POWER SYSTEM STUDY ON INTEGRATING WIND AND PV POWER TO THE GRID SYSTEM

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfilment of the Requirements
for the Degree
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(Electrical & Electronic Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohnad Ibrahim Abdalla Jobbara

ABSTRACT

In the current century the demand of energy increased due to the industrial revolution and the high use of energy. PV and wind power were explored to meet the energy demand requirement. The objective of this research is to study and analyze the effects on the voltages and faults currents levels on the buses of the system when integrating wind and PV farms to the grid system.

The grid system is IEEE industrial power system, modeling and simulation were implemented using DIgSilent software to perform power system studies of load flow and short circuit analysis on grid-connected at steady state condition to study the voltages and faults currents at the buses.

From load flow analysis of PV integration to the industrial system, the voltage is improved at the Buses, the far the grid system from utility supply the more effective the improvement of Buses voltages. Integrating Wind farm to the grid system will affect on the voltage levels, increasing the power from the wind farm decreases the voltage on the system Buses. Short circuit analysis applied base on ANSI and IEEE standards and the comparison between the fault currents contribution of PV grid connected and wind grid connected system showed that the contribution of PV farm is higher than wind farm. The contribution is higher on the Buses near to the point of interconnection.

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LIST OF ABBREVIATIONS

RES	:	Renewable Energy Source(s)
WFs	:	Wind Farms
PV	:	Photovoltaic
IEEE	:	Institute of Electrical and Electronics Engineers
kV	:	kilo-Volt
MVA	:	Mega Volt Ampere
MW	:	Mega Watts
KW	:	Kilo-Watt
KVAR	:	Kio-Volt-Ampere
pu	:	Per unit
AC	:	Alternating Current
DC	:	Direct Current

CHAPTER 1
INTRODUCTION

1.1 Background Study

An alternative to the conventional sources of energy (coal, gas, oil, diesel, and nuclear) are renewable energy technologies (hydro, wind, solar, biomass, geothermal, and ocean). As shown in Figure 1, among the other non-conventional energy sources, wind and solar have increased rapidly and have got great emphasis in the recent years [1].

Figure 1: PV Solar and Wind power [2]

In recent years the industries has grown very fast due to the industrial revolution. There is huge demand of electric power between the power needed by the consumers and the power supplied. The Renewable Energy Sources (RES) can play a big role to help meeting the demand of electrical energy. Photovoltaic (PV) and wind energy are the best alternatives sources that assist in filling the demand in electrical energy [3], and the wind energy is the fastest growing field of non-conventional energy sources [4]. However, in order for the RES such as wind and solar to supply the loads with high power quality, the generated electric power will be integrated with the grid system to fulfill the gap of the demand of electric power.

1.2 Problem Statement

Integrating renewable energy to the grid system is necessary while maintaining the efficiency and the reliability of the power in the grid system. Grid systems face huge transition lead by the necessity to the integration of renewable energy such as solar, wind, and other renewable energy to enhance the efficiency of energy and to minimize the use of conventional energy sources. Electric generating systems are part of the interconnected power system that must be controlled so that their overall output matches the electric load at any given time.

RES by its nature is variable, hard to accurately predict and often anti-correlated with electricity load. Integrating sufficient amount of renewable energy will introduce a unique challenge to the power system and will require more flexibility. Studying and analyzing the impact of renewable energy generation on the power quality of the grid system is very important. The variable and mostly the uncontrollable nature of RES introduce new features into the power system control problem. The grid system must accommodate the variability in the RES in order to maintain the same level of system reliability. The capability of the grid power system to provide the needed reactive power of the wind farms is major problem in evaluating or assessing the electric power to integrate it into the grid. Integrating the electric power generated from wind to the grid system will cause some problems to the power quality of the grid power due to the unstable or variable speeds of wind.

1.3 Objectives and Scope of Study

1.3.1 Objectives

The main objectives of this project are:

- To study the effects of PV solar and wind power generation on the grid system voltage at steady state condition.
- To study the effects of PV solar and wind power generation on the fault level of the grid system at steady state condition.

1.3.2 Scope of study

The scope of study includes studying and analyzing the performance of industrial power system connected to RES of wind and PV solar power.

In this research, the main topics under investigation are:

1. Power flow study and short circuit analysis of IEEE industrial system
2. Power flow and short circuit analysis of IEEE industrial system connected to the wind and PV solar power.

CHAPTER 2
LITERATURE REVIEW

2.1 Wind Power

2.1.1 Overview of Wind Power

Wind farms (WFs) consists of wind turbines, the wind is captured by the blades which in turns rotates the turbines which is connected to the generator through the shaft as explained in Figure 2. The generator generate Alternating Current (AC) electric power, the electricity is then transferred to step-up transformer to step up the voltage to higher levels to meet the grid requirement. The electric power will be sent to the transmission lines and then to the distribution and after that it will supply the customer's loads, which can be industrial, commercial or residential. Integrating the electric power generated from wind to the grid system will cause some problems to the power quality of the grid power due to the unstable or variable speeds of wind [4]. The biggest challenging issues of wind powers are the grid system reliability and the intermittency.

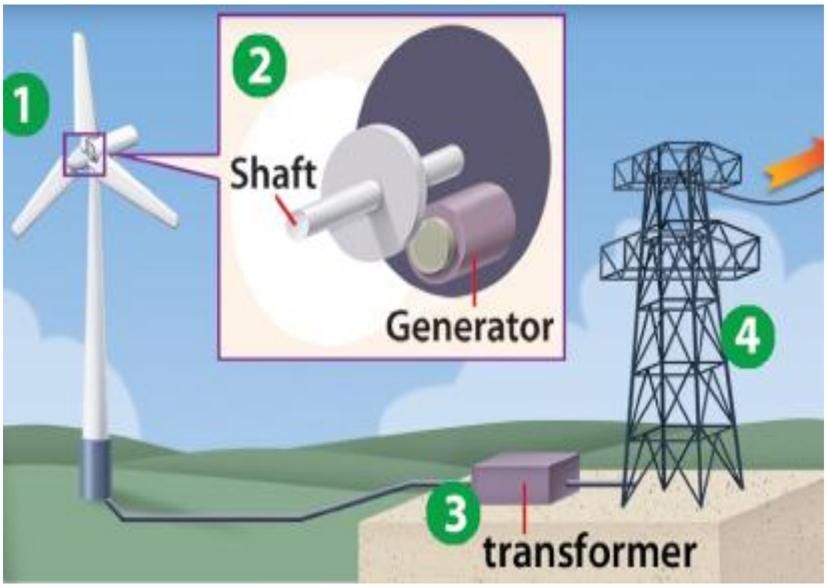

Figure 2: Wind Power Generation Systems [5]

2.1.2 Wind Power Integration into Grid System

The capability of the grid power system to provide the needed reactive power by the WFs is major problem in evaluating or assessing the electric power to integrate it into the grid [6]. According to the study of voltage stability analysis of grid system transmission lines of 220kV connected to WFs in China, where most WFs have established far distance from the consumers. The major problem in wind power integration to the grid is the voltage stability due to the use of induction generators with fixed speed wind turbines. During normal and continuous operation of wind turbine generators, it consumes or absorbs a lot of reactive power which result in deterioration of voltage stability [7]. The wind turbines designed with induction generators which is modified using doubly fed have great capability to mitigate the voltage stability deterioration which is better than the induction generators based wind turbines [7].

2.1.3 Voltage and System losses studies of Grid Connected Wind Farms

In recent years WFs increased a lot in size and number, the larger the WFs the higher the reactive power demand, the increment of overall network losses and voltage stability issues are the results of shortage of reactive power [7-8]. The study which investigates the possibility to integrate large wind farms of full power 40MVA and 80MVA to sub-transmission network, and to determine their effects in the grid system voltage stability and overall losses [6]. It shows that the reactive power demand of the 40MVA WFs integrated to the sub-transmission network is satisfied and will contribute in reducing the system losses [6]. The point of interconnection of WFs has great effect on the system, the closer the WFs to the load is better which reduce losses and minimize their effects on voltage stability [6]. In many electrical power systems the stability of electric power might get affected or influenced when very large farms of wind power is connected to the power system which can be as a result of uncontrolled very high levels of penetrations of the wind in that particular zone [9-11].

2.2 Photovoltaic Power

2.2.1 Overview of Solar PV Power System

The light of the sun is transferred to electrical energy through the PV cells which are arranged together to make module or array. The generated electric power is Direct Current (DC) power which can be stored in batteries, and the electric power can be converted from DC to AC using inverters and then it can supply the loads. If the PV power plant is very big and produce large amount of power from the sun it can be connected to distribution system. Figure 3 explains the generation and distribution of electricity using PV power system.

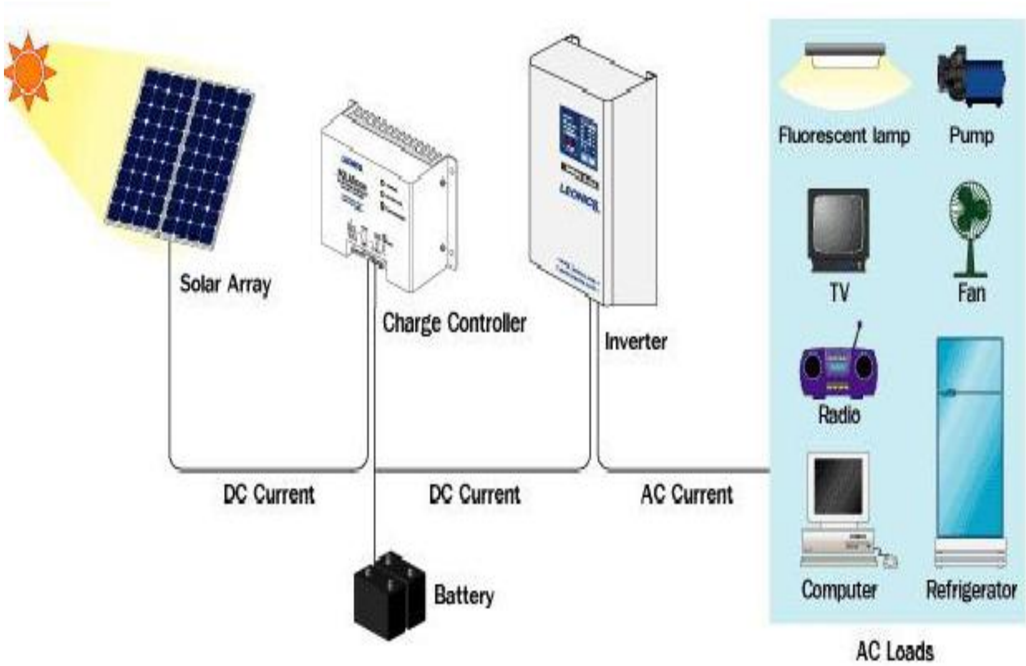

Figure 3: Solar PV Power System [12]

2.2.2 Integration of Photovoltaic Systems to the Grid System

PV systems becomes an outstanding RES comparing to Non-RES[13] and PV is a means to generate electrical energy for many various applications with different ranging of few watts to large amount of electric power[13]. Most of the large PV plants worldwide are connected to the grid [13].

The highest total losses occur in distribution systems [14], and to reduce the total losses there are many methods to be used. One of these methods is to connect PV system to grid system and it is efficient method but very much complicated [14]. Increasing the PV system will significantly increase transient over-voltage [15]. The studies presented the transient over-voltage levels reduction when having a PV system attached with synchronous generator [14]. Higher fault current is the result of unstable levels of penetration of PV connection to grid system comparing to the case without PV installed, which affects on protection elements [13]. The results obtained, presents the possibility of upgrading and choosing the protection elements that allow the penetration of PV system [13].

CHAPTER 3 METHODOLOGY

3.1 Introduction

This section shows a detailed description on the project with the methods and techniques or analysis that will be used for completing this work. Gantt chart explains the work process of the project within the specified period for the completion of the project. The scope of study includes studying and analyzing the performance of industrial power system connected to RES of wind and PV solar power. Figure 4 show the interconnection of wind and PV farms to the grid system

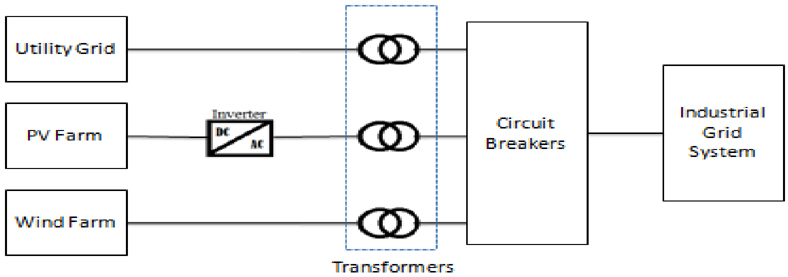

Figure 4: Wind and PV farms Grid Connected

3.2 System Modeling and Simulation

In this project, the power system studies will be implemented on IEEE industrial power system model connected to wind and solar farms to analyze the effect of the electric power generated from RES on the power system at the steady-state under different operating conditions.

