0.03
47.00	2350.00	0.02	49.00	2450.00	0.01												

Bus ID: Bus3
Nom. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.69	23.00	1150.00	0.30	25.00	1250.00	0.49	35.00	1750.00	0.04	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus30
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.78	23.00	1150.00	0.32	25.00	1250.00	0.52	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.03												

Bus ID: Bus31
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.40	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus32
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.78	23.00	1150.00	0.32	25.00	1250.00	0.52	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.03												

Bus ID: Bus33
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.40	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus34
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.23	13.00	650.00	1.93	23.00	1150.00	2.76	25.00	1250.00	2.68	35.00	1750.00	1.23	37.00	1850.00	1.02
47.00	2350.00	0.47	49.00	2450.00	0.51												

Bus ID: Bus35
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.45	13.00	650.00	0.54	23.00	1150.00	1.33	25.00	1250.00	1.38	35.00	1750.00	0.46	37.00	1850.00	0.39
47.00	2350.00	0.16	49.00	2450.00	0.17												

Bus ID: Bus36
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.23	13.00	650.00	1.93	23.00	1150.00	2.76	25.00	1250.00	2.68	35.00	1750.00	1.23	37.00	1850.00	1.02
47.00	2350.00	0.47	49.00	2450.00	0.51												

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus37
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	3.23	13.00	650.00	1.93	23.00	1150.00	2.76	25.00	1250.00	2.68	35.00	1750.00	1.23	37.00	1850.00	1.02
47.00	2350.00	0.47	49.00	2450.00	0.51												

Bus ID: Bus38
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.50	13.00	650.00	1.70	23.00	1150.00	0.26	25.00	1250.00	0.25	35.00	1750.00	0.15	37.00	1850.00	0.13
47.00	2350.00	0.06	49.00	2450.00	0.06												

Bus ID: Bus39
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	2.31	13.00	650.00	3.41	23.00	1150.00	1.77	25.00	1250.00	1.64	35.00	1750.00	0.94	37.00	1850.00	0.77
47.00	2350.00	0.38	49.00	2450.00	0.41												

Bus ID: Bus4
Nom. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %

Bus ID: Bus40
Nom. kV: 0.400

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.50	13.00	650.00	1.70	23.00	1150.00	0.26	25.00	1250.00	0.25	35.00	1750.00	0.15	37.00	1850.00	0.13
47.00	2350.00	0.06	49.00	2450.00	0.06												

Bus ID: Bus41
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	1.54	13.00	650.00	0.58	23.00	1150.00	1.42	25.00	1250.00	1.48	35.00	1750.00	0.49	37.00	1850.00	0.42
47.00	2350.00	0.17	49.00	2450.00	0.19												

Bus ID: Bus42
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.53	13.00	650.00	1.81	23.00	1150.00	0.27	25.00	1250.00	0.27	35.00	1750.00	0.16	37.00	1850.00	0.13
47.00	2350.00	0.06	49.00	2450.00	0.07												

Bus ID: Bus5
Nom. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.33	23.00	1150.00	0.13	25.00	1250.00	0.09	35.00	1750.00	0.02	37.00	1850.00	0.01

Bus Tabulation

Harmonic Voltages (% of Nominal Voltage)

Bus ID: Bus5
Nom. kV: 220.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus6
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.77	23.00	1150.00	0.32	25.00	1250.00	0.51	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus7
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Bus ID: Bus8
Nom. kV: 66.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.02	13.00	650.00	1.77	23.00	1150.00	0.32	25.00	1250.00	0.51	35.00	1750.00	0.05	37.00	1850.00	0.00
47.00	2350.00	0.03	49.00	2450.00	0.02												

Bus ID: Bus9
Nom. kV: 11.000

Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %	Order	Freq. Hz	Mag. %
11.00	550.00	0.00	13.00	650.00	1.39	23.00	1150.00	0.14	25.00	1250.00	0.10	35.00	1750.00	0.02	37.00	1850.00	0.01
47.00	2350.00	0.00	49.00	2450.00	0.00												

Filter Overloading

Filter			Capacitor C1			Inductor L1			Capacitor C2			Inductor L2		
ID	Type	Connection	Max. kV	Opr. kV	% OverVolt	Max. Amp	Opr. Amp	% Overload	Max. kV	Opr. kV	% OverVolt	Max. Amp	Opr. Amp	% Overload
HF1	3	Wye	100.000	64.674	64.7	100.00	2.31	2.3						
HF2	3	Wye	100.000	57.193	57.2	100.00	4.12	4.1						

Filter Types: 0 = By-Pass, 1 = High-Pass (Damped), 2 = High-Pass (Undamped), 3 = Single Tuned, 4 = 3rd Order Damped, 5 = 3rd Order C-Type

Alert Summary Report

% Alert Settings

	Critical	Marginal
Bus		
Individual Bus VTHD / VIHD values are used.		
Transformer		
Total I	100.0	95.0
Filter		
Capacitor kV	100.0	95.0
Inductor Amp	100.0	95.0
Capacitor		
Max kV	100.0	95.0
Cable		
Ampacity	100.0	95.0

APPENDIX 12

TRANSIENT STABILITY ANALYSIS WITHOUT PV

Project:	MASTER THESIS	ETAP		Page:	1
Location:	HOUN CITY - LIBYA	12.6.0H		Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department			SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case:	TS	Revision:	Base
Filename:	HOUN SUBSTATION 220kV			Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Transient Stability Analysis (Without PV)

Initial Loading Category (1): Design

Initial Generation Category (1): Design

Load Diversity Factor: None

	Swing	V-Control	Load	Total
Number of Buses:	3	0	39	42

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	SPDT	Total
Number of Branches:	26	0	0	16	0	10	0	52

	Synchronous Generator	Power Grid	Synchronous Motor	Induction Machines	Lumped Load	Total
Number of Machines:	0	3	0	0	14	17

Method of the Initial LF Solution:	Adaptive Newton-Raphson
Maximum Number of Iterations:	1000
Solution Precision for the Initial LF:	0.0001000000
Acceleration Factor for the Initial LF:	0.00
Time Increment for Integration Steps (Δt):	0.0010
Time Increment for Plots:	20 times Δt
System Frequency:	50.00 Hz
Frequency Dependent Models for Machines and Network are Not Used	
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus1	66.000	1	99.1	-5.1								
Bus2	66.000	1	98.9	-1.9								
Bus3	220.000	1	100.0	0.0								
Bus4	220.000	1	100.0	0.0								
Bus5	220.000	1	100.0	0.0								
Bus6	11.000	1	98.1	-5.1	0.000	0.995	0.000	0.249				
Bus7	66.000	1	98.8	-1.9								
Bus8	66.000	1	99.0	-5.2								
Bus9	11.000	1	98.1	-2.5	1.600	0.992	0.400	0.248				
Bus10	11.000	1	97.8	-7.2	5.600	3.471	1.400	0.868				
Bus11	66.000	1	99.1	-1.2								
Bus12	66.000	1	99.4	-4.2								
Bus13	66.000	1	98.3	-5.6								
Bus14	66.000	1	98.0	-2.4								
Bus15	11.000	1	98.7	-8.5	4.800	2.975	1.200	0.744				
Bus16	11.000	1	98.3	-5.4	4.800	2.975	1.200	0.744				
Bus17	66.000	1	98.9	-6.8								
Bus18	66.000	1	98.8	-2.3								
Bus19	11.000	1	98.7	-8.4	4.400	0.000	1.100	0.000				
Bus20	11.000	1	98.7	-3.3	2.800	0.000	0.700	0.000				
Bus21	66.000	1	98.9	-7.5								
Bus22	11.000	1	98.4	-10.4	4.800	0.000	1.200	0.000				
Bus23	66.000	1	99.3	-7.9								
Bus24	66.000	1	100.0	0.0								
Bus25	11.000	1	98.1	-8.8	1.600	0.991	0.400	0.248				
Bus26	11.000	1	100.0	0.0	4.000	2.479	1.000	0.620				
Bus27	66.000	1	98.8	-5.8								
Bus28	11.000	1	98.4	-6.7	2.400	1.487	0.600	0.372				
Bus29	11.000	1	98.4	-6.7	2.400	1.487	0.600	0.372				
Bus30	66.000	1	98.5	-5.5								
Bus31	66.000	1	98.6	-2.1								
Bus32	11.000	1	98.0	-8.7	8.800	5.455	2.200	1.364				
Bus33	11.000	1	100.5	-3.5	4.000	2.479	1.000	0.620				
Bus34	0.400	1	100.0	1.1								

Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus35	0.400	1	100.0	1.1								
Bus36	0.400	1	100.0	1.1								
Bus37	0.400	1	100.0	1.1								
Bus38	0.400	1	100.0	3.3								
Bus39	0.400	1	100.0	3.3								
Bus40	0.400	1	100.0	3.3								
Bus41	11.000	1	98.9	-1.2								
Bus42	11.000	1	98.6	1.0								
Total Number of Buses: 42					51.999	25.785	13.000	6.446	0.000	0.000	0.000	0.000

Note: Dynamically modeled motor loads are not included in the bus motor load. See machine and motor pages for detail.

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus3	220.000	Swing	1	100.0	0.0					
Bus4	220.000	Swing	1	100.0	0.0					
Bus5	220.000	Swing	1	100.0	0.0					
						0.000	0.000			

Line/Cable Input Data

Line/Cable			Length				Ohms or Siemens per 1000 m per Conductor (Cable) or per Phase (Line)					
ID	Library	Size	Adj. (m)	% Tol.	#/Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Cable1	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646	0.240351	0.215000	
Cable2	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646	0.240351	0.215000	
Line1		674	19300.0	0.0	1	75	0.056003	0.374255	0.0000031	0.200077	1.360791	0.0000017
Line2		674	10300.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line3		674	23000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line4		674	15000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line5		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line6		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line7		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line8		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line9		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line10		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line11		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line12		674	21000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line13		674	161000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line14		674	140000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016

Line / Cable resistances are listed at the specified temperatures.

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
T1	63.000	220.000	66.000	12.50	45.00	0	0	0	0	3.750	12.5000	Dyn	0.000
T2	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0.625	12.5000	Dyn	0.000
T3	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0.625	12.5000	Dyn	0.000
T4	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T5	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T6	20.000	66.000	11.000	10.00	20.00	0	0	0	0	1.250	10.0000	Dyn	0.000
T7	12.500	11.000	66.000	8.35	13.00	0	0	0	-1.250	0	8.3500	YNd	0.000
T8	12.500	11.000	66.000	8.35	13.00	0	0	0	-1.250	0	8.3500	YNd	0.000
T9	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500	Dyn	0.000
T10	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500	Dyn	0.000
T11	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T12	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T13	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T14	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T15	10.000	66.000	11.000	8.35	13.00	0	0	0	0	3.750	8.3500	Dyn	0.000
T16	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000	Dyn	0.000
T17	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000	Dyn	0.000
T18	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000	Dyn	0.000
T19	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000	Dyn	0.000
T20	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T21	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T22	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T23	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T24	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T25	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T26	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T1	63.000	220.000	66.000	D/Y					Solid			
T2	63.000	220.000	66.000	D/Y					Solid			

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T3	63.000	220.000	66.000	D/Y					Solid			
T4	10.000	66.000	11.000	D/Y					Solid			
T5	20.000	66.000	11.000	D/Y					Solid			
T6	20.000	66.000	11.000	D/Y					Solid			
T7	12.500	11.000	66.000	D/Y					Solid			
T8	12.500	11.000	66.000	D/Y					Solid			
T9	10.000	66.000	11.000	D/Y					Solid			
T10	10.000	66.000	11.000	D/Y					Solid			
T11	20.000	66.000	11.000	D/Y					Solid			
T12	20.000	66.000	11.000	D/Y					Solid			
T13	10.000	66.000	11.000	D/Y					Solid			
T14	10.000	66.000	11.000	D/Y					Solid			
T15	10.000	66.000	11.000	D/Y					Solid			
T16	20.000	66.000	11.000	D/Y					Solid			
T17	20.000	66.000	11.000	D/Y					Solid			
T18	20.000	66.000	11.000	D/Y					Solid			
T19	20.000	66.000	11.000	D/Y					Solid			
T20	3.000	0.400	11.000	D/Y					Solid			
T21	3.000	0.400	11.000	D/Y					Solid			
T22	3.000	0.400	11.000	D/Y					Solid			
T23	3.000	0.400	11.000	D/Y					Solid			
T24	3.000	0.400	11.000	D/Y					Solid			
T25	3.000	0.400	11.000	D/Y					Solid			
T26	3.000	0.400	11.000	D/Y					Solid			

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.46	20.58	20.59	
T2	2W XFMR	Bus4	Bus1	0.44	19.96	19.97	
T3	2W XFMR	Bus5	Bus2	0.44	19.96	19.97	
T4	2W XFMR	Bus1	Bus6	6.40	83.25	83.50	
T5	2W XFMR	Bus7	Bus9	2.50	49.94	50.00	
T6	2W XFMR	Bus8	Bus10	2.53	50.56	50.63	
T7	2W XFMR	Bus42	Bus11	5.06	65.77	65.97	
T8	2W XFMR	Bus41	Bus12	5.06	65.77	65.97	
T9	2W XFMR	Bus13	Bus15	6.68	86.90	87.15	
T10	2W XFMR	Bus14	Bus16	6.68	86.90	87.15	
T11	2W XFMR	Bus17	Bus19	2.50	49.94	50.00	
T12	2W XFMR	Bus18	Bus20	2.50	49.94	50.00	
T13	2W XFMR	Bus21	Bus22	6.40	83.25	83.50	
T14	2W XFMR	Bus23	Bus25	6.40	83.25	83.50	
T15	2W XFMR	Bus24	Bus26	6.64	86.38	86.63	
T16	2W XFMR	Bus27	Bus28	2.51	50.25	50.31	
T17	2W XFMR	Bus27	Bus29	2.51	50.25	50.31	
T18	2W XFMR	Bus30	Bus32	2.59	51.81	51.88	
T19	2W XFMR	Bus31	Bus33	2.59	51.81	51.88	
T20	2W XFMR	Bus34	Bus41	34.25	205.50	208.33	
T21	2W XFMR	Bus35	Bus41	34.25	205.50	208.33	
T22	2W XFMR	Bus36	Bus41	34.25	205.50	208.33	
T23	2W XFMR	Bus37	Bus41	34.25	205.50	208.33	
T24	2W XFMR	Bus38	Bus42	34.25	205.50	208.33	
T25	2W XFMR	Bus39	Bus42	34.25	205.50	208.33	
T26	2W XFMR	Bus40	Bus42	34.25	205.50	208.33	
Cable1	Cable	Bus11	Bus2	0.02	0.02	0.03	0.0716998
Cable2	Cable	Bus12	Bus1	0.02	0.02	0.03	0.0716998
Line1	Line	Bus2	Bus14	2.48	16.58	16.77	0.2607629
Line2	Line	Bus1	Bus13	2.48	15.16	15.36	0.2842267
Line3	Line	Bus2	Bus18	2.96	18.06	18.30	0.3387157
Line4	Line	Bus27	Bus17	1.93	11.78	11.94	0.2209015
Line5	Line	Bus1	Bus27	1.03	6.28	6.37	0.1178142
Line6	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line7	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line8	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line9	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
ID	Type	From Bus	To Bus	R	X	Z	Y
Line10	Line	Bus2	Bus31	1.03	6.28	6.37	0.1178142
Line11	Line	Bus1	Bus30	1.03	6.28	6.37	0.1178142
Line12	Line	Bus17	Bus21	2.70	16.49	16.71	0.3092622
Line13	Line	Bus17	Bus23	20.70	126.43	128.11	2.3710100
Line14	Line	Bus21	Bus23	18.00	109.94	111.40	2.0617480
SW1	Tie Switch	Bus1	Bus2				
SW2	Tie Switch	Bus7	Bus8				
SW3	Tie Switch	Bus13	Bus14				
SW4	Tie Switch	Bus17	Bus18				
SW5	Tie Switch	Bus23	Bus24				
SW6	Tie Switch	Bus25	Bus26				
SW7	Tie Switch	Bus28	Bus29				
SW8	Tie Switch	Bus30	Bus31				
SW9	Tie Switch	Bus32	Bus33				
SW10	Tie Switch	Bus41	Bus42				

Branch Connections
Zero Sequence Impedance

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
T1	2W XFMR	Bus3	Bus1				
T2	2W XFMR	Bus4	Bus1				
T3	2W XFMR	Bus5	Bus2				
T4	2W XFMR	Bus1	Bus6				
T5	2W XFMR	Bus7	Bus9				
T6	2W XFMR	Bus8	Bus10				
T7	2W XFMR	Bus42	Bus11				
T8	2W XFMR	Bus41	Bus12				
T9	2W XFMR	Bus13	Bus15				
T10	2W XFMR	Bus14	Bus16				
T11	2W XFMR	Bus17	Bus19				
T12	2W XFMR	Bus18	Bus20				
T13	2W XFMR	Bus21	Bus22				
T14	2W XFMR	Bus23	Bus25				
T15	2W XFMR	Bus24	Bus26				
T16	2W XFMR	Bus27	Bus28				
T17	2W XFMR	Bus27	Bus29				
T18	2W XFMR	Bus30	Bus32				
T19	2W XFMR	Bus31	Bus33				
T20	2W XFMR	Bus34	Bus41				
T21	2W XFMR	Bus35	Bus41				
T22	2W XFMR	Bus36	Bus41				
T23	2W XFMR	Bus37	Bus41				
T24	2W XFMR	Bus38	Bus42				
T25	2W XFMR	Bus39	Bus42				
T26	2W XFMR	Bus40	Bus42				
Cable1	Cable	Bus11	Bus2				
Cable2	Cable	Bus12	Bus1				
Line1	Line	Bus2	Bus14				0.1410145
Line2	Line	Bus1	Bus13				0.1341983
Line3	Line	Bus2	Bus18				0.1599255
Line4	Line	Bus27	Bus17				0.1042992
Line5	Line	Bus1	Bus27				0.0556263
Line6	Line	Bus2	Bus7				0.0278131
Line7	Line	Bus1	Bus8				0.0278131

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
Line8	Line	Bus2	Bus7				0.0278131
Line9	Line	Bus1	Bus8				0.0278131
Line10	Line	Bus2	Bus31				0.0556263
Line11	Line	Bus1	Bus30				0.0556263
Line12	Line	Bus17	Bus21				0.1460189
Line13	Line	Bus17	Bus23				1.1194780
Line14	Line	Bus21	Bus23				0.9734595
SW1	Tie Switch	Bus1	Bus2				
SW2	Tie Switch	Bus7	Bus8				
SW3	Tie Switch	Bus13	Bus14				
SW4	Tie Switch	Bus17	Bus18				
SW5	Tie Switch	Bus23	Bus24				
SW6	Tie Switch	Bus25	Bus26				
SW7	Tie Switch	Bus28	Bus29				
SW8	Tie Switch	Bus30	Bus31				
SW9	Tie Switch	Bus32	Bus33				
SW10	Tie Switch	Bus41	Bus42				

Synchronous Machine Parameters

Machine			Rating		Positive Sequence Impedance (%)								Zero Seq. Z (%)		
ID	Type	Model	MVA	kV	Ra	Xd"	Xd'	Xd	Xq"	Xq'	Xq	Xl	X/R	R0	X0
U1	Power Grid	N/A	22.101	220.000	9.95		99.50							35.65	356.48
U2	Power Grid	N/A	22.101	220.000	9.95		99.50							17.74	177.38
U3	Power Grid	N/A	22.101	220.000	9.95		99.50							17.74	177.38

Machine	Connected Bus	Time Constants (Sec.)				H (Sec.), D (MWpu/Hz) & Saturati					Generator or Loading		Grounding		
ID	ID	Tdo"	Tdo'	Tqo"	Tqo'	H	%D	S100	S120	Sbreak	MW	Mvar	Conn.	Type	Amp

Machine		Generator/Motor			Coupling			Prime Mover/Load			Equivalent Total		
ID	Type	RPM	WR²	H	RPM	WR²	H	RPM	WR²	H	RPM	WR²	H

WR²: kg-m²   H: MW-Sec/MVA

Machine		Shaft Torsion			
ID	Type	D1	D2	K1	K2

D1, D2: MW (pu)/Speed (pu)   K1, K2: MW (pu)/Radiant

Lumped Load Input Data

Conventional Type

							Load			
ID	kV	kVA	kW	kvar	% PF	Amp	% Motor	% Static	Ta	Gamma
Lump1	11.000	1243	0	1243	0.01	65.3	80	20	0	0
Lump10	11.000	5882	5000	3098	85.000	308.7	80	20	0	0
Lump11	11.000	3529	3000	1859	85	185.2	80	20	0	0
Lump12	11.000	3529	3000	1859	85	185.2	80	20	0	0
Lump13	11.000	12942	11000	6818	85.000	679.3	80	20	0	0
Lump14	11.000	5883	5000	3099	85.000	308.8	80	20	0	0
Lump2	11.000	2353	2000	1240	85	123.5	80	20	0	0
Lump3	11.000	8236	7000	4339	85.000	432.3	80	20	0	0
Lump4	11.000	7058	6000	3718	85	370.5	80	20	0	0
Lump5	11.000	7058	6000	3718	85	370.5	80	20	0	0
Lump6	11.000	5500	5500	0	100	288.7	80	20	0	0
Lump7	11.000	3500	3500	0	100	183.7	80	20	0	0
Lump8	11.000	6000	6000	0	100	314.9	80	20	0	0
Lump9	11.000	2352	2000	1239	85	123.5	80	20	0	0

LOAD FLOW REPORT (Without PV) @ T = 0.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus1	66.000	99.118	-44.6	0	0	0	0	Bus13	6.017	3.963	63.6	83.5	
								Bus27	19.518	1.155	172.6	99.8	
								Bus8	3.479	2.276	36.7	83.7	
								Bus8	3.479	2.276	36.7	83.7	
								Bus30	10.979	7.688	118.3	81.9	
								Bus3	-43.474	-18.606	417.3	91.9	3.750
								Bus6	0.001	1.247	11.0	0.1	
Bus2	66.000	98.852	-27.5	0	0	0	0	Bus14	6.009	3.992	63.8	83.3	
								Bus18	3.488	-0.246	30.9	-99.8	
								Bus7	0.994	0.572	10.1	86.7	
								Bus7	0.994	0.572	10.1	86.7	
								Bus31	5.022	3.198	52.7	84.4	
								Bus5	-16.507	-8.089	162.7	89.8	0.625
* Bus3	220.000	100.000	-39.5	0	0	0	0	Bus1	43.582	23.466	129.9	88.0	
								U1	-43.582	-23.466	129.9	88.0	
* Bus4	220.000	100.000	0.0	0	0	0	0	U2	0.000	0.000	0.0	0.0	
* Bus5	220.000	100.000	-25.6	0	0	0	0	Bus2	16.522	8.783	49.1	88.3	
								U3	-16.522	-8.783	49.1	88.3	
Bus6	11.000	98.071	-44.6	0	0	0.000	1.234	Bus1	0.000	-1.234	66.0	0.0	
Bus7	66.000	98.828	-27.5	0	0	0	0	Bus2	-0.994	-0.629	10.4	84.5	
								Bus2	-0.994	-0.629	10.4	84.5	
								Bus9	1.987	1.259	20.8	84.5	
Bus8	66.000	99.027	-44.7	0	0	0	0	Bus1	-3.478	-2.329	37.0	83.1	
								Bus1	-3.478	-2.329	37.0	83.1	
								Bus10	6.956	4.657	73.9	83.1	
Bus9	11.000	98.146	-28.1	0	0	1.986	1.231	Bus7	-1.986	-1.231	124.9	85.0	
Bus10	11.000	97.770	-46.7	0	0	6.938	4.301	Bus8	-6.938	-4.301	438.2	85.0	1.250
Bus13	66.000	98.344	-45.1	0	0	0	0	Bus1	-6.004	-4.158	65.0	82.2	
								Bus15	6.004	4.158	65.0	82.2	
Bus14	66.000	98.015	-28.0	0	0	0	0	Bus2	-5.996	-4.155	65.1	82.2	
								Bus16	5.996	4.155	65.1	82.2	
Bus15	11.000	98.692	-48.8	0	0	5.968	3.699	Bus13	-5.968	-3.699	373.4	85.0	4.375
Bus16	11.000	98.339	-31.0	0	0	5.960	3.694	Bus14	-5.960	-3.694	374.2	85.0	4.375
Bus17	66.000	98.917	-46.3	0	0	0	0	Bus27	-13.472	2.810	121.7	-97.9	
								Bus21	6.602	-1.319	59.5	-98.1	
								Bus23	1.390	-1.644	19.0	-64.6	
								Bus19	5.480	0.153	48.5	100.0	