The power system will be simulated before and after integrating the wind and solar PV to assess the effect of each system using these techniques:

1. Load flow study
2. Short circuit analysis
3. Contingency analysis

3.3 Work Flow Chart

Figure 5 shows the work progress of the research and analysis in the project

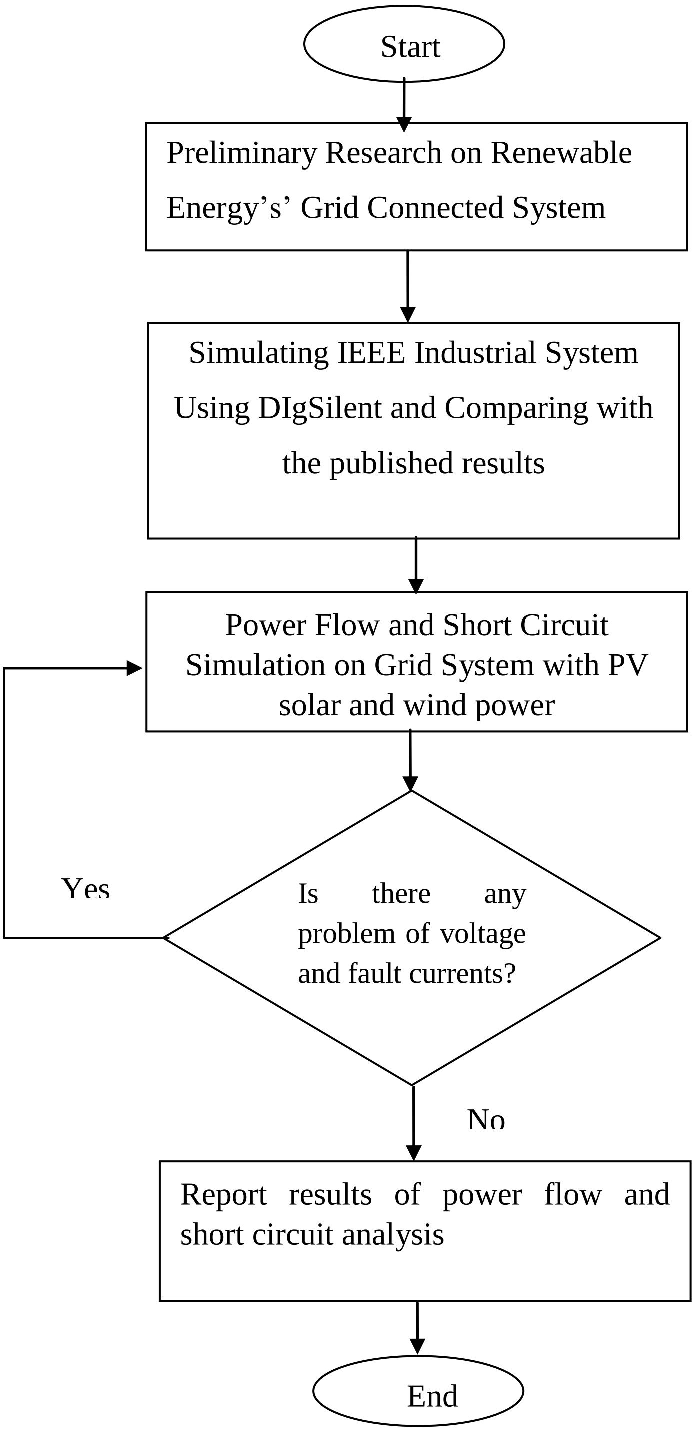

Figure 5: Work Flow Chart

3.4 Tools

3.4.1 Power System Simulation software

The software proposed to be used in this project is DIgSilent Software. This software is one of the best software to be used in power system analysis for generation, transmission, distribution and industrial systems. It contains all the needed analysis functions for this research such as load flow, short circuit, and protection [14].

3.4.2 IEEE Industrial System Model

Figure 6 represents the IEEE industrial power system used as the grid system for the research.

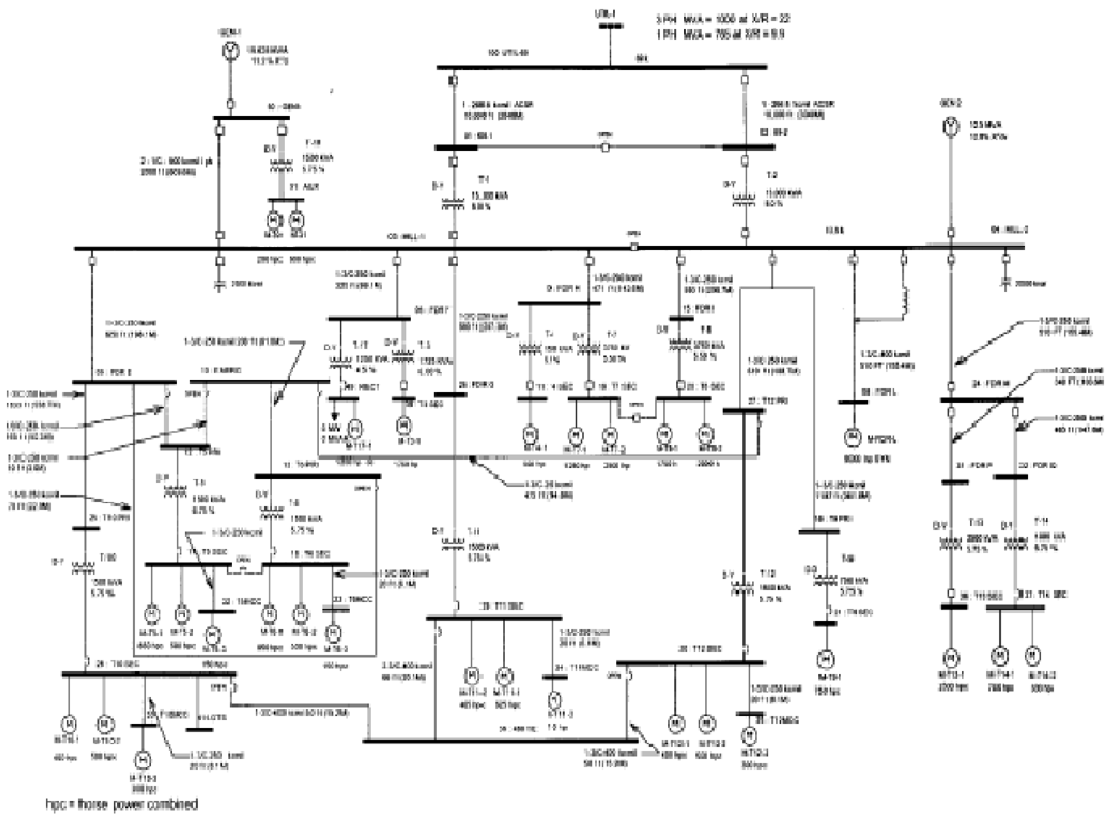

Figure 6: IEEE Industrial System [17]

3.5 Project Gantt chart

Table 1: FYP1 Gantt chart

NO	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of project topic														
2	Research work														
3	Submission of Extended proposal														
4	Proposal Defense														
5	Project work continues														
6	Interim draft report submission														
7	Interim report submission														

Table 2: FYP2 Gantt chart

NO	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Research continues															
2	Work progress continues															
3	Progress report submission															
4	ElectrEX Poster Presentation															
5	Draft Final Report															
6	Final Report & Technical paper Submission															
7	VIVA															

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Modeling and Simulation of IEEE Industrial System

Load flow analysis has been implemented on IEEE industrial system. The results shown in Figure 7 are almost the same results as published model in IEEE recommended practices for industrial and commercial power system analysis. All the Bus voltages are in pu and degrees, and all power flow in KW and KVAR [Refer to Appendix H and Appendix I]

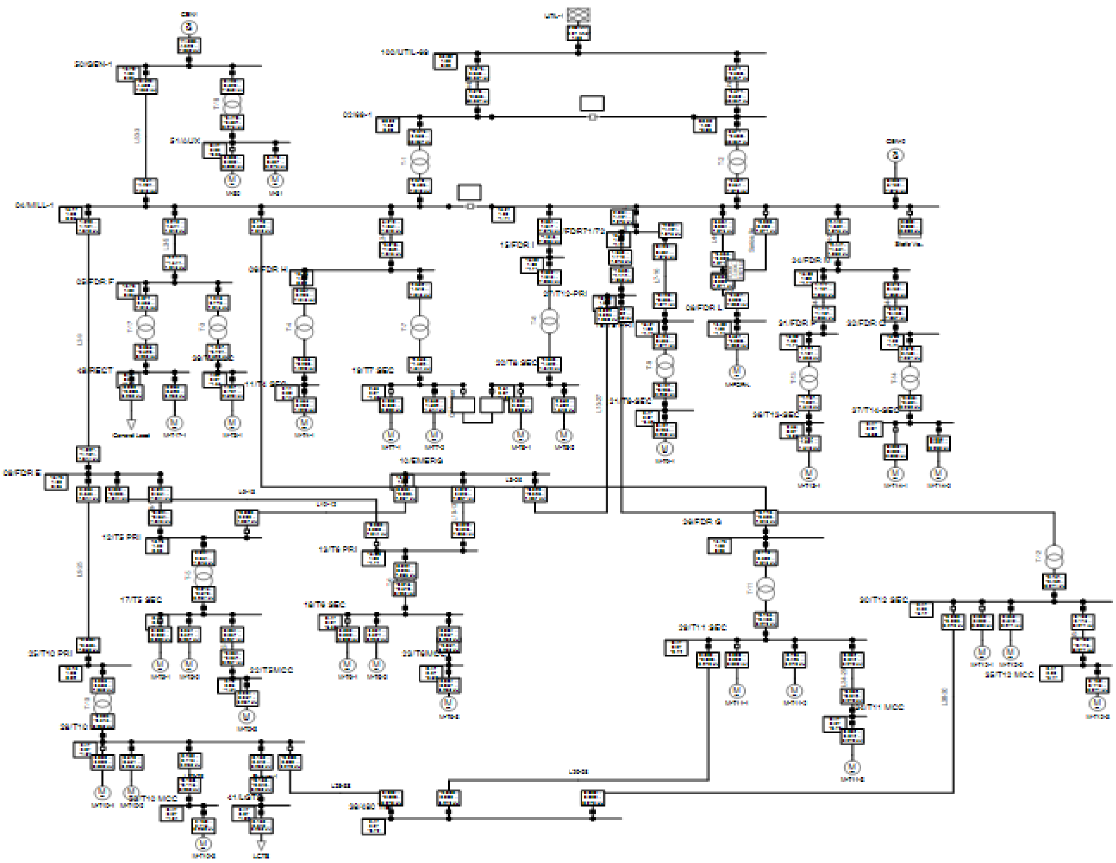

Figure 7: Load Flow Results of IEEE Industrial System

The load Buses voltage averaging around 0.970 pu and most of the real power around 86.75 % is supplied by the plant generators (GEN1, and GEN2) and remaining power is supplied by the Utility. The loading on cables and transformers are under normal operation.

4.2 Load Flow Studies

4.2.1 Base Case

The load flow results achieved after running the industrial power system without integrating PV or wind power shows that the system is running under normal conditions and there is no problem in the grid power and voltages.

Analysis of load flow on the base case shows that:

1) The voltage is somehow low on the load Buses at average of 0.970 pu

2) Most of the loads in the system are supplied by the system generators located at Bus 4 and 50, however the generators supply about 86.7 % and the remaining is supplied from the utility.

3) The reactive power need by the system are supplied by the two generators and small reactive power is drawn from the utility.

4) The loadings are under normal operating limits for the transformers and cables.

The voltages at the load Buses vary between 0.970 pu and 0.98 pu as shown in the grid load flow diagram. The 0.48 kV Buses have the large voltage drop of 0.03 pu of Bus 37, 17, 22, 33, 41 which have 0.97 pu voltage (0.466 kV) while Bus 39 (4.01856 kV). This voltage drop is due to the loading of the motors. (With reference to ANSI C48.1 (-5%, +5%))

In the flow diagram of the base case, as in Figure 8 it is clear that transformers T-13 (Bus 31-36), T-8 (Bus 15-20), T-7 (Bus 6-19), T-3 (Bus 5-39) and T-17 (5-49) are operating with more than 80 % loading which is normal and preferable. It is observed that T-17 is 90 % being the highest loaded.

The motors loading is 85 % for motors M-T17-1 (Bus 49), M-T3-1(Bus 39), M-T4-1(Bus 11), M-T7-1 / M-T7-2 (Bus 19), M-T8-1 / M-T8-2(Bus 20) and M-T13-1 (Bus 36).