LOAD FLOW REPORT (Without PV) @ T = 0.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus18	66.000	98.765	-27.9	0	0	0	0	Bus2	-3.484	-0.062	30.9	100.0	
								Bus20	3.484	0.062	30.9	100.0	
Bus19	11.000	98.740	-47.9	0	0	5.472	0.000	Bus17	-5.472	0.000	290.9	100.0	
Bus20	11.000	98.661	-28.9	0	0	3.481	0.000	Bus18	-3.481	0.000	185.2	100.0	
Bus21	66.000	98.938	-47.0	0	0	0	0	Bus17	-6.590	1.092	59.1	-98.7	
								Bus23	0.604	-1.398	13.5	-39.6	
								Bus22	5.986	0.306	53.0	99.9	
Bus22	11.000	98.422	-49.9	0	0	5.962	0.000	Bus21	-5.962	0.000	318.0	100.0	
Bus23	66.000	99.263	-47.4	0	0	0	0	Bus17	-1.385	-0.656	13.5	90.4	
								Bus21	-0.603	-0.621	7.6	69.6	
								Bus25	1.988	1.277	20.8	84.1	
Bus25	11.000	98.077	-48.3	0	0	1.984	1.230	Bus23	-1.984	-1.230	124.9	85.0	
Bus27	66.000	98.847	-45.3	0	0	0	0	Bus17	13.509	-2.797	122.1	-97.9	
								Bus1	-19.478	-1.026	172.6	99.9	
								Bus28	2.984	1.912	31.4	84.2	
								Bus29	2.984	1.912	31.4	84.2	
Bus28	11.000	98.428	-46.2	0	0	2.981	1.848	Bus27	-2.981	-1.848	187.0	85.0	0.625
Bus29	11.000	98.428	-46.2	0	0	2.981	1.848	Bus27	-2.981	-1.848	187.0	85.0	0.625
Bus30	66.000	98.515	-45.0	0	0	0	0	Bus1	-10.961	-7.688	118.9	81.9	
								Bus32	10.961	7.688	118.9	81.9	
Bus31	66.000	98.594	-27.7	0	0	0	0	Bus2	-5.019	-3.290	53.2	83.6	
								Bus33	5.019	3.290	53.2	83.6	
Bus32	11.000	98.036	-48.2	0	0	10.914	6.765	Bus30	-10.914	-6.765	687.5	85.0	3.750
Bus33	11.000	100.463	-29.1	0	0	5.009	3.105	Bus31	-5.009	-3.105	307.9	85.0	3.750
U1	220.000	291.912	0.0	54.612	133.771	0	0	Bus3	54.612	133.771	129.9	37.8	
U2	220.000	100.000	0.0	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
U3	220.000	162.988	0.0	18.099	24.547	0	0	Bus5	18.099	24.547	49.1	59.3	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# indicates a bus with a load mismatch of more than 0.1 MVA

LOAD FLOW REPORT (Without PV) @ T = 0.800-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus1	66.000	193.796	-35.3	0	0	0	0	Bus13	9.563	5.183	49.1	87.9	
								Bus27	30.507	-10.788	146.1	-94.3	
								Bus8	5.446	3.266	28.7	85.8	
								Bus8	5.446	3.266	28.7	85.8	
								Bus30	17.411	10.974	92.9	84.6	
								Bus3	-68.374	-13.828	314.9	98.0	3.750
								Bus6	0.001	1.929	8.7	0.0	
Bus2	66.000	98.852	-27.5	0	0	0	0	Bus14	6.009	3.992	63.8	83.3	
								Bus18	3.488	-0.246	30.9	-99.8	
								Bus7	0.994	0.572	10.1	86.7	
								Bus7	0.994	0.572	10.1	86.7	
								Bus31	5.022	3.198	52.7	84.4	
								Bus5	-16.507	-8.089	162.7	89.8	0.625
Bus3	220.000	188.559	-33.1	0	0	0	0	Bus1	68.435	16.594	98.0	97.2	
								U1	-68.435	-16.594	98.0	97.2	
Bus4	220.000	100.000	0.0	0	0	0	0	U2	0.000	0.000	0.0	0.0	
Bus5	220.000	100.000	-25.6	0	0	0	0	Bus2	16.522	8.783	49.1	88.3	
								U3	-16.522	-8.783	49.1	88.3	
Bus6	11.000	192.907	-35.3	0	0	0.000	1.920	Bus1	0.000	-1.920	52.2	0.0	
Bus7	66.000	98.828	-27.5	0	0	0	0	Bus2	-0.994	-0.629	10.4	84.5	
								Bus2	-0.994	-0.629	10.4	84.5	
								Bus9	1.987	1.259	20.8	84.5	
Bus8	66.000	193.727	-35.3	0	0	0	0	Bus1	-5.446	-3.483	29.2	84.2	
								Bus1	-5.446	-3.483	29.2	84.2	
								Bus10	10.891	6.966	58.4	84.2	
Bus9	11.000	98.146	-28.1	0	0	1.986	1.231	Bus7	-1.986	-1.231	124.9	85.0	
Bus10	11.000	194.207	-36.1	0	0	10.880	6.744	Bus8	-10.880	-6.744	346.0	85.0	1.250
Bus13	66.000	193.227	-35.5	0	0	0	0	Bus1	-9.555	-6.197	51.6	83.9	
								Bus15	9.555	6.197	51.6	83.9	
Bus14	66.000	98.015	-28.0	0	0	0	0	Bus2	-5.996	-4.155	65.1	82.2	
								Bus16	5.996	4.155	65.1	82.2	
Bus15	11.000	198.606	-36.7	0	0	9.533	5.908	Bus13	-9.533	-5.908	296.4	85.0	4.375
Bus16	11.000	98.339	-31.0	0	0	5.960	3.694	Bus14	-5.960	-3.694	374.2	85.0	4.375
Bus17	66.000	194.744	-36.0	0	0	0	0	Bus27	-21.105	15.770	118.3	-80.1	
								Bus21	10.341	-7.834	58.3	-79.7	
								Bus23	2.193	-8.032	37.4	-26.3	
								Bus19	8.571	0.097	38.5	100.0	

LOAD FLOW REPORT (Without PV) @ T = 0.800-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus18	66.000	98.765	-27.9	0	0	0	0	Bus2	-3.484	-0.062	30.9	100.0	
								Bus20	3.484	0.062	30.9	100.0	
Bus19	11.000	194.622	-36.7	0	0	8.567	0.000	Bus17	-8.567	0.000	231.0	100.0	
Bus20	11.000	98.661	-28.9	0	0	3.481	0.000	Bus18	-3.481	0.000	185.2	100.0	
Bus21	66.000	195.217	-36.3	0	0	0	0	Bus17	-10.329	6.728	55.2	-83.8	
								Bus23	0.958	-6.920	31.3	-13.7	
								Bus22	9.372	0.192	42.0	100.0	
Bus22	11.000	194.868	-37.5	0	0	9.357	0.000	Bus21	-9.357	0.000	252.0	100.0	
Bus23	66.000	196.815	-36.6	0	0	0	0	Bus17	-2.183	-0.998	10.7	90.9	
								Bus21	-0.953	-0.973	6.1	70.0	
								Bus25	3.136	1.972	16.5	84.7	
Bus25	11.000	195.883	-36.9	0	0	3.134	1.942	Bus23	-3.134	-1.942	98.8	85.0	
Bus27	66.000	193.979	-35.6	0	0	0	0	Bus17	21.141	-16.385	120.6	-79.0	
								Bus1	-30.478	10.520	145.4	-94.5	
								Bus28	4.669	2.932	24.9	84.7	
								Bus29	4.669	2.932	24.9	84.7	
Bus28	11.000	194.375	-36.0	0	0	4.667	2.892	Bus27	-4.667	-2.892	148.2	85.0	0.625
Bus29	11.000	194.375	-36.0	0	0	4.667	2.892	Bus27	-4.667	-2.892	148.2	85.0	0.625
Bus30	66.000	193.341	-35.5	0	0	0	0	Bus1	-17.399	-11.343	94.0	83.8	
								Bus32	17.399	11.343	94.0	83.8	
Bus31	66.000	98.594	-27.7	0	0	0	0	Bus2	-5.019	-3.290	53.2	83.6	
								Bus33	5.019	3.290	53.2	83.6	
Bus32	11.000	197.370	-36.8	0	0	17.370	10.767	Bus30	-17.370	-10.767	543.5	85.0	3.750
Bus33	11.000	100.463	-29.1	0	0	5.009	3.105	Bus31	-5.009	-3.105	307.9	85.0	3.750
U1	220.000	291.912	0.0	74.714	79.386	0	0	Bus3	74.714	79.386	98.0	68.5	
U2	220.000	100.000	0.0	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
U3	220.000	162.988	0.0	18.099	24.547	0	0	Bus5	18.099	24.547	49.1	59.3	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# indicates a bus with a load mismatch of more than 0.1 MVA

LOAD FLOW REPORT (Without PV) @ T = 1.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus1	66.000	0.000	90.0	0	0	0	0	Bus13	0.000	0.000	0.0	0.0	
								Bus27	0.000	0.000	0.0	0.0	
								Bus8	0.000	0.000	0.0	0.0	
								Bus8	0.000	0.000	0.0	0.0	
								Bus30	0.000	0.000	0.0	0.0	
								Bus3	0.000	0.000	521.2	0.0	3.750
								Bus6	0.000	0.000	0.0	0.0	
Bus2	66.000	0.000	90.0	0	0	0	0	Bus14	0.000	0.000	0.0	0.0	
								Bus18	0.000	0.000	0.0	0.0	
								Bus7	0.000	0.000	0.0	0.0	
								Bus7	0.000	0.000	0.0	0.0	
								Bus31	0.000	0.000	0.0	0.0	
								Bus5	0.000	0.000	0.0	0.0	0.625
Bus3	220.000	12.264	4.3	0	0	0	0	Bus1	0.168	7.579	162.2	2.2	
								U1	-0.168	-7.579	162.2	2.2	
Bus4	220.000	100.000	0.0	0	0	0	0	U2	0.000	0.000	0.0	0.0	
Bus5	220.000	0.000	90.0	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								U3	0.000	0.000	94.5	0.0	
Bus6	11.000	0.000	90.0	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
Bus7	66.000	0.000	90.0	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus2	0.000	0.000	0.0	0.0	
								Bus9	0.000	0.000	0.0	0.0	
Bus8	66.000	0.000	90.0	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus1	0.000	0.000	0.0	0.0	
								Bus10	0.000	0.000	0.0	0.0	
Bus9	11.000	0.000	90.0	0	0	0	0	Bus7	0.000	0.000	0.0	0.0	
Bus10	11.000	0.000	90.0	0	0	0	0	Bus8	0.000	0.000	0.0	0.0	1.250
Bus13	66.000	0.000	90.0	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus15	0.000	0.000	0.0	0.0	
Bus14	66.000	0.000	90.0	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus16	0.000	0.000	0.0	0.0	
Bus15	11.000	0.000	90.0	0	0	0	0	Bus13	0.000	0.000	0.0	0.0	4.375
Bus16	11.000	0.000	90.0	0	0	0	0	Bus14	0.000	0.000	0.0	0.0	4.375
Bus17	66.000	0.000	90.0	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	
								Bus21	0.000	0.000	0.0	0.0	
								Bus23	0.000	0.000	0.0	0.0	
								Bus19	0.000	0.000	0.0	0.0	