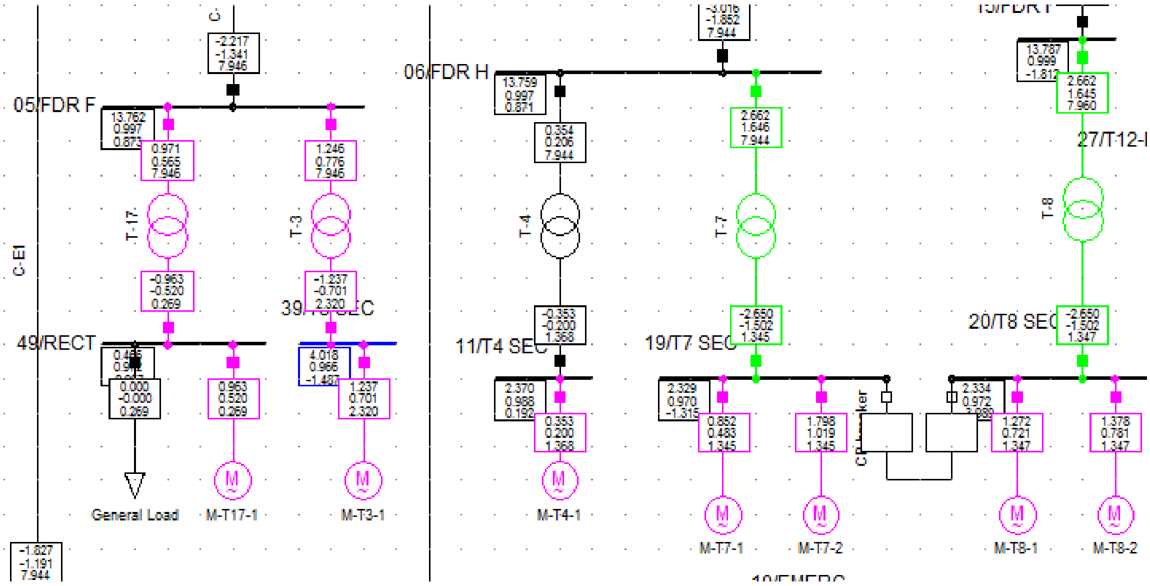

Figure 8: The industrial power system running under normal conditions

However, one of the critical contingencies for this industrial system is the outage of one of the two generators which will result in high voltage drop in all the Buses and system equipments which will lead to low voltage profile.

In order to overcome this voltage drop problem, two options are possible namely:

a) Change the transformers tap.

b) Change the voltage control set points of the two generators

The low voltage profile has been improved for Buses 37, 17, 22, 33, 41, and 39 by changing the tap position on all the system transformers (except T-1 and T-2). The entire load Buses voltage is close to the unity. The lowest voltage levels occurred at Buses 17, and 22 at 0.99 and 0.989 pu respectively.

Table 3 shows the Buses voltages for base case A (System is running normally with transformers taps at position 0), and base case B (Transformers (except T-1 and T-2) taps at position 0.975 (-1= -2.5 %).

Table 3: Buses voltages at Base Case

	Base Case A			Base Case B		
Bus No	Voltage(kV	Pu	phase angle	Voltage(kV)	Pu	phase angle
Bus 8	13.793	1	-1.838	13.795	1	-1.837
Bus 11	2.37	0.988	0.192	2.433	1.014	0.226
Bus 17	0.462	0.963	-1.321	0.475	0.99	-1.208
Bus 18	0.466	0.971	-3.657	0.479	0.997	-3.562
Bus 19	2.329	0.97	-1.315	2.392	0.997	-1.203
Bus 20	2.334	0.972	-3.989	2.398	0.999	-3.877
Bus 21	0.466	0.971	-3.422	0.479	0.998	-3.339
Bus 22	0.462	0.963	-1.32	0.475	0.989	-1.207
Bus 23	0.466	0.97	-3.656	0.479	0.997	-3.561
Bus 28	0.466	0.971	-0.967	0.479	0.997	-0.873
Bus 29	0.468	0.974	-0.674	0.48	1.001	-0.596
Bus 30	0.469	0.977	-3.274	0.482	1.003	-3.199
Bus 33	0.465	0.97	-0.966	0.478	0.996	-0.872
Bus 34	0.467	0.974	-0.674	0.48	1	-0.595
Bus 35	0.469	0.976	-3.273	0.481	1.002	-3.198
Bus 36	2.33	0.971	-4.063	2.394	0.997	-3.948
Bus 37	0.465	0.969	-3.789	0.478	0.995	-3.687
Bus 39	4.018	0.966	-1.487	4.128	0.992	-1.366
Bus 41	0.466	0.97	-0.976	0.478	0.996	-0.882
Bus 49	0.466	0.972	-0.967	0.479	0.998	-0.873
Bus 51	0.474	0.987	0.185	0.486	1.014	0.231

4.2.2 Contingency Case Study

Scenario 1: Outage of GEN-1 on Bus 50

After all the changes being done and the outage of the generator (GEN-1) on Bus 50, the voltages will remain above 0.95 pu. The system generator on Bus 4 (GEN-2) is supplying 36.49 % of the total load and the remaining power needed is supplied by the utility.

The load Buses voltage as shown in Table 4 have minor voltage drop, but after closing the breaker between Bus 3 and Bus 4 the voltage profile improved at all the load Buses. The voltage and loadings were still at the acceptable limits.

Table 4: Buses voltages at scenario1

Scenario 1			
Bus No	Voltage(KV)	Pu	phase angle
Bus 8	13.795	1	-1.838
Bus 11	2.351	0.979	-3.33
Bus 17	0.458	0.955	-4.868
Bus 18	0.479	0.997	-3.562
Bus 19	2.309	0.962	-4.862
Bus 20	2.397	0.999	-3.877
Bus 21	0.479	0.998	-3.339
Bus 22	0.458	0.954	-4.868
Bus 23	0.479	0.997	-3.561
Bus 28	0.462	0.962	-4.509
Bus 29	0.464	0.966	-4.211
Bus 30	0.482	1.003	-3.199
Bus 33	0.461	0.961	-4.507
Bus 34	0.463	0.966	-4.21
Bus 35	0.481	1.002	-3.198
Bus 36	2.394	0.997	-3.948
Bus 37	0.478	0.995	-3.687
Bus 39	3.983	0.957	-5.037
Bus 41	0.462	0.962	-4.518
Bus 49	0.463	0.964	-4.508
Bus 51	0.468	0.974	-3.592

* Scenario1: Outage of the generator at Bus 50 (GEN-1) with transformers taps at position -1 (-2.5 %), (Except T-1 and T-2)

Scenario 2: Outage of the system generators GEN-1 and GEN-2

Outage of the system generators forced the system to get supply power from the utility for real and reactive power. The transformer taps are kept at 0.975 pu, and the voltage profile is still under the acceptable limits (above 0.95 pu). The loadings on equipment were also within their capabilities. It is clear that all the Buses connected through Bus 3 did not face any change comparing to Case 2 since there was no connection between Bus 3 and Bus 4. All the previous cases have been executed on the industrial power system taking in consideration that the breaker between Bus 3 and Bus 4 is opened, and the lines between Buses 9, 10, 28, and 30 are disconnected from Bus 13, 12, 38, 38 respectively.

Refer to Table 5 to see the Buses voltage for scenario 2.

Table 5: Buses voltages at scenario 2

Scenario2			
Bus No	Voltage(kV)	pu	phase angle
Bus 8	13.293	0.963	-4.448
Bus 11	2.351	0.979	-3.33
Bus 17	0.458	0.955	-4.868
Bus 18	0.46	0.959	-6.309
Bus 19	2.309	0.962	-4.862
Bus 20	2.305	0.961	-6.649
Bus 21	0.46	0.959	-6.069
Bus 22	0.458	0.954	-4.868
Bus 23	0.46	0.958	-6.308
Bus 28	0.462	0.962	-4.509
Bus 29	0.464	0.966	-4.211
Bus 30	0.463	0.965	-5.916
Bus 33	0.461	0.961	-4.507
Bus 34	0.463	0.966	-4.21
Bus 35	0.463	0.964	-5.915
Bus 36	2.301	0.959	-6.725
Bus 37	0.459	0.957	-6.444
Bus 39	3.983	0.957	-5.037
Bus 41	0.462	0.962	-4.518
Bus 49	0.463	0.964	-4.508
Bus 51	0.468	0.974	-3.592

* Scenario 2: Outage of the both plant generators at Bus 50 (GEN-1) and Bus 4 (GEN-2) with transformers taps (except T-1 and T-2) kept at position -1 (-2.5 %). The industrial system in this scenario running properly with supply voltage at 1 pu, and adjustment of transformers taps to position (-1) (except T-1 and T-2).

However it is possible to adjust only T-1 and T-2 taps to positions -2 to maintain the voltage limits and the breakers between Bus 4 and Bus 3 have to be closed to reduce the loading on T-2.

4.2.3 PV grid connected

Scenario 3: Outage of GEN1 and GEN2 and Integrating PV at Bus 4

Let us assume the scenario when the two plant generators are out of service due to maintenance, some damage, or replacement to new generators. The electricity need to be supplied to the industry to be drawn from the utility.

The utility always supply power with voltage limit between 0.95-1.05 pu (- or + 5 %). In this scenario the voltage set points of supply from the grid is 0.98 pu which is within the limits promised by utility. However, the load flow results show that all the Buses voltage are below the 0.95 pu which is unacceptable (except 69 kV Bus) (see Figure 9). This happened because both the plant generators are out of service and all the supply comes from the grid. The transformers taps in this case are all in normal position 0.

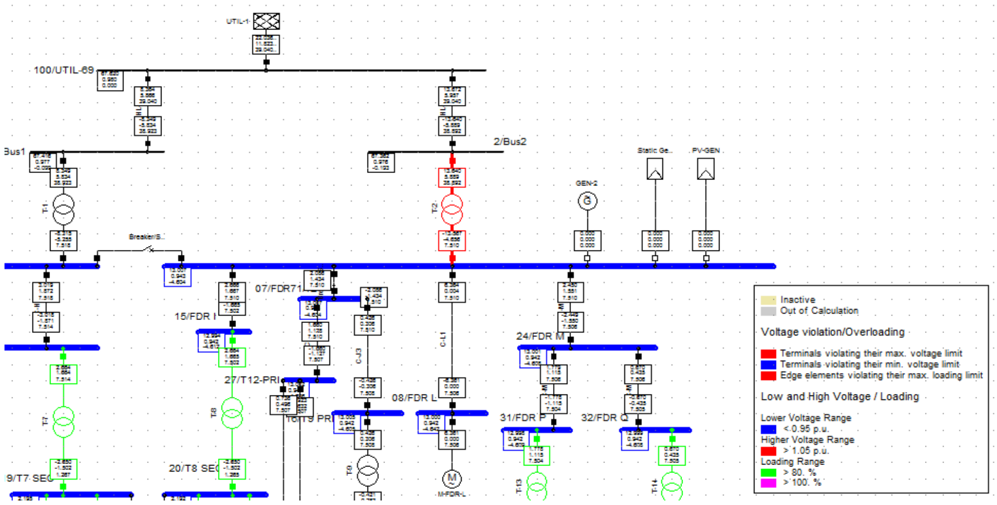

Figure 9: Plant generators are out of service

The step down transformer (69/13.8 kV), T-2 is violating its maximum loading limit which might lead to equipment damage. In order to overcome this kind of problems there are several ways to be implemented:

1. Adjusting the transformer tap position on T-1 and T-2

2. Integration of PV plant

PV connection at Bus 4 (13.8kV)

Studying the effect on some of the Buses in the system when integrating PV to the industrial system with the transformers T-1 and T-2 tap position at -1. The voltage profile at Bus 4 (13.8 kV) when PV power supplied vary from 1 to 4MW as in Table 6.

Table 6: Voltage at Bus 4 in Scenario2

PV power (MW)	0	1	2	3	4
Voltage (kV)	13.37	13.383	13.395	13.407	13.419
Voltage in pu	0.969	0.97	0.971	0.972	0.972

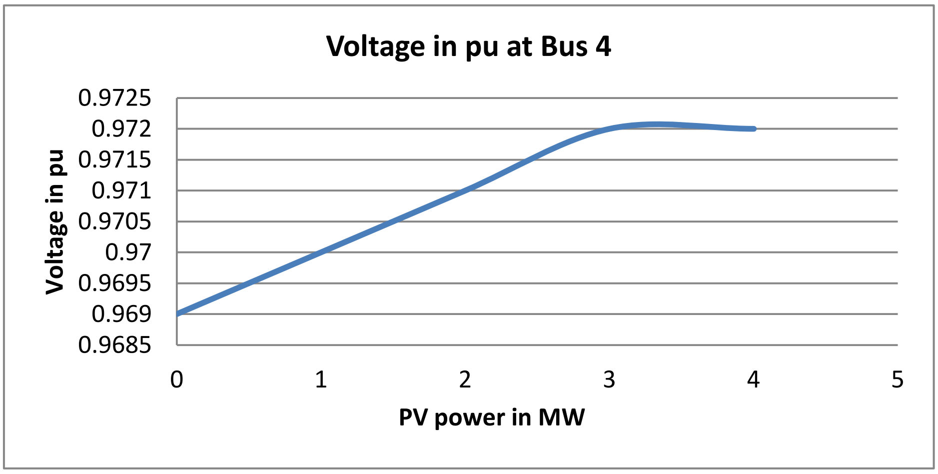

Figure 10: Voltage increment in pu at Bus 4 due to PV integration

The voltage at Bus 4 as shown in Figure 10, it has been improved from 0.969 to 0.972 pu while increasing the supplied power from PV farms between 1 to 4 MW respectively.

Table 7: Buses voltage during PV integration

Bus No/ PV power	0 MW	1MW	2MW	3MW	4MW
Bus 20 voltage in pu	0.94	0.941	0.942	0.943	0.944
Bus 35 voltage in pu	0.944	0.945	0.946	0.947	0.948
Bus 37 voltage in pu	0.937	0.937	0.938	0.939	0.94

Result observed in Table 7 for the selected Buses for study shows that voltage have been improved due to the increment of PV power supplied. Refer to Figure 11-12 to see the effect on Bus 20 and Bus 37.

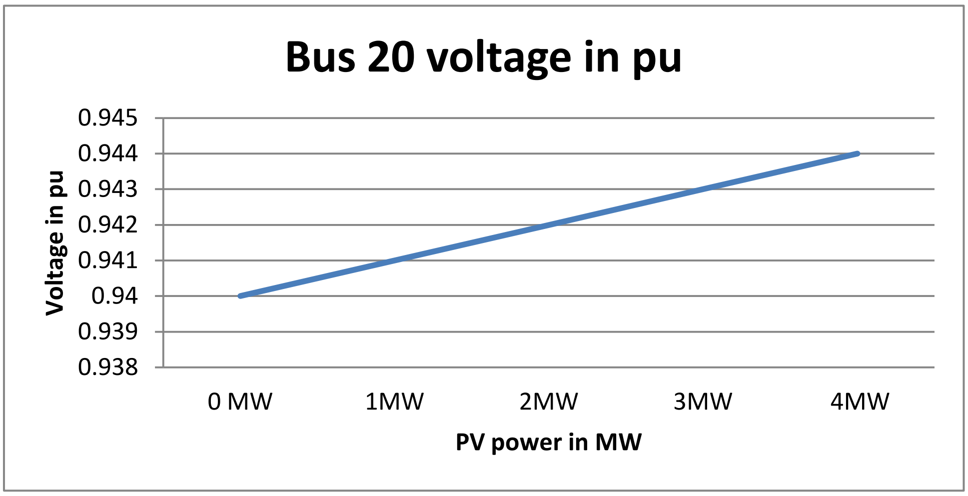

Figure 11: Voltage in pu at Bus 20

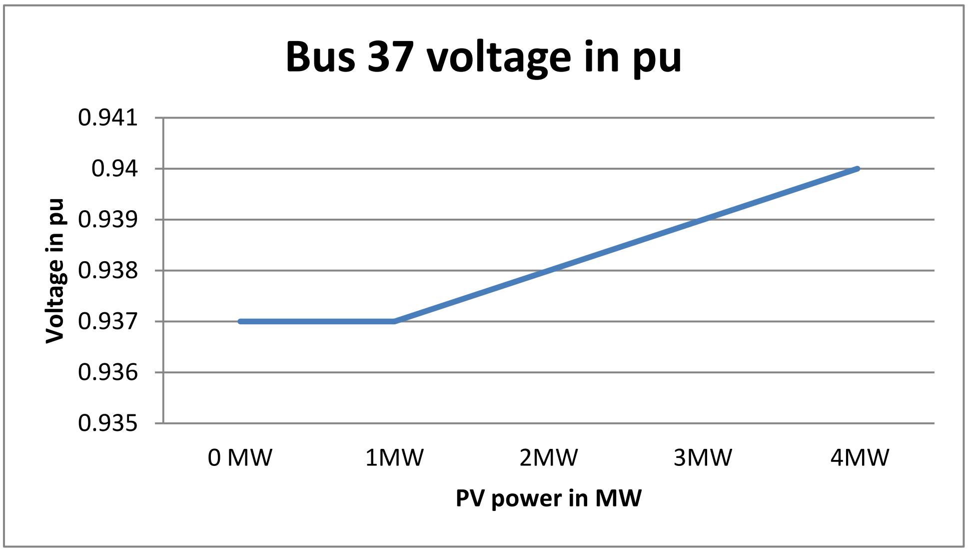

Figure 12: Voltage at Bus 37

Scenario 4: PV connection at Bus 30 (0.48 kV)

The load at Bus 30 is 0.731 MW at 0.48 kV, the power from PV will be supplied at an amount as follow, 0.250, 0.500, 0.750, 1 MW in order to study its effect on voltages at Bus 30, and 35 (See Figure 13). Taking in consideration that voltage of utility supply is at 0.98 pu and the transformers tap position for T-1 and T-2 are at -1

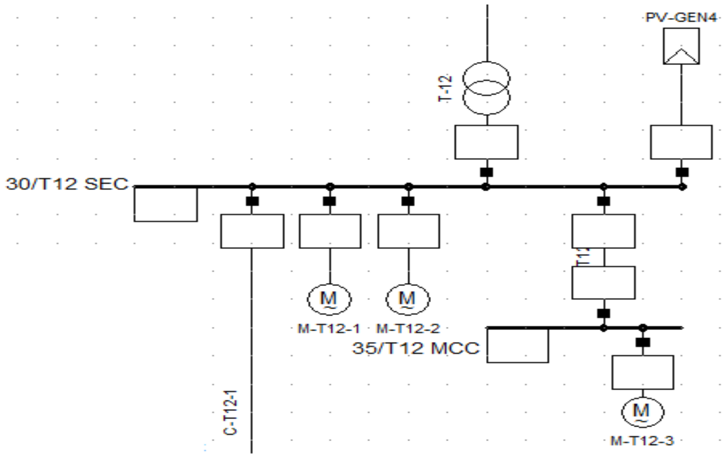

Figure 13: Integration of PV at Bus 30 (0.48kV)

Table 8: Voltages at Bus 30, and 35 during PV integration at Bus 30

Bus No/ PV power	0 MW	0.250MW	0.500MW	0.750MW	1 MW
Bus 30 voltage in pu	0.945	0.947	0.949	0.951	0.953
Bus 35 voltage in pu	0.944	0.946	0.948	0.95	0.952

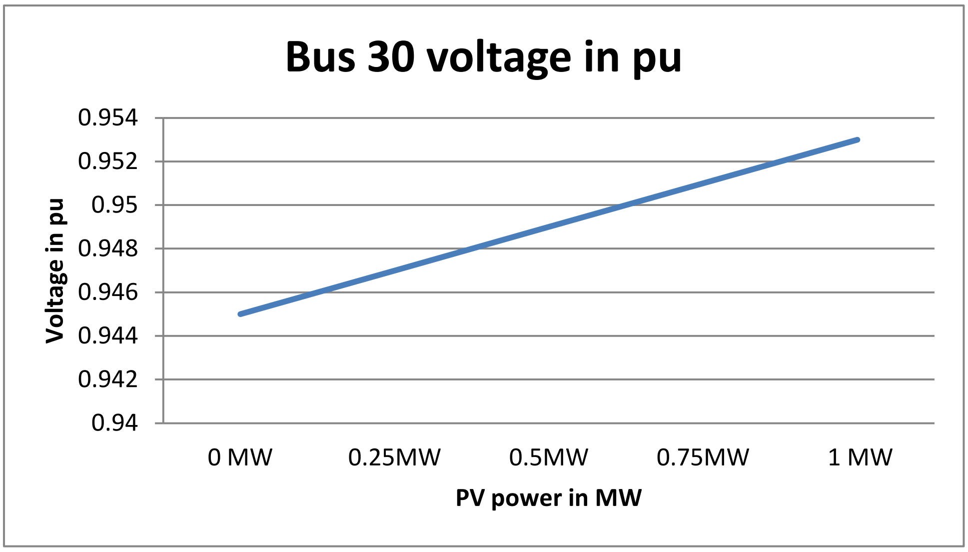

Figure 14: Voltages at Bus 3

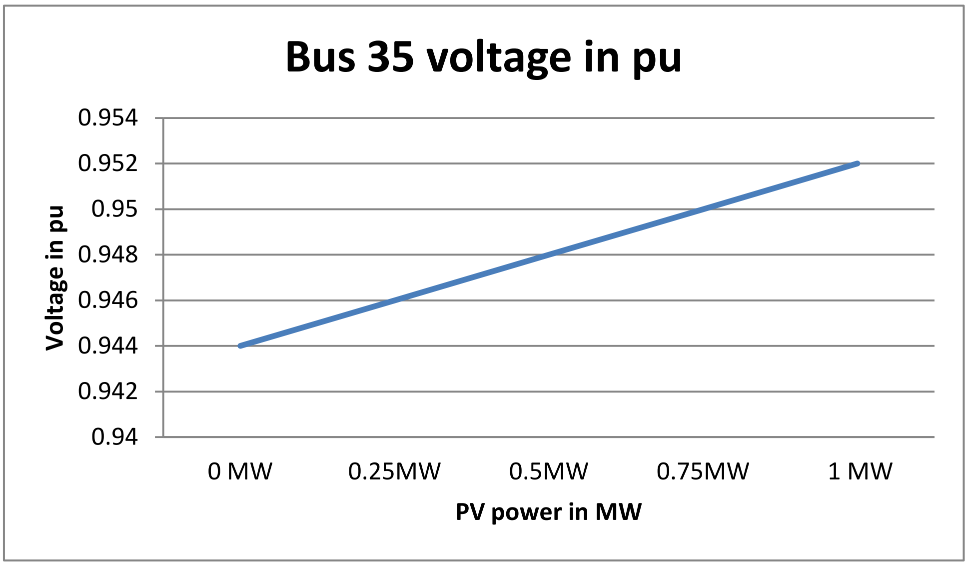

Figure 15: Voltages at Bus 35

The voltage at the load Buses (Bus 30, and Bus 35) increased exponentially with the increment of the power supplied from PV farm. (see Figure 14-15)

Scenario 5: PV connected at Bus 4 with GEN2 while GEN1is out of Service

In this scenario the system will be examined at the case when GEN1 is out of service and the PV is integrated at Bus 4 with GEN2 (under power factor mode of local voltage controller) while the utility supplying the voltage at 0.98 pu, and the transformer T-1 tap position at -1 and T-2 tap position is maintained at 0.

Table 9: Bus voltages during PV integration at Bus 4

Bus No/ PV power	0 MW	1MW	2MW	3MW	4MW
Bus 4 voltage in pu	0.98	0.981	0.981	0.982	0.982
Bus 8 voltage in pu	0.979	0.98	0.981	0.981	0.982
Bus 36 voltage in pu	0.95	0.951	0.951	0.952	0.952
Bus 37 voltage in pu	0.948	0.949	0.949	0.95	0.95

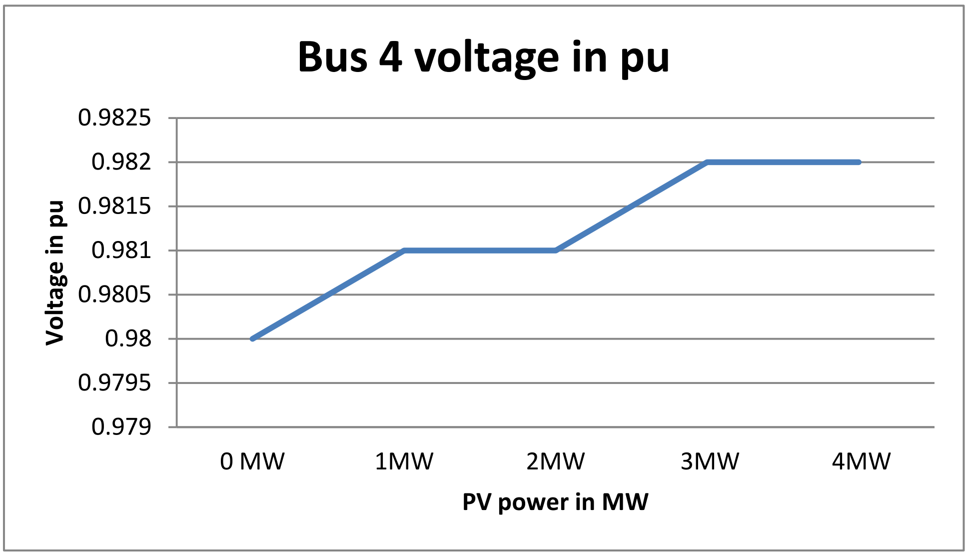

Figure 16: Voltage at Bus 4 during PV Integration at Bus 4

With reference to Table 9 the voltage at Buses are increasing but not exponentional relationship with the increment of the injected power from PV power plant. This might be due to the large loads connected to the Bus . When increasing the power supplied by PV plant the power drawn from the utility is reduced by the amount supplied by PV plant. In this scenario the maximum power supplied by PV is 4 MW. However the Buses which are far from point of interconnection are not highly affected with the amount of power drawn from the PV power plant. Figure 16-19 shows the effect of PV power on the Bus 4, Bus 8, Bus 36 and Bus 37.