LOAD FLOW REPORT (Without PV) @ T = 1.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus18	66.000	0.000	90.0	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus20	0.000	0.000	0.0	0.0	
Bus19	11.000	0.000	90.0	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
Bus20	11.000	0.000	90.0	0	0	0	0	Bus18	0.000	0.000	0.0	0.0	
Bus21	66.000	0.000	90.0	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
								Bus23	0.000	0.000	0.0	0.0	
								Bus22	0.000	0.000	0.0	0.0	
Bus22	11.000	0.000	90.0	0	0	0	0	Bus21	0.000	0.000	0.0	0.0	
Bus23	66.000	0.000	90.0	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
								Bus21	0.000	0.000	0.0	0.0	
								Bus25	0.000	0.000	0.0	0.0	
Bus25	11.000	0.000	90.0	0	0	0	0	Bus23	0.000	0.000	0.0	0.0	
Bus27	66.000	0.000	90.0	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
								Bus1	0.000	0.000	0.0	0.0	
								Bus28	0.000	0.000	0.0	0.0	
								Bus29	0.000	0.000	0.0	0.0	
Bus28	11.000	0.000	90.0	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	0.625
Bus29	11.000	0.000	90.0	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	0.625
Bus30	66.000	0.000	90.0	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus32	0.000	0.000	0.0	0.0	
Bus31	66.000	0.000	90.0	0	0	0	0	Bus2	0.000	0.000	0.0	0.0	
								Bus33	0.000	0.000	0.0	0.0	
Bus32	11.000	0.000	90.0	0	0	0	0	Bus30	0.000	0.000	0.0	0.0	3.750
Bus33	11.000	0.000	90.0	0	0	0	0	Bus31	0.000	0.000	0.0	0.0	3.750
U1	220.000	291.912	0.0	17.371	179.600	0	0	Bus3	17.371	179.600	162.2	9.6	
U2	220.000	100.000	0.0	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
U3	220.000	162.988	0.0	5.842	58.420	0	0	Bus5	5.842	58.420	94.5	10.0	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# indicates a bus with a load mismatch of more than 0.1 MVA

Dynamic Stability

The tabulated plot data is not printed since the option of "Skip Tabulated Plots" is checked.
To print tabulated plot data go to the Transient Stability Study Case Editor and in the Info Page uncheck the "Skip Tabulated Plots" option.

System Islanding Index

Time (Sec.)	Element ID	Type	Zone No.
0.000	Bus1	Bus	2
0.000	Bus10	Bus	2
0.000	Bus13	Bus	2
0.000	Bus14	Bus	1
0.000	Bus15	Bus	2
0.000	Bus16	Bus	1
0.000	Bus17	Bus	2
0.000	Bus18	Bus	1
0.000	Bus19	Bus	2
0.000	Bus2	Bus	1
0.000	Bus20	Bus	1
0.000	Bus21	Bus	2
0.000	Bus22	Bus	2
0.000	Bus23	Bus	2
0.000	Bus25	Bus	2
0.000	Bus27	Bus	2
0.000	Bus28	Bus	2
0.000	Bus29	Bus	2
0.000	Bus3	Bus	2
0.000	Bus30	Bus	2
0.000	Bus31	Bus	1
0.000	Bus32	Bus	2
0.000	Bus33	Bus	1
0.000	Bus4	Bus	3
0.000	Bus5	Bus	1
0.000	Bus6	Bus	2
0.000	Bus7	Bus	1
0.000	Bus8	Bus	2
0.000	Bus9	Bus	1
0.000	U1	Power Grid (Ref.)	2
0.000	U2	Power Grid (Ref.)	3
0.000	U3	Power Grid (Ref.)	1

Action Summary

Event ID	Time (Sec.)	Device Type	Device ID	Action
event2	0.800	Bus	Bus1	3 Phase Fault
event2	0.800	Bus	Bus5	3 Phase Fault

APPENDIX 13

TRANSIENT STABILITY ANALYSIS WITH PV

Project:	MASTER THESIS	ETAP	Page:	1
Location:	HOUN CITY - LIBYA	12.6.0H	Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department		SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case: TS	Revision:	Base
Filename:	HOUN SUBSTATION 220kV		Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Electrical Transient Analyzer Program

Transient Stability Analysis (With PV)

Initial Loading Category (1): Design

Initial Generation Category (1): Design

Load Diversity Factor: None

	Swing	V-Control	Load	Total
Number of Buses:	3	7	32	42

	XFMR2	XFMR3	Reactor	Line/Cable	Impedance	Tie PD	SPDT	Total
Number of Branches:	26	0	0	16	0	10	0	52

	Synchronous Generator	Power Grid	Synchronous Motor	Induction Machines	Lumped Load	Total
Number of Machines:	0	3	0	0	14	17

Method of the Initial LF Solution:	Adaptive Newton-Raphson
Maximum Number of Iterations:	1000
Solution Precision for the Initial LF:	0.0001000000
Acceleration Factor for the Initial LF:	0.00
Time Increment for Integration Steps (Δt):	0.0010
Time Increment for Plots:	20 times Δt
System Frequency:	50.00 Hz
Frequency Dependent Models for Machines and Network are Not Used	
Unit System:	Metric

Adjustments

Tolerance	Apply Adjustments	Individual /Global	Percent
Transformer Impedance:	Yes	Individual	
Reactor Impedance:	Yes	Individual	
Overload Heater Resistance:	No		
Transmission Line Length:	No		
Cable Length:	No		

Temperature Correction	Apply Adjustments	Individual /Global	Degree C
Transmission Line Resistance:	Yes	Individual	
Cable Resistance:	Yes	Individual	

Bus Input Data

Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus1	66.000	1	99.4	-4.2								
Bus2	66.000	1	99.1	-1.2								
Bus3	220.000	1	100.0	0.0								
Bus4	220.000	1	100.0	0.0								
Bus5	220.000	1	100.0	0.0								
Bus6	11.000	1	98.3	-4.2	0.000	0.995	0.000	0.249				
Bus7	66.000	1	99.0	-1.2								
Bus8	66.000	1	99.3	-4.3								
Bus9	11.000	1	98.4	-1.8	1.600	0.992	0.400	0.248				
Bus10	11.000	1	98.0	-6.3	5.600	3.471	1.400	0.868				
Bus11	66.000	1	99.1	-1.2								
Bus12	66.000	1	99.4	-4.2								
Bus13	66.000	1	98.6	-4.7								
Bus14	66.000	1	98.2	-1.7								
Bus15	11.000	1	99.0	-7.6	4.800	2.975	1.200	0.744				
Bus16	11.000	1	98.6	-4.7	4.800	2.975	1.200	0.744				
Bus17	66.000	1	99.2	-5.9								
Bus18	66.000	1	99.0	-1.6								
Bus19	11.000	1	99.0	-7.5	4.400	0.000	1.100	0.000				
Bus20	11.000	1	98.9	-2.6	2.800	0.000	0.700	0.000				
Bus21	66.000	1	99.2	-6.5								
Bus22	11.000	1	98.7	-9.4	4.800	0.000	1.200	0.000				
Bus23	66.000	1	99.5	-6.9								
Bus24	66.000	1	100.0	0.0								
Bus25	11.000	1	98.4	-7.9	1.600	0.991	0.400	0.248				
Bus26	11.000	1	100.0	0.0	4.000	2.479	1.000	0.620				
Bus27	66.000	1	99.1	-4.9								
Bus28	11.000	1	98.7	-5.8	2.400	1.487	0.600	0.372				
Bus29	11.000	1	98.7	-5.8	2.400	1.487	0.600	0.372				
Bus30	66.000	1	98.8	-4.6								
Bus31	66.000	1	98.8	-1.4								
Bus32	11.000	1	98.3	-7.8	8.800	5.455	2.200	1.364				
Bus33	11.000	1	100.7	-2.8	4.000	2.479	1.000	0.620				
Bus34	0.400	1	100.0	1.1								

Project:	MASTER THESIS	ETAP	Page:	4
Location:	HOUN CITY - LIBYA	12.6.0H	Date:	28-06-2016
Contract:	NEAR EAST UNIVERSITY - EEE Department		SN:	
Engineer:	SAND MUSTAFA AL-REFAI	Study Case: TS	Revision:	Base
Filename:	HOUN SUBSTATION 220kV		Config:	Normal

DESIGN OF A LARGE SCALE SOLAR PV SYSTEM AND IMPACT ANALYSIS OF ITS INTEGRATION INTO LIBYAN POWER GRID

Bus			Initial Voltage		Load							
					Constant kVA		Constant Z		Constant I		Generic	
ID	kV	Sub-sys	% Mag.	Ang.	MW	Mvar	MW	Mvar	MW	Mvar	MW	Mvar
Bus35	0.400	1	100.0	1.1								
Bus36	0.400	1	100.0	1.1								
Bus37	0.400	1	100.0	1.1								
Bus38	0.400	1	100.0	3.3								
Bus39	0.400	1	100.0	3.3								
Bus40	0.400	1	100.0	3.3								
Bus41	11.000	1	98.9	-1.2								
Bus42	11.000	1	98.6	1.0								
Total Number of Buses: 42					51.999	25.785	13.000	6.446	0.000	0.000	0.000	0.000

Note: Dynamically modeled motor loads are not included in the bus motor load. See machine and motor pages for detail.

Generation Bus				Voltage		Generation			Mvar Limits	
ID	kV	Type	Sub-sys	% Mag.	Angle	MW	Mvar	% PF	Max	Min
Bus3	220.000	Swing	1	100.0	0.0					
Bus4	220.000	Swing	1	100.0	0.0					
Bus5	220.000	Swing	1	100.0	0.0					
Bus34	0.400	Voltage Control	1	100.0	1.1	1.960			0.899	0.000
Bus35	0.400	Voltage Control	1	100.0	1.1	1.960			0.899	0.000
Bus36	0.400	Voltage Control	1	100.0	1.1	1.960			0.899	0.000
Bus37	0.400	Voltage Control	1	100.0	1.1	1.960			0.899	0.000
Bus38	0.400	Voltage Control	1	100.0	3.3	1.960			0.899	0.000
Bus39	0.400	Voltage Control	1	100.0	3.3	1.960			0.899	0.000
Bus40	0.400	Voltage Control	1	100.0	3.3	1.960			0.899	0.000
						13.719	0.000			

Line/Cable Input Data

Line/Cable			Length				Ohms or Siemens per 1000 m per Conductor (Cable) or per Phase (Line)					
ID	Library	Size	Adj. (m)	% Tol.	#/Phase	T (°C)	R1	X1	Y1	R0	X0	Y0
Cable1	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646	0.240351	0.215000	
Cable2	11MCUS3	300	100.0	0.0	1	75	0.076302	0.087400	0.0001646	0.240351	0.215000	
Line1		674	19300.0	0.0	1	75	0.056003	0.374255	0.0000031	0.200077	1.360791	0.0000017
Line2		674	19300.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line3		674	23000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line4		674	15000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line5		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line6		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line7		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line8		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line9		674	4000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line10		674	3000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line11		674	8000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line12		674	21000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line13		674	161000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016
Line14		674	140000.0	0.0	1	75	0.056001	0.342069	0.0000034	0.200637	1.424041	0.0000016

Line / Cable resistances are listed at the specified temperatures.