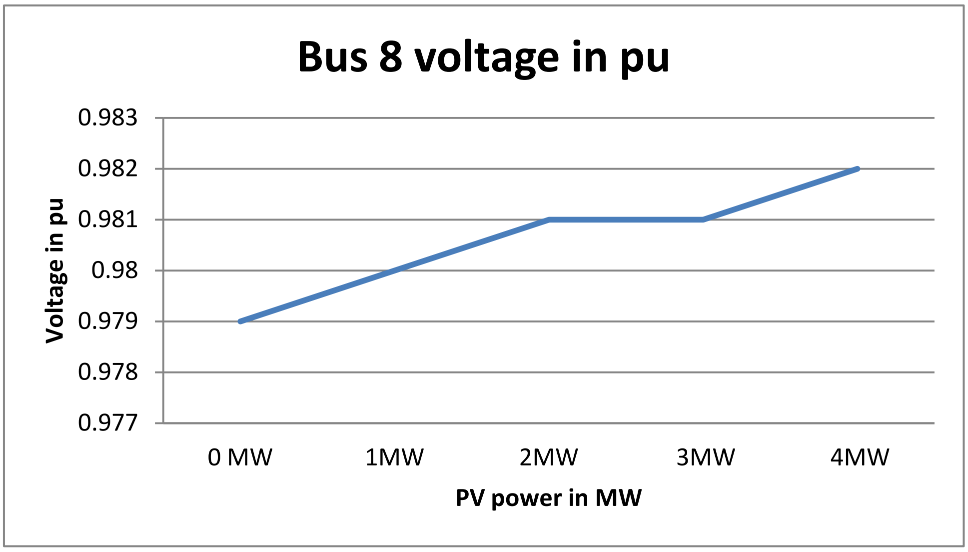

Figure 17: Voltage at Bus 8 during PV Integration at Bus 4

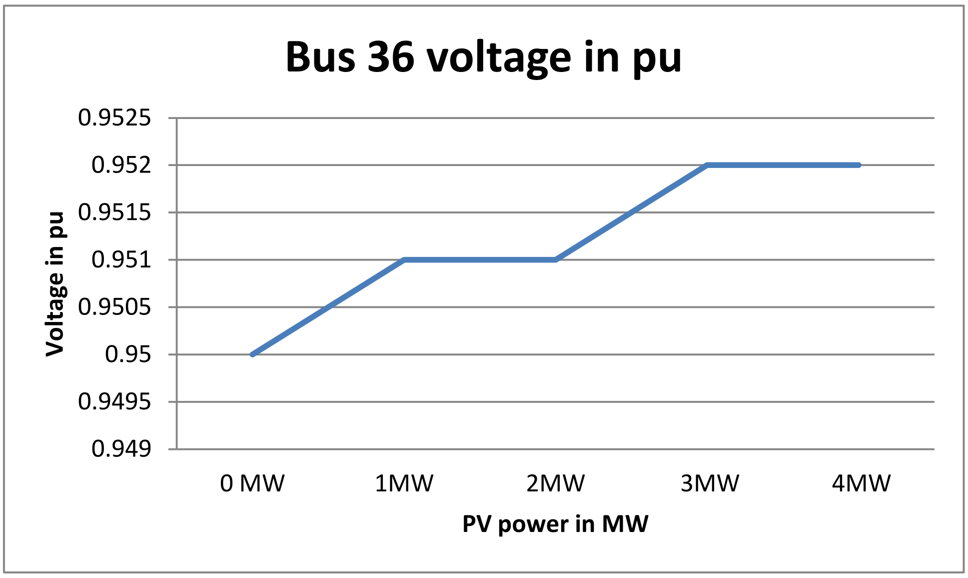

Figure 18: Voltage at Bus 36 during PV Integration at Bus 4

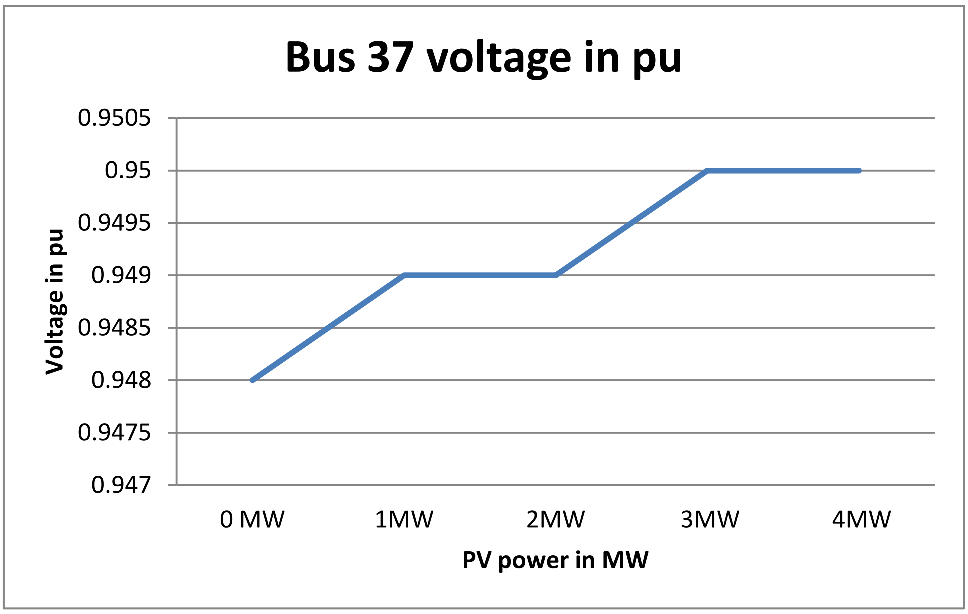

Figure 19: Voltage at Bus 37 during PV Integration at Bus 4

Scenario 6: PV connected at Bus 3 when GEN2 supplying at Bus 4 while GEN1 is out of Service

In this scenario the system will be examined at the case when GEN1 is out of service (see Figure 20) and PV is integrated at Bus 3 while GEN2 supplying at Bus 4 with the utility voltage at 0.98 pu, and the transformer T-1 tap position at -1 and T-2 tap position is maintained at 0.

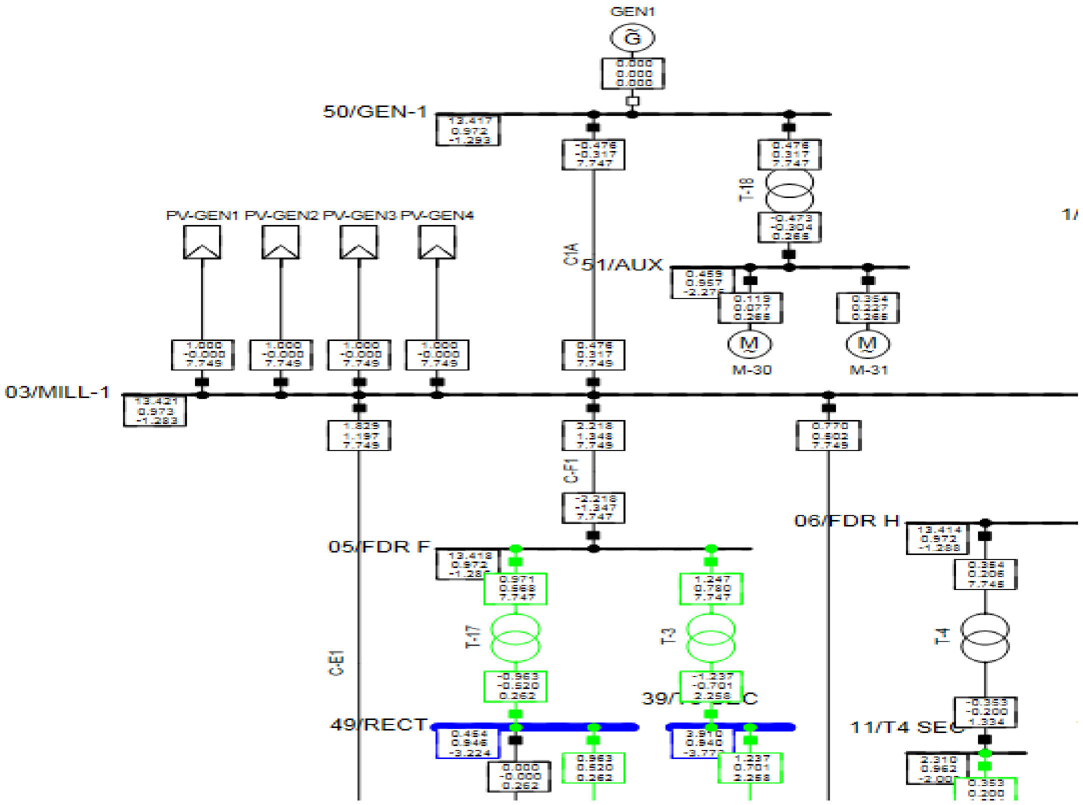

Figure 20: Integration of PV plant to the industrial system at Bus 3

Table 10: Bus voltages During PV integration at Bus 3

Bus No/ PV power	0 MW	1MW	2MW	3MW	4MW
Bus 3 voltage in pu	0.97	0.971	0.971	0.972	0.973
Bus 17 voltage in pu	0.934	0.935	0.936	0.936	0.937
Bus 19 voltage in pu	0.942	0.942	0.943	0.944	0.945
Bus 28 voltage in pu	0.942	0.943	0.943	0.944	0.945
Bus 39 voltage in pu	0.937	0.938	0.939	0.939	0.94