2-Winding Transformer Input Data

Transformer	Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	MVA	Prim. kV	Sec. kV	% Z	X/R	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
T1	63.000	220.000	66.000	12.50	45.00	0	0	0	0	3.750	12.5000	Dyn	0.000
T2	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0.625	12.5000	Dyn	0.000
T3	63.000	220.000	66.000	12.50	45.00	0	0	0	0	0.625	12.5000	Dyn	0.000
T4	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T5	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T6	20.000	66.000	11.000	10.00	20.00	0	0	0	0	1.250	10.0000	Dyn	0.000
T7	12.500	11.000	66.000	8.35	13.00	0	0	0	-1.250	0	8.3500	YNd	0.000
T8	12.500	11.000	66.000	8.35	13.00	0	0	0	-1.250	0	8.3500	YNd	0.000
T9	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500	Dyn	0.000
T10	10.000	66.000	11.000	8.35	13.00	0	0	0	0	4.375	8.3500	Dyn	0.000
T11	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T12	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0	10.0000	Dyn	0.000
T13	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T14	10.000	66.000	11.000	8.35	13.00	0	0	0	0	0	8.3500	Dyn	0.000
T15	10.000	66.000	11.000	8.35	13.00	0	0	0	0	3.750	8.3500	Dyn	0.000
T16	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000	Dyn	0.000
T17	20.000	66.000	11.000	10.00	20.00	0	0	0	0	0.625	10.0000	Dyn	0.000
T18	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000	Dyn	0.000
T19	20.000	66.000	11.000	10.00	20.00	0	0	0	0	3.750	10.0000	Dyn	0.000
T20	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T21	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T22	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T23	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T24	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T25	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000
T26	3.000	0.400	11.000	6.25	6.00	0	0	0	0	0	6.2500	YNd	0.000

2-Winding Transformer Grounding Input Data

Transformer	Rating			Grounding								
				Conn.	Primary				Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T1	63.000	220.000	66.000	D/Y					Solid			
T2	63.000	220.000	66.000	D/Y					Solid			

2-Winding Transformer Grounding Input Data

Transformer	Rating			Conn.	Grounding: Primary				Grounding: Secondary			
ID	MVA	Prim. kV	Sec. kV	Type	Type	kV	Amp	Ohm	Type	kV	Amp	Ohm
T3	63.000	220.000	66.000	D/Y					Solid			
T4	10.000	66.000	11.000	D/Y					Solid			
T5	20.000	66.000	11.000	D/Y					Solid			
T6	20.000	66.000	11.000	D/Y					Solid			
T7	12.500	11.000	66.000	D/Y					Solid			
T8	12.500	11.000	66.000	D/Y					Solid			
T9	10.000	66.000	11.000	D/Y					Solid			
T10	10.000	66.000	11.000	D/Y					Solid			
T11	20.000	66.000	11.000	D/Y					Solid			
T12	20.000	66.000	11.000	D/Y					Solid			
T13	10.000	66.000	11.000	D/Y					Solid			
T14	10.000	66.000	11.000	D/Y					Solid			
T15	10.000	66.000	11.000	D/Y					Solid			
T16	20.000	66.000	11.000	D/Y					Solid			
T17	20.000	66.000	11.000	D/Y					Solid			
T18	20.000	66.000	11.000	D/Y					Solid			
T19	20.000	66.000	11.000	D/Y					Solid			
T20	3.000	0.400	11.000	D/Y					Solid			
T21	3.000	0.400	11.000	D/Y					Solid			
T22	3.000	0.400	11.000	D/Y					Solid			
T23	3.000	0.400	11.000	D/Y					Solid			
T24	3.000	0.400	11.000	D/Y					Solid			
T25	3.000	0.400	11.000	D/Y					Solid			
T26	3.000	0.400	11.000	D/Y					Solid			

Branch Connections

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
ID	Type	From Bus	To Bus	R	X	Z	Y
T1	2W XFMR	Bus3	Bus1	0.46	20.58	20.59	
T2	2W XFMR	Bus4	Bus1	0.44	19.96	19.97	
T3	2W XFMR	Bus5	Bus2	0.44	19.96	19.97	
T4	2W XFMR	Bus1	Bus6	6.40	83.25	83.50	
T5	2W XFMR	Bus7	Bus9	2.50	49.94	50.00	
T6	2W XFMR	Bus8	Bus10	2.53	50.56	50.63	
T7	2W XFMR	Bus42	Bus11	5.06	65.77	65.97	
T8	2W XFMR	Bus41	Bus12	5.06	65.77	65.97	
T9	2W XFMR	Bus13	Bus15	6.68	86.90	87.15	
T10	2W XFMR	Bus14	Bus16	6.68	86.90	87.15	
T11	2W XFMR	Bus17	Bus19	2.50	49.94	50.00	
T12	2W XFMR	Bus18	Bus20	2.50	49.94	50.00	
T13	2W XFMR	Bus21	Bus22	6.40	83.25	83.50	
T14	2W XFMR	Bus23	Bus25	6.40	83.25	83.50	
T15	2W XFMR	Bus24	Bus26	6.64	86.38	86.63	
T16	2W XFMR	Bus27	Bus28	2.51	50.25	50.31	
T17	2W XFMR	Bus27	Bus29	2.51	50.25	50.31	
T18	2W XFMR	Bus30	Bus32	2.59	51.81	51.88	
T19	2W XFMR	Bus31	Bus33	2.59	51.81	51.88	
T20	2W XFMR	Bus34	Bus41	34.25	205.50	208.33	
T21	2W XFMR	Bus35	Bus41	34.25	205.50	208.33	
T22	2W XFMR	Bus36	Bus41	34.25	205.50	208.33	
T23	2W XFMR	Bus37	Bus41	34.25	205.50	208.33	
T24	2W XFMR	Bus38	Bus42	34.25	205.50	208.33	
T25	2W XFMR	Bus39	Bus42	34.25	205.50	208.33	
T26	2W XFMR	Bus40	Bus42	34.25	205.50	208.35	
Cable1	Cable	Bus11	Bus2	0.02	0.02	0.03	0.0716998
Cable2	Cable	Bus12	Bus1	0.02	0.02	0.03	0.0716998
Line1	Line	Bus2	Bus14	2.48	16.58	16.77	0.2607629
Line2	Line	Bus1	Bus13	2.48	15.16	15.36	0.2842267
Line3	Line	Bus2	Bus18	2.96	18.06	18.30	0.3387157
Line4	Line	Bus27	Bus17	1.93	11.78	11.94	0.2209015
Line5	Line	Bus1	Bus27	1.03	6.28	6.37	0.1178142
Line6	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line7	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071
Line8	Line	Bus2	Bus7	0.51	3.14	3.18	0.0589071
Line9	Line	Bus1	Bus8	0.51	3.14	3.18	0.0589071

CKT/Branch		Connected Bus ID		% Impedance, Pos. Seq., 100 MVA Base			
ID	Type	From Bus	To Bus	R	X	Z	Y
Line10	Line	Bus2	Bus31	1.03	6.28	6.37	0.1178142
Line11	Line	Bus1	Bus30	1.03	6.28	6.37	0.1178142
Line12	Line	Bus17	Bus21	2.70	16.49	16.71	0.3092622
Line13	Line	Bus17	Bus23	20.70	126.43	128.11	2.3710100
Line14	Line	Bus21	Bus23	18.00	109.94	111.40	2.0617480
SW1	Tie Switch	Bus1	Bus2				
SW2	Tie Switch	Bus7	Bus8				
SW3	Tie Switch	Bus13	Bus14				
SW4	Tie Switch	Bus17	Bus18				
SW5	Tie Switch	Bus23	Bus24				
SW6	Tie Switch	Bus25	Bus26				
SW7	Tie Switch	Bus28	Bus29				
SW8	Tie Switch	Bus30	Bus31				
SW9	Tie Switch	Bus32	Bus33				
SW10	Tie Switch	Bus41	Bus42				

Branch Connections
Zero Sequence Impedance

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
T1	2W XFMR	Bus3	Bus1				
T2	2W XFMR	Bus4	Bus1				
T3	2W XFMR	Bus5	Bus2				
T4	2W XFMR	Bus1	Bus6				
T5	2W XFMR	Bus7	Bus9				
T6	2W XFMR	Bus8	Bus10				
T7	2W XFMR	Bus42	Bus11				
T8	2W XFMR	Bus41	Bus12				
T9	2W XFMR	Bus13	Bus15				
T10	2W XFMR	Bus14	Bus16				
T11	2W XFMR	Bus17	Bus19				
T12	2W XFMR	Bus18	Bus20				
T13	2W XFMR	Bus21	Bus22				
T14	2W XFMR	Bus23	Bus25				
T15	2W XFMR	Bus24	Bus26				
T16	2W XFMR	Bus27	Bus28				
T17	2W XFMR	Bus27	Bus29				
T18	2W XFMR	Bus30	Bus32				
T19	2W XFMR	Bus31	Bus33				
T20	2W XFMR	Bus34	Bus41				
T21	2W XFMR	Bus35	Bus41				
T22	2W XFMR	Bus36	Bus41				
T23	2W XFMR	Bus37	Bus41				
T24	2W XFMR	Bus38	Bus42				
T25	2W XFMR	Bus39	Bus42				
T26	2W XFMR	Bus40	Bus42				
Cable1	Cable	Bus11	Bus2				
Cable2	Cable	Bus12	Bus1				
Line1	Line	Bus2	Bus14				0.1410145
Line2	Line	Bus1	Bus13				0.1341983
Line3	Line	Bus2	Bus18				0.1599255
Line4	Line	Bus27	Bus17				0.1042992
Line5	Line	Bus1	Bus27				0.0556263
Line6	Line	Bus2	Bus7				0.0278131
Line7	Line	Bus1	Bus8				0.0278131

CKT/Branch		Connected Bus ID		% Impedance, Zero Seq., 100 MVAb			
ID	Type	From Bus	To Bus	R0	X0	Z0	Y0
Line8	Line	Bus2	Bus7				0.0278131
Line9	Line	Bus1	Bus8				0.0278131
Line10	Line	Bus2	Bus31				0.0556263
Line11	Line	Bus1	Bus30				0.0556263
Line12	Line	Bus17	Bus21				0.1460189
Line13	Line	Bus17	Bus23				1.1194780
Line14	Line	Bus21	Bus23				0.9734595
SW1	Tie Switch	Bus1	Bus2				
SW2	Tie Switch	Bus7	Bus8				
SW3	Tie Switch	Bus13	Bus14				
SW4	Tie Switch	Bus17	Bus18				
SW5	Tie Switch	Bus23	Bus24				
SW6	Tie Switch	Bus25	Bus26				
SW7	Tie Switch	Bus28	Bus29				
SW8	Tie Switch	Bus30	Bus31				
SW9	Tie Switch	Bus32	Bus33				
SW10	Tie Switch	Bus41	Bus42				

Synchronous Machine Parameters

Machine			Rating		Positive Sequence Impedance (%)								Zero Seq. Z (%)		
ID	Type	Model	MVA	kV	Ra	Xd"	Xd'	Xd	Xq"	Xq'	Xq	Xl	X/R	R0	X0
U1	Power Grid	N/A	22.101	220.000	9.95		99.50							35.65	356.48
U2	Power Grid	N/A	22.101	220.000	9.95		99.50							17.74	177.38
U3	Power Grid	N/A	22.101	220.000	9.95		99.50							17.74	177.38

Machine	Connected Bus	Time Constants (Sec.)				H (Sec.), D (MWpu/Hz) & Saturati					Generator or Loading		Grounding		
ID	ID	Tdo"	Tdo'	Tqo"	Tqo'	H	%D	S100	S120	Sbreak	MW	Mvar	Conn.	Type	Amp

Machine		Generator/Motor			Coupling			Prime Mover/Load			Equivalent Total		
ID	Type	RPM	WR²	H	RPM	WR²	H	RPM	WR²	H	RPM	WR²	H