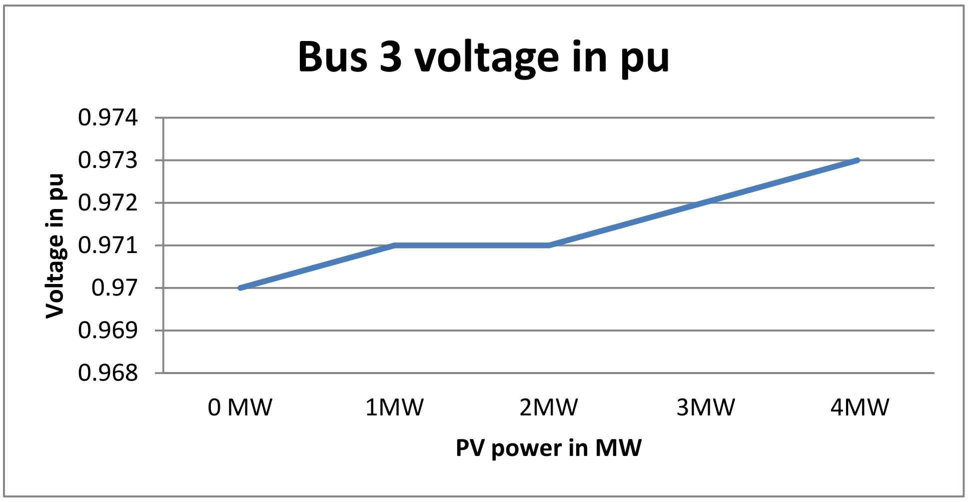

Figure 21: Voltage at Bus 3 during PV Integration at Bus 3

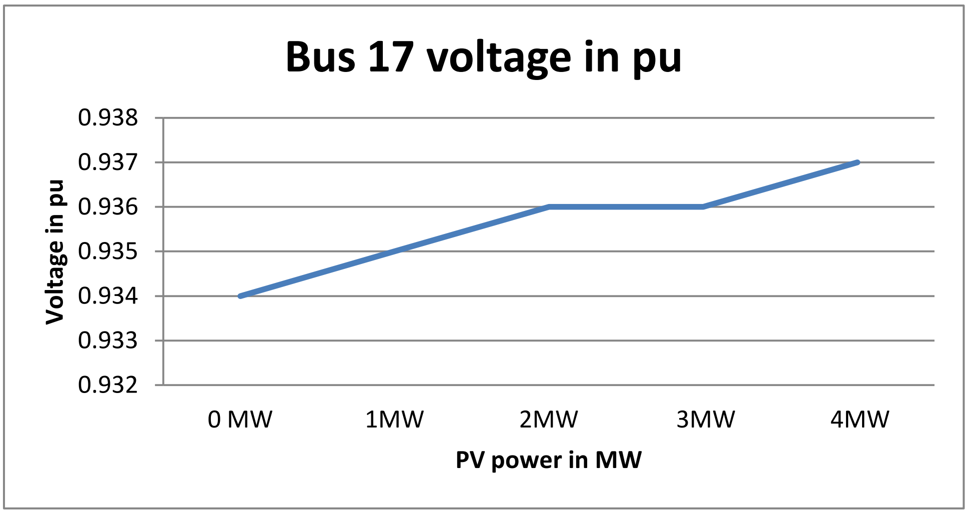

Figure 22: Voltage at Bus 17 during PV Integration at Bus 3

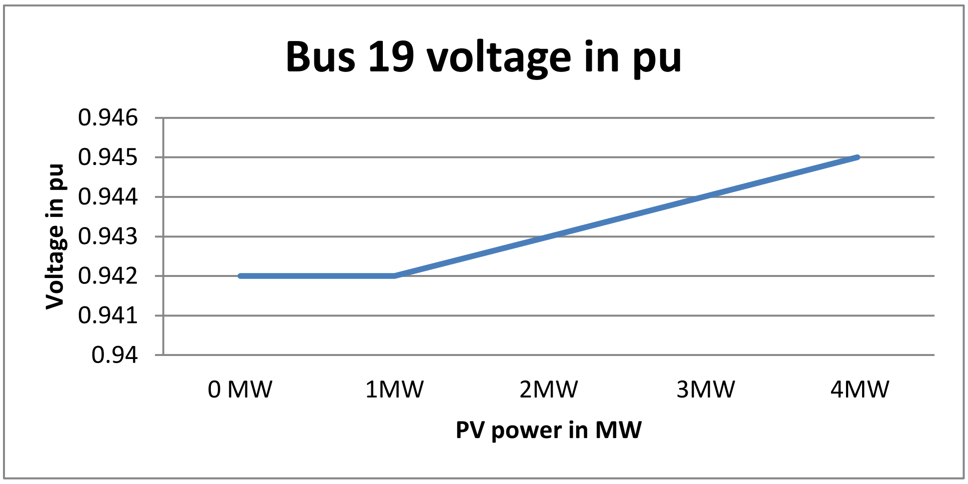

Figure 23: Voltage at Bus 19 during PV Integration at Bus 3

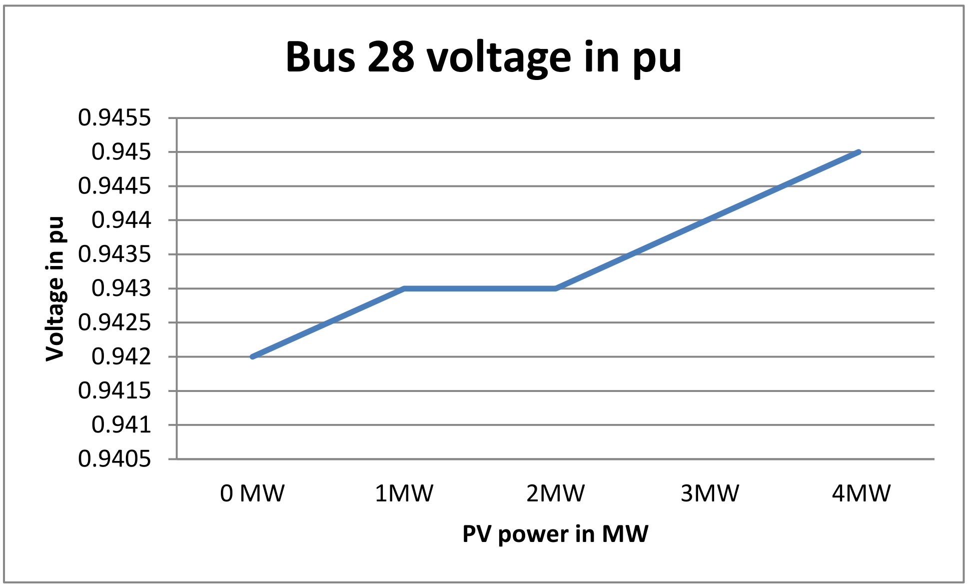

Figure 24: Voltage at Bus 28 during PV Integration at Bus 3

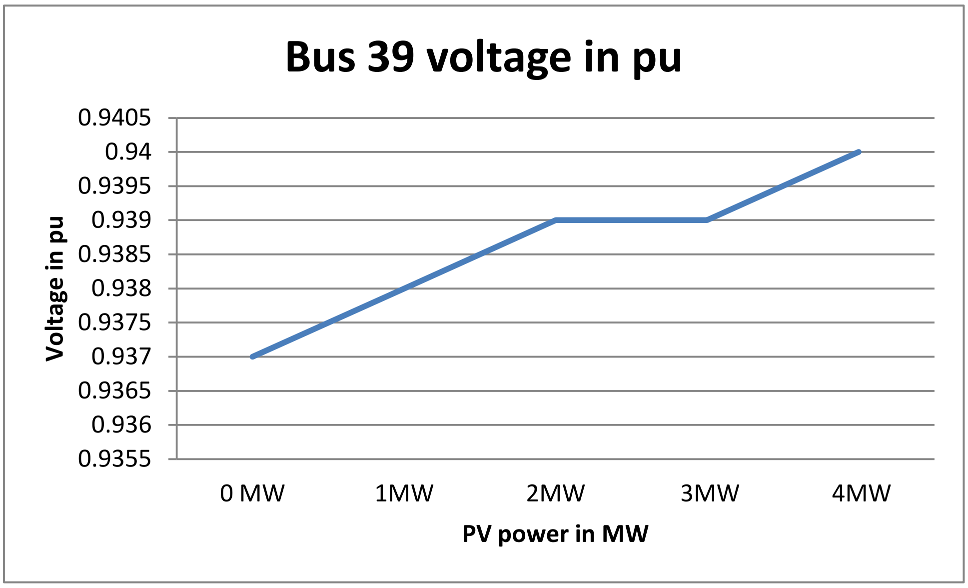

Figure 25: Voltage at Bus 39 during PV Integration at Bus 3

As shown Figure 21-25, the voltage at Bus 3,19,28,39 is not increasing exponentional with the increment of the injected power from PV power plant. This might be due to the large loads connected to the Bus . When increasing the power supplied by PV plant the power drawn from the utility is reduced by the same amount supplied by PV plant.

Scenario 7: GEN1 and GEN2 are in services, and the transformers taps all are in normal position 0, the utility supply power at voltage set point of 0.98pu

In this scenario the system will be examined with the integration of PV power to Bus 3 at the case when GEN1 and GEN2 are in service while the utility supplying the voltage at 0.98 pu, and all the transformer tap position is maintained at 0.

Results in Table 11 show that the Buses voltage increase very slightly with the increased power supplied by PV this is because the generators are in service supplying power to the industrial grid system. So the PV does not have high effect on the voltage in this scenario (see Figure 26-30).

Table 11: Bus voltages During PV integration at Bus 3

Bus No/ PV power	0 MW	1MW	2MW	3MW	4MW
Bus 3 voltage in pu	0.977	0.978	0.978	0.978	0.979
Bus 17 voltage in pu	0.942	0.942	0.943	0.943	0.943
Bus 19 voltage in pu	0.95	0.95	0.95	0.951	0.951
Bus 28 voltage in pu	0.95	0.95	0.95	0.951	0.951
Bus 33 voltage in pu	0.949	0.949	0.95	0.95	0.95

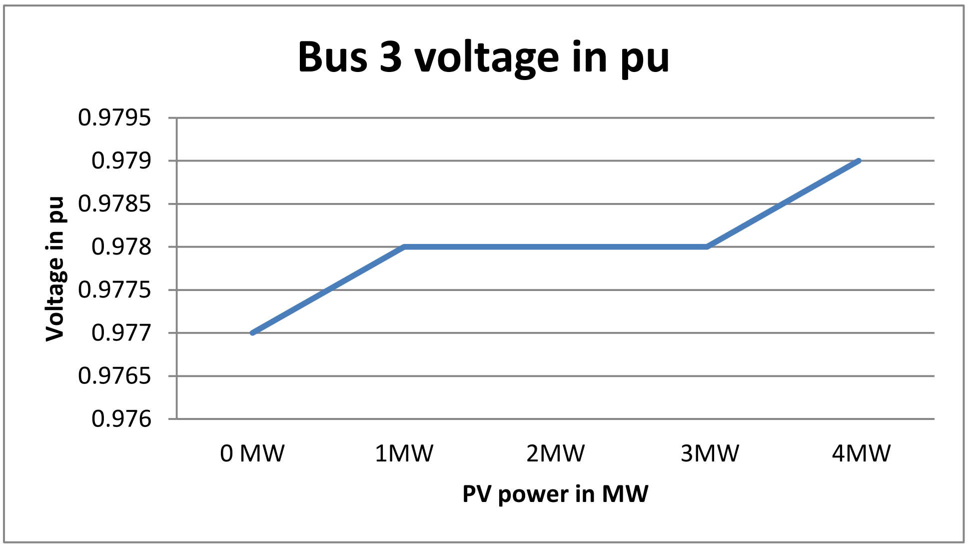

Figure 26: Voltage at Bus 3 when PV power integrated to the system at Bus 3

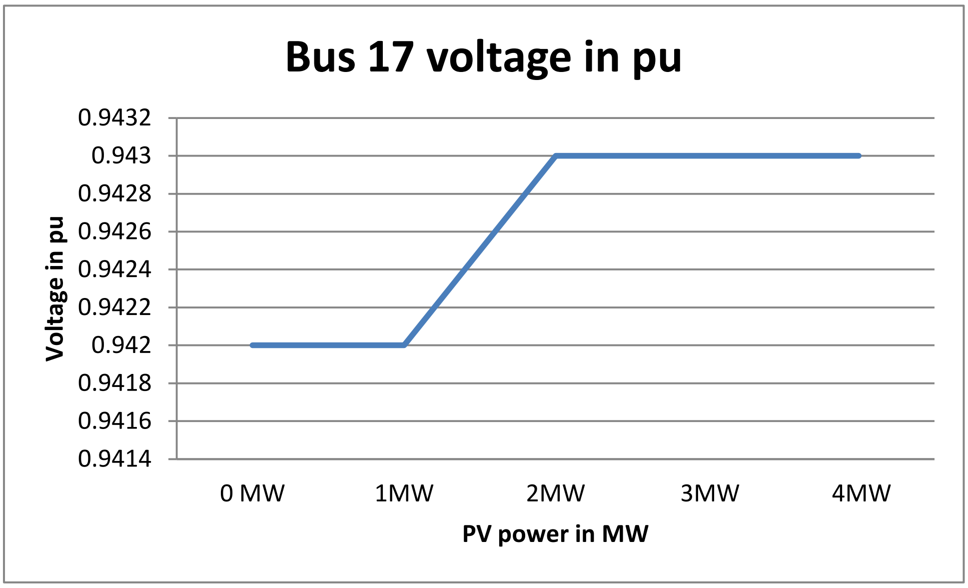

Figure 27: Voltage at Bus 17 when PV power integrated to the system at Bus 3

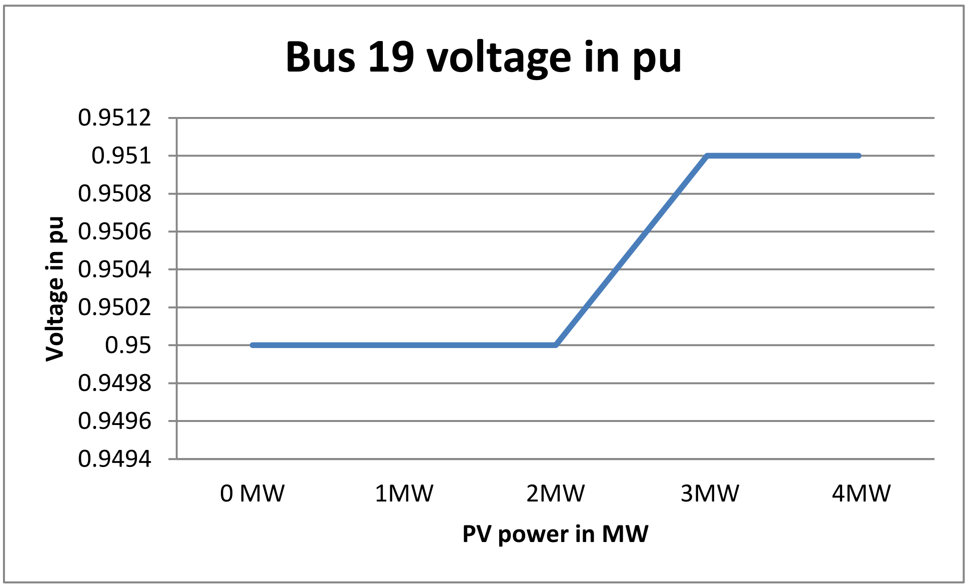

Figure 28: Voltage at Bus 19 when PV power integrated to the system at Bus 3

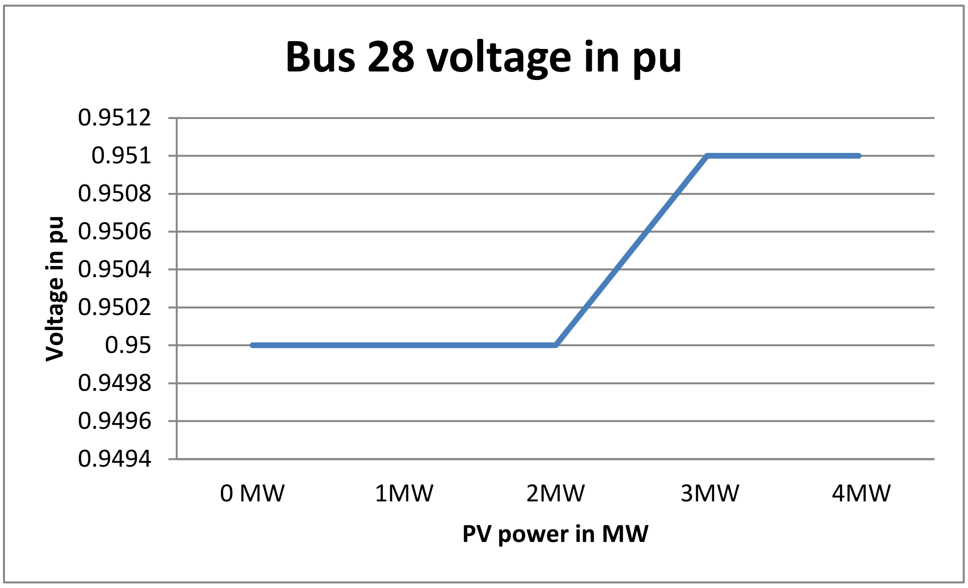

Figure 29: Voltage at Bus 28 when PV power integrated to the system at Bus 3

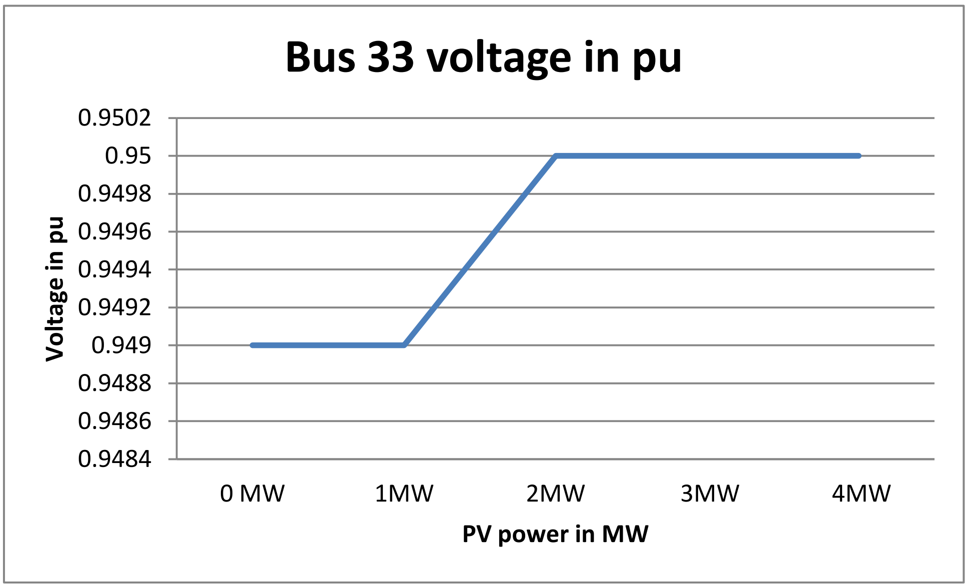

Figure 30: Voltage at Bus 33 when PV power integrated to the system at Bus 3

Scenario 8: PV Integration at Bus 4 when GEN2 is under Voltage Control Mode

Let us examine the system for the case when GEN2 at Bus 4 is integrated with PV power, and the mode of local voltage controller is voltage. The voltage of the power supplied from the grid is at 0.98 pu, and the transformers taps at position 0

Table 12: Bus voltages During PV integration at Bus 4

Bus No/ PV power	0 MW	1MW	2MW	3MW	4MW	8MW
Bus 4 voltage in pu	1	1	1	1	1	1
Bus 20 voltage in pu	0.972	0.972	0.972	0.972	0.972	0.972
Bus 23 voltage in pu	0.97	0.97	0.97	0.97	0.97	0.97
Bus 35 voltage in pu	0.976	0.976	0.976	0.976	0.976	0.976
Bus 37 voltage in pu	0.969	0.969	0.969	0.969	0.969	0.969

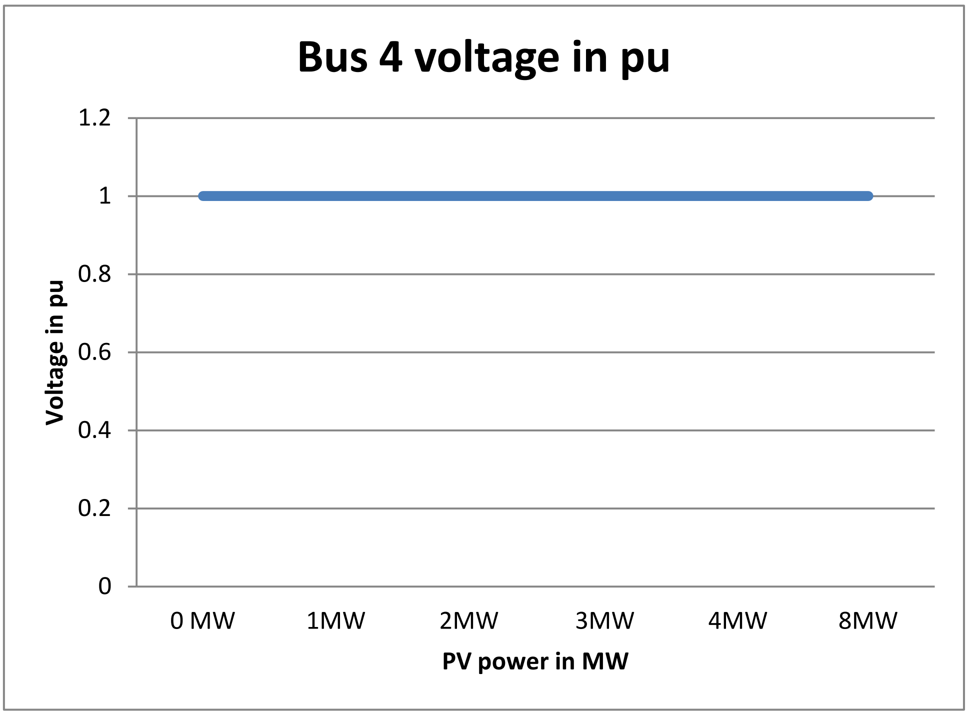

Figure 31: Voltage at Bus 4 when PV power integrated to the system at Bus 4

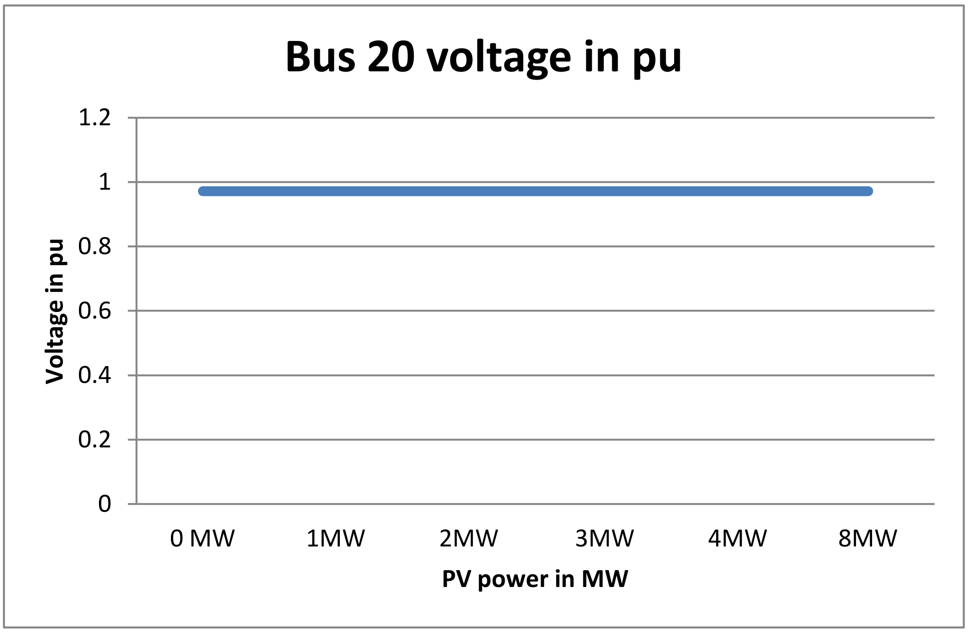

Figure 32: Voltage at Bus 20 when PV power integrated to the system at Bus 4

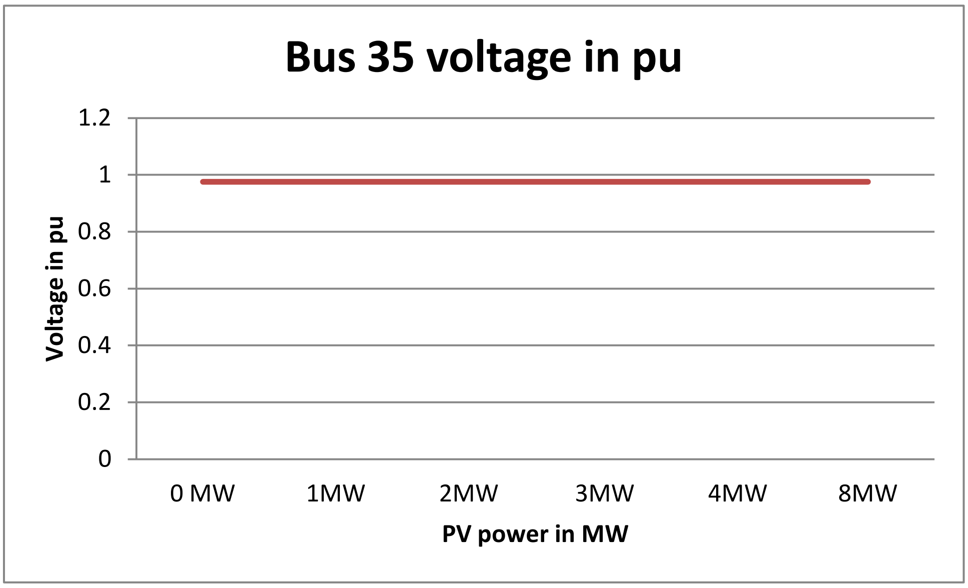

Figure 33: Voltage at Bus 35 when PV power integrated to the system at Bus 4

The results in Table 12 and Figure 31-33 show that when the generator is under voltage control mode, the voltage at the system Buses will not change when integrating the PV power to the grid system at Bus 4. The system Buses maintained its voltage when increasing the power supplied by the PV farms from 1 up to 8 MW.

Scenario 9: Over-head lines length increased from 3.048 km to 50 km

Assuming that the length of the overhead lines are increased, and the supply power from the grid is at 1.00 pu, all the transformers taps at position 0. The load flow analysis shows that the system is running normally with no problems in the voltages when the two generators are supplying power to the industrial system.

But in the case of utility is supplying power at 0.98 pu voltage, there will be a lot of voltage drop which leads to voltages below the lower voltage range at some of the load Buses. However the problem can be solved by changing the transformers taps to position -1 in order to improve the voltage at the load Buses. The voltage can also be improved when supplying power from PV.

Table 13: Voltage at Bus 2 after increasing OHL length to 50 km

Bus No/ PV power	0 MW	1MW	2MW	3MW	4MW
Bus 2 voltage in pu	0.968	0.971	0.974	0.976	0.979

Table 13 and Figure 34 shows that the voltage highly improved when increasing the power supplied by PV. This can be due to remote distance utility supply.

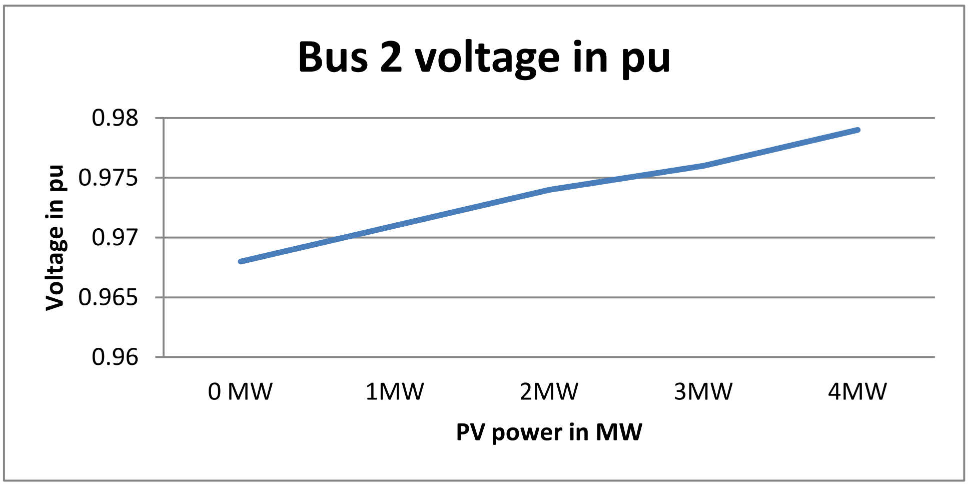

Figure 34: Voltage at Bus 2 when PV power integrated to the system at Bus 4

Table 14: Buses voltage after increasing OHL to 50 km

Bus No/ PV power	0 MW	1MW	2MW	3MW	4MW
Bus 4 voltage in pu	0.969	0.972	0.975	0.978	0.981
Bus 20 voltage in pu	0.94	0.944	0.947	0.95	0.953
Bus 23 voltage in pu	0.938	0.941	0.945	0.948	0.951
Bus 35 voltage in pu	0.944	0.947	0.951	0.954	0.957