WR²: kg-m²　　　H: MW-Sec/MVA

Machine		Shaft Torsion			
ID	Type	D1	D2	K1	K2

D1, D2: MW (pu)/Speed (pu)　　　K1, K2: MW (pu)/Radians

Lumped Load Input Data

Conventional Type

ID	kV	kVA	kW	kvar	% PF	Amp	Load		Ta	Gamma
							% Motor	% Static		
Lump1	11.000	1243	0	1243	0.01	65.3	80	20	0	0
Lump10	11.000	5882	5000	3098	85.000	308.7	80	20	0	0
Lump11	11.000	3529	3000	1859	85	185.2	80	20	0	0
Lump12	11.000	3529	3000	1859	85	185.2	80	20	0	0
Lump13	11.000	12942	11000	6818	85.000	679.3	80	20	0	0
Lump14	11.000	5883	5000	3099	85.000	308.8	80	20	0	0
Lump2	11.000	2353	2000	1240	85	123.5	80	20	0	0
Lump3	11.000	8236	7000	4339	85.000	432.3	80	20	0	0
Lump4	11.000	7058	6000	3718	85	370.5	80	20	0	0
Lump5	11.000	7058	6000	3718	85	370.5	80	20	0	0
Lump6	11.000	5500	5500	0	100	288.7	80	20	0	0
Lump7	11.000	3500	3500	0	100	183.7	80	20	0	0
Lump8	11.000	6000	6000	0	100	314.9	80	20	0	0
Lump9	11.000	2352	2000	1239	85	123.5	80	20	0	0

LOAD FLOW REPORT (With PV) @ T = 0.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus1	66.000	99.388	-39.5	0	0	0	0	Bus12	-7.754	-0.376	68.3	99.9	
								Bus13	6.024	3.964	63.5	83.5	
								Bus27	19.539	1.129	172.3	99.8	
								Bus8	3.483	2.278	36.6	83.7	
								Bus8	3.483	2.278	36.6	83.7	
								Bus30	10.992	7.691	118.1	81.9	
								Bus3	-35.767	-18.211	353.3	89.1	3.750
								Bus6	0.001	1.248	11.0	0.1	
Bus2	66.000	99.061	-19.0	0	0	0	0	Bus11	-5.821	-0.725	51.8	99.2	
								Bus14	6.014	3.993	63.7	83.3	
								Bus18	3.491	-0.248	30.9	-99.7	
								Bus7	0.994	0.573	10.1	86.7	
								Bus7	0.994	0.573	10.1	86.7	
								Bus31	5.027	3.200	52.6	84.4	
								Bus5	-10.700	-7.365	114.7	82.4	0.625
* Bus3	220.000	100.000	-35.3	0	0	0	0	Bus1	35.844	21.694	110.0	85.6	
								U1	-35.844	-21.694	110.0	85.6	
* Bus4	220.000	100.000	0.0	0	0	0	0	U2	0.000	0.000	0.0	0.0	
* Bus5	220.000	100.000	-17.8	0	0	0	0	Bus2	10.708	7.711	34.6	81.1	
								U3	-10.708	-7.711	34.6	81.1	
Bus6	11.000	98.343	-39.5	0	0	0.000	1.235	Bus1	0.000	-1.235	65.9	0.0	
Bus7	66.000	99.036	-19.0	0	0	0	0	Bus2	-0.994	-0.630	10.4	84.5	
								Bus2	-0.994	-0.630	10.4	84.5	
								Bus9	1.989	1.260	20.8	84.5	
Bus8	66.000	99.297	-39.6	0	0	0	0	Bus1	-3.482	-2.330	36.9	83.1	
								Bus1	-3.482	-2.330	36.9	83.1	
								Bus10	6.964	4.661	73.8	83.1	
Bus9	11.000	98.356	-19.6	0	0	1.987	1.232	Bus7	-1.987	-1.232	124.8	85.0	
Bus10	11.000	98.048	-41.6	0	0	6.946	4.305	Bus8	-6.946	-4.305	437.5	85.0	1.250
Bus11	66.000	99.062	-19.0	0	0	0	0	Bus2	5.821	0.654	51.7	99.4	
								Bus42	-5.821	-0.654	51.7	99.4	
Bus12	66.000	99.390	-39.5	0	0	0	0	Bus1	7.754	0.306	68.3	99.9	
								Bus41	-7.754	-0.306	68.3	99.9	
Bus13	66.000	98.615	-40.0	0	0	0	0	Bus1	-6.011	-4.161	64.8	82.2	
								Bus15	6.011	4.161	64.8	82.2	
Bus14	66.000	98.224	-19.5	0	0	0	0	Bus2	-6.001	-4.157	65.0	82.2	
								Bus16	6.001	4.157	65.0	82.2	

LOAD FLOW REPORT (With PV) @ T = 0.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus15	11.000	98.983	-42.9	0	0	5.975	3.703	Bus13	-5.975	-3.703	372.8	85.0	4.375
Bus16	11.000	98.564	-22.4	0	0	5.965	3.697	Bus14	-5.965	-3.697	373.7	85.0	4.375
Bus17	66.000	99.192	-41.2	0	0	0	0	Bus27	-13.487	2.837	121.5	-97.9	
								Bus21	6.609	-1.333	59.5	-98.0	
								Bus23	1.391	-1.657	19.1	-64.3	
								Bus19	5.486	0.153	48.4	100.0	
Bus18	66.000	98.973	-19.4	0	0	0	0	Bus2	-3.487	-0.062	30.8	100.0	
								Bus20	3.487	0.062	30.8	100.0	
Bus19	11.000	99.016	-42.8	0	0	5.478	0.000	Bus17	-5.478	0.000	290.4	100.0	
Bus20	11.000	98.870	-20.4	0	0	3.484	0.000	Bus18	-3.484	0.000	185.0	100.0	
Bus21	66.000	99.215	-41.9	0	0	0	0	Bus17	-6.597	1.104	59.0	-98.6	
								Bus23	0.604	-1.409	13.5	-39.4	
								Bus22	5.992	0.304	52.9	99.9	
Bus22	11.000	98.700	-44.8	0	0	5.969	0.000	Bus21	-5.969	0.000	317.4	100.0	
Bus23	66.000	99.545	-42.3	0	0	0	0	Bus17	-1.387	-0.656	13.5	90.4	
								Bus21	-0.603	-0.622	7.6	69.6	
								Bus25	1.990	1.278	20.8	84.1	
Bus25	11.000	98.360	-43.2	0	0	1.987	1.231	Bus23	-1.987	-1.231	124.7	85.0	
Bus27	66.000	99.119	-40.2	0	0	0	0	Bus17	13.524	-2.826	121.9	-97.9	
								Bus1	-19.499	-1.001	172.3	99.9	
								Bus28	2.988	1.914	51.3	84.2	
								Bus29	2.988	1.914	31.3	84.2	
Bus28	11.000	98.703	-41.1	0	0	2.984	1.850	Bus27	-2.984	-1.850	186.7	85.0	0.625
Bus29	11.000	98.703	-41.1	0	0	2.984	1.850	Bus27	-2.984	-1.850	186.7	85.0	0.625
Bus30	66.000	98.787	-39.9	0	0	0	0	Bus1	-10.973	-7.692	118.7	81.9	
								Bus32	10.973	7.692	118.7	81.9	
Bus31	66.000	98.802	-19.2	0	0	0	0	Bus2	-5.023	-3.292	53.2	83.6	
								Bus33	5.023	3.292	53.2	83.6	
Bus32	11.000	98.326	-43.1	0	0	10.927	6.773	Bus30	-10.927	-6.773	686.2	85.0	3.750
Bus33	11.000	100.682	-20.6	0	0	5.014	3.108	Bus31	-5.014	-3.108	307.5	85.0	3.750
* Bus34	0.400	100.000	-34.3	0	0	0	0	Bus41	1.960	0.258	2853.2	99.1	
								Inv2	-0.980	-0.129	1426.6	99.1	
								Inv4	-0.980	-0.129	1426.6	99.1	
* Bus35	0.400	100.000	-34.3	0	0	0	0	Bus41	1.960	0.258	2853.2	99.1	
								Inv8	-0.980	-0.129	1426.6	99.1	
								Inv7	-0.980	-0.129	1426.6	99.1	
* Bus36	0.400	100.000	-34.3	0	0	0	0	Bus41	1.960	0.258	2853.2	99.1	

LOAD FLOW REPORT (With PV) @ T = 0.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
								Inv10	-0.980	-0.129	1426.6	99.1	
								Inv9	-0.980	-0.129	1426.6	99.1	
* Bus37	0.400	100.000	-34.3	0	0	0	0	Bus41	1.960	0.258	2853.2	99.1	
								Inv12	-0.980	-0.129	1426.6	99.1	
								Inv91	-0.980	-0.129	1426.6	99.1	
* Bus38	0.400	100.000	-14.5	0	0	0	0	Bus42	1.960	0.378	2880.8	98.2	
								Inv90	-0.980	-0.189	1440.4	98.2	
								Inv89	-0.980	-0.189	1440.4	98.2	
* Bus39	0.400	100.000	-14.5	0	0	0	0	Bus42	1.960	0.378	2880.8	98.2	
								Inv87	-0.980	-0.189	1440.4	98.2	
								Inv86	-0.980	-0.189	1440.4	98.2	
* Bus40	0.400	100.000	-14.5	0	0	0	0	Bus42	1.960	0.378	2880.8	98.2	
								Inv102	-0.980	-0.189	1440.4	98.2	
								Inv14	-0.980	-0.189	1440.4	98.2	
Bus41	11.000	98.877	-36.6	0	0	0	0	Bus12	7.786	0.712	415.0	99.6	-1.250
								Bus34	-1.946	-0.178	103.8	99.6	
								Bus35	-1.946	-0.178	103.8	99.6	
								Bus36	-1.946	-0.178	103.8	99.6	
								Bus37	-1.946	-0.178	103.8	99.6	
Bus42	11.000	98.630	-16.8	0	0	0	0	Bus11	5.838	0.887	314.3	98.9	-1.250
								Bus38	-1.946	-0.296	104.8	98.9	
								Bus39	-1.946	-0.296	104.8	98.9	
								Bus40	-1.946	-0.296	104.8	98.9	
U1	220.000	262.107	0.0	43.747	100.727	0	0	Bus3	43.747	100.727	110.0	39.8	
U2	220.000	100.000	0.0	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
U3	220.000	146.534	0.0	11.492	15.550	0	0	Bus5	11.492	15.550	34.6	59.4	
Inv2	0.400	160.800	-37.1	1.584	0.129	0	0	Bus34	1.584	0.129	1426.6	99.7	
Inv4	0.400	160.800	-37.1	1.584	0.129	0	0	Bus34	1.584	0.129	1426.6	99.7	
Inv8	0.400	160.800	-37.1	1.584	0.129	0	0	Bus35	1.584	0.129	1426.6	99.7	
Inv7	0.400	160.800	-37.1	1.584	0.129	0	0	Bus35	1.584	0.129	1426.6	99.7	
Inv10	0.400	160.800	-37.1	1.584	0.129	0	0	Bus36	1.584	0.129	1426.6	99.7	
Inv9	0.400	160.800	-37.1	1.584	0.129	0	0	Bus36	1.584	0.129	1426.6	99.7	
Inv12	0.400	160.800	-37.1	1.584	0.129	0	0	Bus37	1.584	0.129	1426.6	99.7	
Inv91	0.400	160.800	-37.1	1.584	0.129	0	0	Bus37	1.584	0.129	1426.6	99.7	
Inv90	0.400	161.026	-18.7	1.596	0.189	0	0	Bus38	1.596	0.189	1440.4	99.3	
Inv89	0.400	161.026	-18.7	1.596	0.189	0	0	Bus38	1.596	0.189	1440.4	99.3	
Inv87	0.400	161.026	-18.7	1.596	0.189	0	0	Bus39	1.596	0.189	1440.4	99.3	

LOAD FLOW REPORT (With PV) @ T = 0.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Inv86	0.400	161.026	-18.7	1.596	0.189	0	0	Bus39	1.596	0.189	1440.4	99.3	
Inv102	0.400	161.026	-18.7	1.596	0.189	0	0	Bus40	1.596	0.189	1440.4	99.3	
Inv14	0.400	161.026	-18.7	1.596	0.189	0	0	Bus40	1.596	0.189	1440.4	99.3	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# indicates a bus with a load mismatch of more than 0.1 MVA

LOAD FLOW REPORT (With PV) @ T = 0.800-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus1	66.000	136.647	-38.2	0	0	0	0	Bus12	-4.409	-0.283	28.5	99.8	
								Bus13	7.142	4.264	53.2	85.9	
								Bus27	23.005	-2.852	148.4	-99.2	
								Bus8	4.105	2.563	31.0	84.8	
								Bus8	4.105	2.563	31.0	84.8	
								Bus30	13.023	8.567	99.8	83.5	
								Bus3	-46.971	-16.283	318.2	94.5	3.750
								Bus6	0.001	1.462	9.4	0.1	
Bus2	66.000	99.061	-19.0	0	0	0	0	Bus11	-5.821	-0.725	51.8	99.2	
								Bus14	6.014	3.993	63.7	83.3	
								Bus18	3.491	-0.248	30.9	-99.7	
								Bus7	0.994	0.573	10.1	86.7	
								Bus7	0.994	0.573	10.1	86.7	
								Bus31	5.027	3.200	52.6	84.4	
								Bus5	-10.700	-7.365	114.7	82.4	0.625
Bus3	220.000	134.501	-35.2	0	0	0	0	Bus1	47.034	19.109	99.1	92.6	
								U1	-47.034	-19.109	99.1	92.6	
Bus4	220.000	100.000	0.0	0	0	0	0	U2	0.000	0.000	0.0	0.0	
Bus5	220.000	100.000	-17.8	0	0	0	0	Bus2	10.708	7.711	34.6	81.1	
								U3	-10.708	-7.711	34.6	81.1	
Bus6	11.000	135.756	-38.2	0	0	0.000	1.453	Bus1	0.000	-1.453	56.2	0.0	
Bus7	66.000	99.036	-19.0	0	0	0	0	Bus2	-0.994	-0.630	10.4	84.5	
								Bus2	-0.994	-0.630	10.4	84.5	
								Bus9	1.989	1.260	20.8	84.5	
Bus8	66.000	136.572	-38.2	0	0	0	0	Bus1	-4.105	-2.669	31.4	83.8	
								Bus1	-4.105	-2.669	31.4	83.8	
								Bus10	8.209	5.337	62.7	83.8	
Bus9	11.000	98.356	-19.6	0	0	1.987	1.232	Bus7	-1.987	-1.232	124.8	85.0	
Bus10	11.000	136.183	-39.5	0	0	8.196	5.080	Bus8	-8.196	-5.080	371.7	85.0	1.250
Bus11	66.000	99.062	-19.0	0	0	0	0	Bus2	5.821	0.654	51.7	99.4	
								Bus42	-5.821	-0.654	51.7	99.4	
Bus12	66.000	136.648	-38.2	0	0	0	0	Bus1	4.410	0.150	28.2	99.9	
								Bus41	-4.410	-0.150	28.2	99.9	
Bus13	66.000	136.017	-38.5	0	0	0	0	Bus1	-7.132	-4.734	55.1	83.3	
								Bus15	7.132	4.734	55.1	83.3	
Bus14	66.000	98.224	-19.5	0	0	0	0	Bus2	-6.001	-4.157	65.0	82.2	
								Bus16	6.001	4.157	65.0	82.2	

LOAD FLOW REPORT (With PV) @ T = 0.800-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus15	11.000	138.660	-40.3	0	0	7.107	4.404	Bus13	-7.107	-4.404	316.5	85.0	4.375
Bus16	11.000	98.564	-22.4	0	0	5.965	3.697	Bus14	-5.965	-3.697	373.7	85.0	4.375
Bus17	66.000	136.996	-39.2	0	0	0	0	Bus27	-15.901	7.046	111.1	-91.4	
								Bus21	7.790	-3.462	54.4	-91.4	
								Bus23	1.645	-3.695	25.8	-40.7	
								Bus19	6.466	0.111	41.3	100.0	
Bus18	66.000	98.973	-19.4	0	0	0	0	Bus2	-3.487	-0.062	30.8	100.0	
								Bus20	3.487	0.062	30.8	100.0	
Bus19	11.000	136.858	-40.2	0	0	6.460	0.000	Bus17	-6.460	0.000	247.8	100.0	
Bus20	11.000	98.870	-20.4	0	0	3.484	0.000	Bus18	-3.484	0.000	185.0	100.0	
Bus21	66.000	137.228	-39.7	0	0	0	0	Bus17	-7.780	2.943	53.0	-93.5	
								Bus23	0.716	-3.163	20.7	-22.1	
								Bus22	7.064	0.221	45.1	100.0	
Bus22	11.000	136.831	-41.5	0	0	7.047	0.000	Bus21	-7.047	0.000	270.3	100.0	
Bus23	66.000	138.115	-40.0	0	0	0	0	Bus17	-1.640	-0.759	11.4	90.8	
								Bus21	-0.714	-0.733	6.5	69.8	
								Bus25	2.354	1.491	17.6	84.5	
Bus25	11.000	137.114	-40.5	0	0	2.351	1.457	Bus23	-2.351	-1.457	105.9	85.0	
Bus27	66.000	136.604	-38.6	0	0	0	0	Bus17	15.933	-7.267	112.1	-91.0	
								Bus1	-22.975	2.813	148.2	-99.3	
								Bus28	3.521	2.227	26.7	84.5	
								Bus29	3.521	2.227	26.7	84.5	
Bus28	11.000	136.580	-39.2	0	0	3.519	2.181	Bus27	-3.519	-2.181	159.1	85.0	0.625
Bus29	11.000	136.580	-39.2	0	0	3.519	2.181	Bus27	-3.519	-2.181	159.1	85.0	0.625
Bus30	66.000	136.151	-38.4	0	0	0	0	Bus1	-13.009	-8.704	100.6	83.1	
								Bus32	13.009	8.704	100.6	83.1	
Bus31	66.000	98.802	-19.2	0	0	0	0	Bus2	-5.023	-3.292	53.2	83.6	
								Bus33	5.023	3.292	53.2	83.6	
Bus32	11.000	137.781	-40.4	0	0	12.976	8.044	Bus30	-12.976	-8.044	581.6	85.0	3.750
Bus33	11.000	100.682	-20.6	0	0	5.014	3.108	Bus31	-5.014	-3.108	307.5	85.0	3.750
Bus34	0.400	135.565	-36.6	0	0	0	0	Bus41	1.106	0.068	1179.8	99.8	
								Inv2	-0.553	-0.034	589.9	99.8	
								Inv4	-0.553	-0.034	589.9	99.8	
Bus35	0.400	135.565	-36.6	0	0	0	0	Bus41	1.106	0.068	1179.8	99.8	
								Inv8	-0.553	-0.034	589.9	99.8	
								Inv7	-0.553	-0.034	589.9	99.8	
Bus36	0.400	135.565	-36.6	0	0	0	0	Bus41	1.106	0.068	1179.8	99.8	

LOAD FLOW REPORT (With PV) @ T = 0.800-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
								Inv10	-0.553	-0.034	589.9	99.8	
								Inv9	-0.553	-0.034	589.9	99.8	
Bus37	0.400	135.565	-36.6	0	0	0	0	Bus41	1.106	0.068	1179.8	99.8	
								Inv12	-0.553	-0.034	589.9	99.8	
								Inv91	-0.553	-0.034	589.9	99.8	
Bus38	0.400	100.000	-14.5	0	0	0	0	Bus42	1.960	0.378	2880.8	98.2	
								Inv90	-0.980	-0.189	1440.4	98.2	
								Inv89	-0.980	-0.189	1440.4	98.2	
Bus39	0.400	100.000	-14.5	0	0	0	0	Bus42	1.960	0.378	2880.8	98.2	
								Inv87	-0.980	-0.189	1440.4	98.2	
								Inv86	-0.980	-0.189	1440.4	98.2	
Bus40	0.400	100.000	-14.5	0	0	0	0	Bus42	1.960	0.378	2880.8	98.2	
								Inv102	-0.980	-0.189	1440.4	98.2	
								Inv14	-0.980	-0.189	1440.4	98.2	
Bus41	11.000	135.192	-37.3	0	0	0	0	Bus12	4.415	0.219	171.6	99.9	-1.250
								Bus34	-1.104	-0.055	42.9	99.9	
								Bus35	-1.104	-0.055	42.9	99.9	
								Bus36	-1.104	-0.055	42.9	99.9	
								Bus37	-1.104	-0.055	42.9	99.9	
Bus42	11.000	98.630	-16.8	0	0	0	0	Bus11	5.838	0.887	314.3	98.9	-1.250
								Bus38	-1.946	-0.296	104.8	98.9	
								Bus39	-1.946	-0.296	104.8	98.9	
								Bus40	-1.946	-0.296	104.8	98.9	
U1	220.000	262.107	0.0	53.448	83.252	0	0	Bus3	53.448	83.252	99.1	54.0	
U2	220.000	100.000	0.0	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
U3	220.000	146.534	0.0	11.492	15.550	0	0	Bus5	11.492	15.550	34.6	59.4	
Inv2	0.400	160.800	-37.1	0.656	0.034	0	0	Bus34	0.656	0.034	589.9	99.9	
Inv4	0.400	160.800	-37.1	0.656	0.034	0	0	Bus34	0.656	0.034	589.9	99.9	
Inv8	0.400	160.800	-37.1	0.656	0.034	0	0	Bus35	0.656	0.034	589.9	99.9	
Inv7	0.400	160.800	-37.1	0.656	0.034	0	0	Bus35	0.656	0.034	589.9	99.9	
Inv10	0.400	160.800	-37.1	0.656	0.034	0	0	Bus36	0.656	0.034	589.9	99.9	
Inv9	0.400	160.800	-37.1	0.656	0.034	0	0	Bus36	0.656	0.034	589.9	99.9	
Inv12	0.400	160.800	-37.1	0.656	0.034	0	0	Bus37	0.656	0.034	589.9	99.9	
Inv91	0.400	160.800	-37.1	0.656	0.034	0	0	Bus37	0.656	0.034	589.9	99.9	
Inv90	0.400	161.026	-18.7	1.596	0.189	0	0	Bus38	1.596	0.189	1440.4	99.3	
Inv89	0.400	161.026	-18.7	1.596	0.189	0	0	Bus38	1.596	0.189	1440.4	99.3	
Inv87	0.400	161.026	-18.7	1.596	0.189	0	0	Bus39	1.596	0.189	1440.4	99.3	

LOAD FLOW REPORT (With PV) @ T = 0.800-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Inv86	0.400	161.026	-18.7	1.596	0.189	0	0	Bus39	1.596	0.189	1440.4	99.3	
Inv102	0.400	161.026	-18.7	1.596	0.189	0	0	Bus40	1.596	0.189	1440.4	99.3	
Inv14	0.400	161.026	-18.7	1.596	0.189	0	0	Bus40	1.596	0.189	1440.4	99.3	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# indicates a bus with a load mismatch of more than 0.1 MVA

LOAD FLOW REPORT (With PV) @ T = 1.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus1	66.000	0.000	90.0	0	0	0	0	Bus12	0.000	0.000	174.7	0.0	
								Bus13	0.000	0.000	0.0	0.0	
								Bus27	0.000	0.000	0.0	0.0	
								Bus8	0.000	0.000	0.0	0.0	
								Bus8	0.000	0.000	0.0	0.0	
								Bus30	0.000	0.000	0.0	0.0	
								Bus3	0.000	0.000	468.0	0.0	3.750
								Bus6	0.000	0.000	0.0	0.0	
Bus2	66.000	2.964	59.9	0	0	0	0	Bus11	-0.024	-0.444	131.3	5.5	
								Bus14	0.005	0.003	1.9	83.4	
								Bus18	0.003	0.000	0.9	-99.7	
								Bus7	0.001	0.000	0.3	86.7	
								Bus7	0.001	0.000	0.3	86.7	
								Bus31	0.005	0.003	1.6	84.3	
								Bus5	0.010	0.437	129.1	2.2	0.625
Bus3	220.000	11.012	4.3	0	0	0	0	Bus1	0.136	6.110	145.7	2.2	
								U1	-0.136	-6.110	145.7	2.2	
Bus4	220.000	100.000	0.0	0	0	0	0	U2	0.000	0.000	0.0	0.0	
Bus5	220.000	0.000	90.0	0	0	0	0	Bus2	0.000	0.000	39.0	0.0	
								U3	0.000	0.000	85.0	0.0	
Bus6	11.000	0.000	90.0	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
Bus7	66.000	2.963	59.9	0	0	0	0	Bus2	-0.001	-0.001	0.3	84.5	
								Bus2	-0.001	-0.001	0.3	84.5	
								Bus9	0.002	0.001	0.6	84.5	
Bus8	66.000	0.000	90.0	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus1	0.000	0.000	0.0	0.0	
								Bus10	0.000	0.000	0.0	0.0	
Bus9	11.000	2.943	59.3	0	0	0.002	0.001	Bus7	-0.002	-0.001	3.6	85.0	
Bus10	11.000	0.000	90.0	0	0	0	0	Bus8	0.000	0.000	0.0	0.0	1.250
Bus11	66.000	2.967	59.9	0	0	0	0	Bus2	0.025	0.445	131.3	5.6	
								Bus42	-0.025	-0.445	131.3	5.6	
Bus12	66.000	0.005	3.3	0	0	0	0	Bus1	0.001	0.001	174.7	65.8	
								Bus41	-0.001	-0.001	174.7	65.8	
Bus13	66.000	0.000	90.0	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus15	0.000	0.000	0.0	0.0	
Bus14	66.000	2.940	59.4	0	0	0	0	Bus2	-0.005	-0.004	1.9	82.3	
								Bus16	0.005	0.004	1.9	82.3	

LOAD FLOW REPORT (With PV) @ T = 1.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Bus15	11.000	0.000	90.0	0	0	0	0	Bus13	0.000	0.000	0.0	0.0	4.375
Bus16	11.000	2.952	56.5	0	0	0.005	0.003	Bus14	-0.005	-0.003	10.9	85.0	4.375
Bus17	66.000	0.000	90.0	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	
								Bus21	0.000	0.000	0.0	0.0	
								Bus23	0.000	0.000	0.0	0.0	
								Bus19	0.000	0.000	0.0	0.0	
Bus18	66.000	2.961	59.6	0	0	0	0	Bus2	-0.003	0.000	0.9	100.0	
								Bus20	0.003	0.000	0.9	100.0	
Bus19	11.000	0.000	90.0	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
Bus20	11.000	2.958	58.6	0	0	0.003	0.000	Bus18	-0.003	0.000	5.4	100.0	
Bus21	66.000	0.000	90.0	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
								Bus23	0.000	0.000	0.0	0.0	
								Bus22	0.000	0.000	0.0	0.0	
Bus22	11.000	0.000	90.0	0	0	0	0	Bus21	0.000	0.000	0.0	0.0	
Bus23	66.000	0.000	90.0	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
								Bus21	0.000	0.000	0.0	0.0	
								Bus25	0.000	0.000	0.0	0.0	
Bus25	11.000	0.000	90.0	0	0	0	0	Bus23	0.000	0.000	0.0	0.0	
Bus27	66.000	0.000	90.0	0	0	0	0	Bus17	0.000	0.000	0.0	0.0	
								Bus1	0.000	0.000	0.0	0.0	
								Bus28	0.000	0.000	0.0	0.0	
								Bus29	0.000	0.000	0.0	0.0	
Bus28	11.000	0.000	90.0	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	0.625
Bus29	11.000	0.000	90.0	0	0	0	0	Bus27	0.000	0.000	0.0	0.0	0.625
Bus30	66.000	0.000	90.0	0	0	0	0	Bus1	0.000	0.000	0.0	0.0	
								Bus32	0.000	0.000	0.0	0.0	
Bus31	66.000	2.956	59.7	0	0	0	0	Bus2	-0.005	-0.003	1.6	83.6	
								Bus33	0.005	0.003	1.6	83.6	
Bus32	11.000	0.000	90.0	0	0	0	0	Bus30	0.000	0.000	0.0	0.0	3.750
Bus33	11.000	3.012	58.3	0	0	0.005	0.003	Bus31	-0.005	-0.003	9.3	85.0	3.750
Bus34	0.400	23.686	37.8	0	0	0	0	Bus41	0.139	1.189	7296.8	11.6	
								Inv2	-0.069	-0.595	3648.4	11.6	
								Inv4	-0.069	-0.595	3648.4	11.6	
Bus35	0.400	23.686	37.8	0	0	0	0	Bus41	0.139	1.189	7296.8	11.6	
								Inv8	-0.069	-0.595	3648.4	11.6	
								Inv7	-0.069	-0.595	3648.4	11.6	
Bus36	0.400	23.686	37.8	0	0	0	0	Bus41	0.139	1.189	7296.8	11.6	

LOAD FLOW REPORT (With PV) @ T = 1.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
								Inv10	-0.069	-0.595	3648.4	11.6	
								Inv9	-0.069	-0.595	3648.4	11.6	
Bus37	0.400	23.686	37.8	0	0	0	0	Bus41	0.139	1.189	7296.8	11.6	
								Inv12	-0.069	-0.595	3648.4	11.6	
								Inv91	-0.069	-0.595	3648.4	11.6	
Bus38	0.400	23.363	56.5	0	0	0	0	Bus42	0.135	1.176	7313.7	11.4	
								Inv90	-0.067	-0.588	3656.9	11.4	
								Inv89	-0.067	-0.588	3656.9	11.4	
Bus39	0.400	23.363	56.5	0	0	0	0	Bus42	0.135	1.176	7313.7	11.4	
								Inv87	-0.067	-0.588	3656.9	11.4	
								Inv86	-0.067	-0.588	3656.9	11.4	
Bus40	0.400	23.363	56.5	0	0	0	0	Bus42	0.135	1.176	7313.7	11.4	
								Inv102	-0.067	-0.588	3656.9	11.4	
								Inv14	-0.067	-0.588	3656.9	11.4	
Bus41	11.000	13.177	40.0	0	0	0	0	Bus12	0.205	2.657	1061.4	7.7	-1.250
								Bus34	-0.051	-0.664	265.3	7.7	
								Bus35	-0.051	-0.664	265.3	7.7	
								Bus36	-0.051	-0.664	265.3	7.7	
								Bus37	-0.051	-0.664	265.3	7.7	
Bus42	11.000	12.832	58.9	0	0	0	0	Bus11	0.140	1.946	797.9	7.2	-1.250
								Bus38	-0.047	-0.649	266.0	7.2	
								Bus39	-0.047	-0.649	266.0	7.2	
								Bus40	-0.047	-0.649	266.0	7.2	
U1	220.000	262.107	0.0	14.004	144.797	0	0	Bus3	14.004	144.797	145.7	9.6	
U2	220.000	100.000	0.0	0	0	0	0	Bus4	0.000	0.000	0.0	0.0	
U3	220.000	146.534	0.0	4.722	47.220	0	0	Bus5	4.722	47.220	85.0	10.0	
Inv2	0.400	160.800	-37.1	4.021	0.595	0	0	Bus34	4.021	0.595	3648.4	98.9	
Inv4	0.400	160.800	-37.1	4.021	0.595	0	0	Bus34	4.021	0.595	3648.4	98.9	
Inv8	0.400	160.800	-37.1	4.021	0.595	0	0	Bus35	4.021	0.595	3648.4	98.9	
Inv7	0.400	160.800	-37.1	4.021	0.595	0	0	Bus35	4.021	0.595	3648.4	98.9	
Inv10	0.400	160.800	-37.1	4.021	0.595	0	0	Bus36	4.021	0.595	3648.4	98.9	
Inv9	0.400	160.800	-37.1	4.021	0.595	0	0	Bus36	4.021	0.595	3648.4	98.9	
Inv12	0.400	160.800	-37.1	4.021	0.595	0	0	Bus37	4.021	0.595	3648.4	98.9	
Inv91	0.400	160.800	-37.1	4.021	0.595	0	0	Bus37	4.021	0.595	3648.4	98.9	
Inv90	0.400	161.026	-18.7	4.037	0.588	0	0	Bus38	4.037	0.588	3656.9	99.0	
Inv89	0.400	161.026	-18.7	4.037	0.588	0	0	Bus38	4.037	0.588	3656.9	99.0	
Inv87	0.400	161.026	-18.7	4.037	0.588	0	0	Bus39	4.037	0.588	3656.9	99.0	

LOAD FLOW REPORT (With PV) @ T = 1.000-

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	% Tap
Inv86	0.400	161.026	-18.7	4.037	0.588	0	0	Bus39	4.037	0.588	3656.9	99.0	
Inv102	0.400	161.026	-18.7	4.037	0.588	0	0	Bus40	4.037	0.588	3656.9	99.0	
Inv14	0.400	161.026	-18.7	4.037	0.588	0	0	Bus40	4.037	0.588	3656.9	99.0	

* Indicates a voltage regulated bus (voltage controlled or swing type machine connected to it)

\# indicates a bus with a load mismatch of more than 0.1 MVA

Dynamic Stability

The tabulated plot data is not printed since the option of "Skip Tabulated Plots" is checked.
To print tabulated plot data go to the Transient Stability Study Case Editor and in the Info Page uncheck the "Skip Tabulated Plots" option.

System Islanding Index

Time (Sec.)	Element ID	Type	Zone No.
0.000	Bus1	Bus	2
0.000	Bus10	Bus	2
0.000	Bus11	Bus	1
0.000	Bus12	Bus	2
0.000	Bus13	Bus	2
0.000	Bus14	Bus	1
0.000	Bus15	Bus	2
0.000	Bus16	Bus	1
0.000	Bus17	Bus	2
0.000	Bus18	Bus	1
0.000	Bus19	Bus	2
0.000	Bus2	Bus	1
0.000	Bus20	Bus	1
0.000	Bus21	Bus	2
0.000	Bus22	Bus	2
0.000	Bus23	Bus	2
0.000	Bus25	Bus	2
0.000	Bus27	Bus	2
0.000	Bus28	Bus	2
0.000	Bus29	Bus	2
0.000	Bus3	Bus	2
0.000	Bus30	Bus	2
0.000	Bus31	Bus	1
0.000	Bus32	Bus	2
0.000	Bus33	Bus	1
0.000	Bus34	Bus	2
0.000	Bus35	Bus	2
0.000	Bus36	Bus	2
0.000	Bus37	Bus	2
0.000	Bus38	Bus	1
0.000	Bus39	Bus	1
0.000	Bus4	Bus	3
0.000	Bus40	Bus	1
0.000	Bus41	Bus	2
0.000	Bus42	Bus	1
0.000	Bus5	Bus	1

System Islanding Index

Time (Sec.)	Element ID	Type	Zone No.
0.000	Bus6	Bus	2
0.000	Bus7	Bus	1
0.000	Bus8	Bus	2
0.000	Bus9	Bus	1
0.000	Inv10	Power Grid	2
0.000	Inv102	Power Grid	1
0.000	Inv12	Power Grid	2
0.000	Inv14	Power Grid	1
0.000	Inv2	Power Grid	2
0.000	Inv4	Power Grid	2
0.000	Inv7	Power Grid	2
0.000	Inv8	Power Grid	2
0.000	Inv86	Power Grid	1
0.000	Inv87	Power Grid	1
0.000	Inv89	Power Grid	1
0.000	Inv9	Power Grid	2
0.000	Inv90	Power Grid	1
0.000	Inv91	Power Grid	2
0.000	U1	Power Grid (Ref.)	2
0.000	U2	Power Grid (Ref.)	3
0.000	U3	Power Grid (Ref.)	1

Action Summary

Event ID	Time (Sec.)	Device Type	Device ID	Action
event2	0.800	Bus	Bus1	3 Phase Fault
event2	0.800	Bus	Bus5	3 Phase Fault