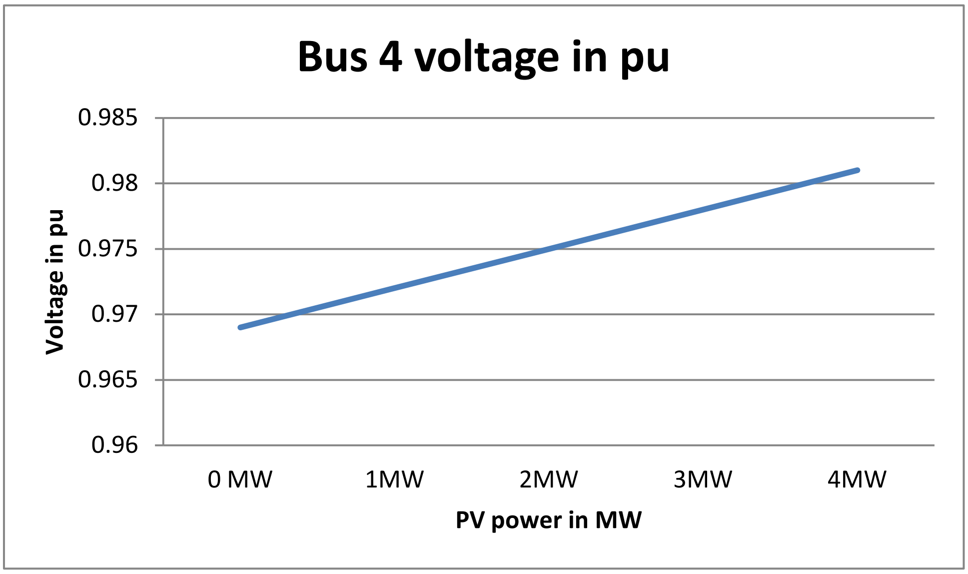

Figure 35: Voltage at Bus 4 when PV power integrated to the system at Bus 4

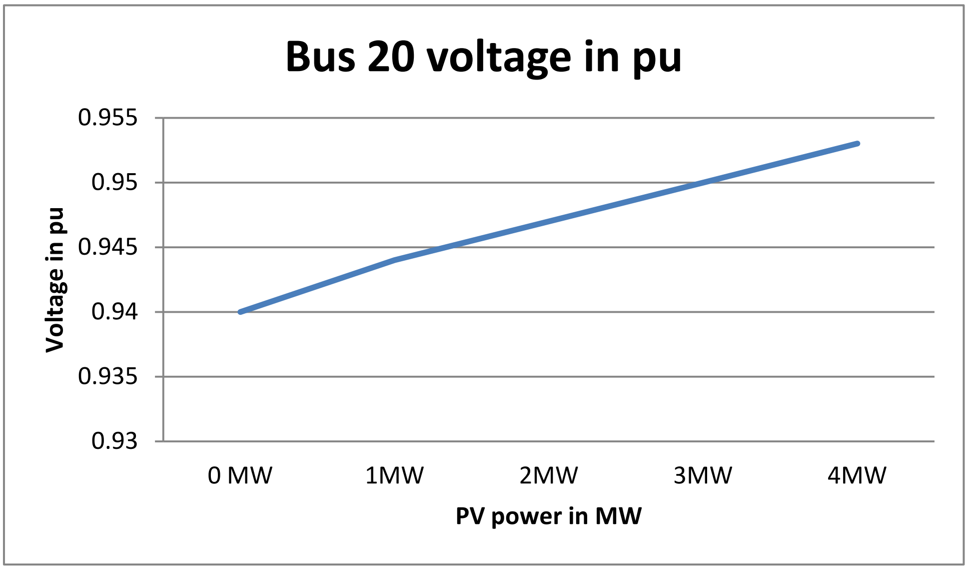

Figure 36: Voltage at Bus 20 when PV power integrated to the system at Bus 4

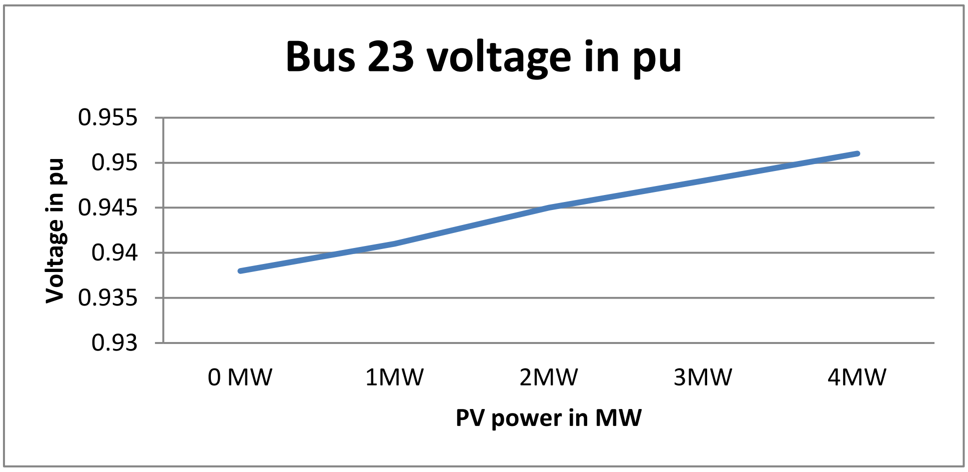

Figure 37: Voltage at Bus 20 when PV power integrated to the system at Bus 4

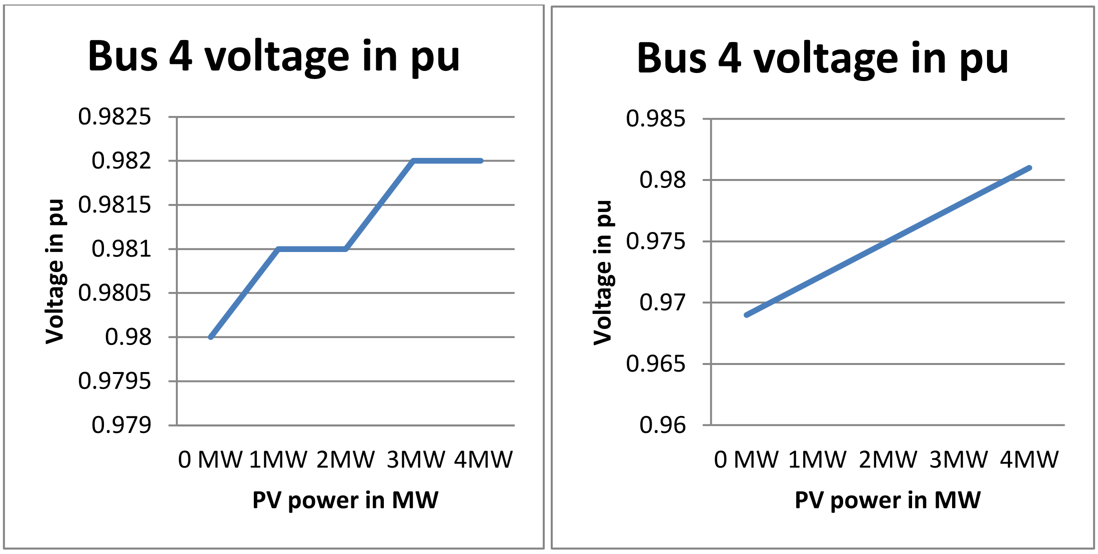

Figure 38: Comparison between PV effect when increasing the length of OHL

The results in Table 14 and Figure 35-38 show that increasing the length of the overhead lines to 50 km has clear effect on the power quality of the industrial system. But in this scenario it shows that the PV farms has very good contribution in improving the system voltages, comparing to the case when the length was 3.048 km. The voltage increased exponentially with increasing power supplied by PV. This proved that the PV farms has great contribution in improving the system voltage when the industrial system is far from the utility supply.

Scenario 10: Over-head Lines length increased from 3.048 km to 100 km

Table 15: Comparison of Voltages in pu at Buses during 3.048 km and 100 km

Bus No/ OHL length	OHL length=3.048km	OHL length=100km
Bus 1	1	1.005
Bus 2	0.999	0.976
Bus 3	0.998	1.003
Bus 4	1	0.976
Bus 20	0.972	0.948
Bus 23	0.97	0.946

In Table 15, the output results of load flow analysis show that the voltage of the Buses have been reduced due to the voltage drop of 100 km length of the overhead line comparing to the normal case of 3.048 km length. In this scenario the PV power will be integrated to the grid system of 100 km overhead lines to see the effect of PV power on Buses voltages.

The results in Table 16 and Figure 39-43 show that increasing the length of the overhead lines to 100 km has clear effect on the power quality of the industrial system. But in this scenario it shows that the PV farms has very good contribution in improving the system voltages, comparing to the case when the length was 3.048 km and 50 km. The voltage increased exponentially with increasing power supplied by PV. This proved that the PV farms has great contribution in improving the system voltage when the industrial system is far from the utility supply.

Table 16: Bus voltages During PV integration at Bus 4 during Scenario 10

Bus No/ PV power	0 MW	1MW	2MW	3MW	4MW
Bus 4 voltage in pu	0.976	0.983	0.989	0.995	1
Bus 8 voltage in pu	0.976	0.982	0.988	0.994	1
Bus 20 voltage in pu	0.948	0.955	0.961	0.967	0.973
Bus 23 voltage in pu	0.946	0.952	0.959	0.965	0.97
Bus 37 voltage in pu	0.944	0.951	0.957	0.963	0.969

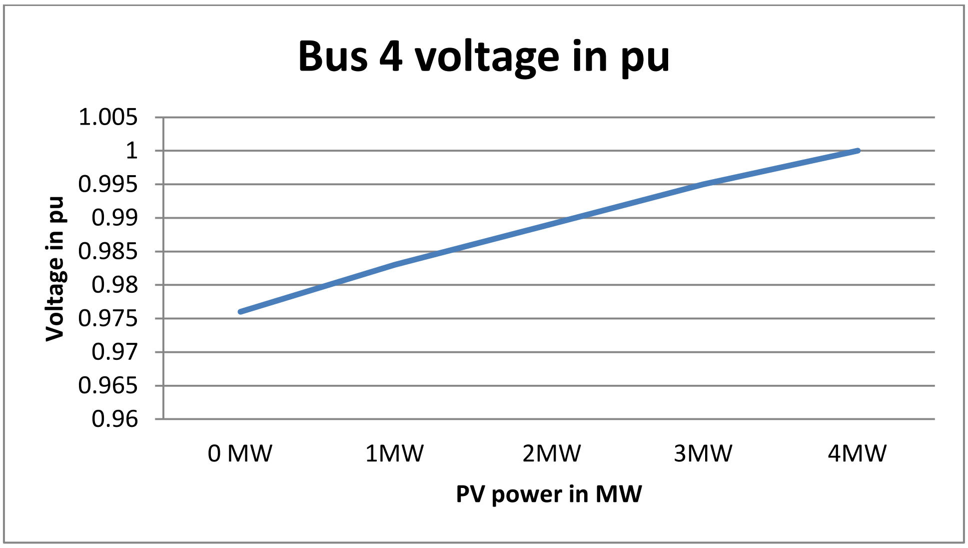

Figure 39: Voltage at Bus 4 during Scenario 10

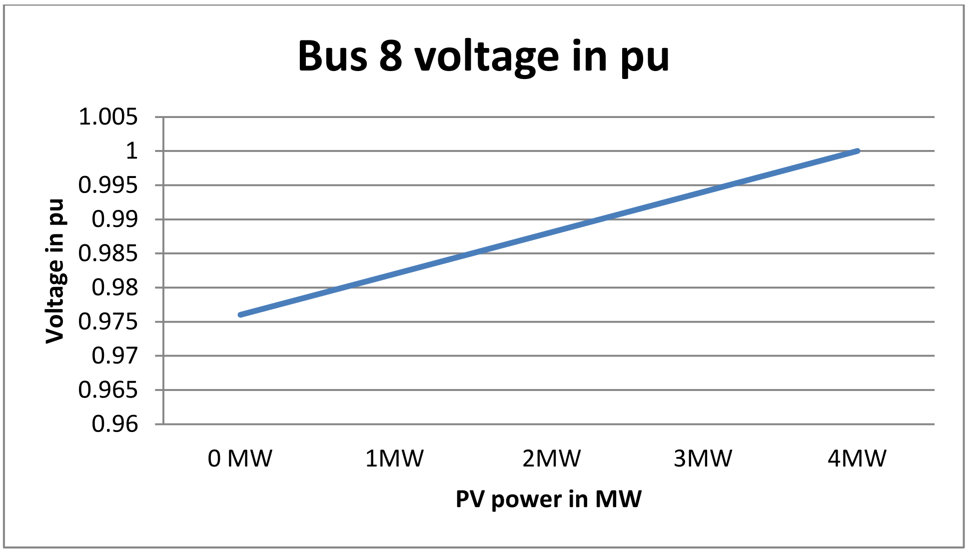

Figure 40: Voltage at Bus 8 during Scenario 10

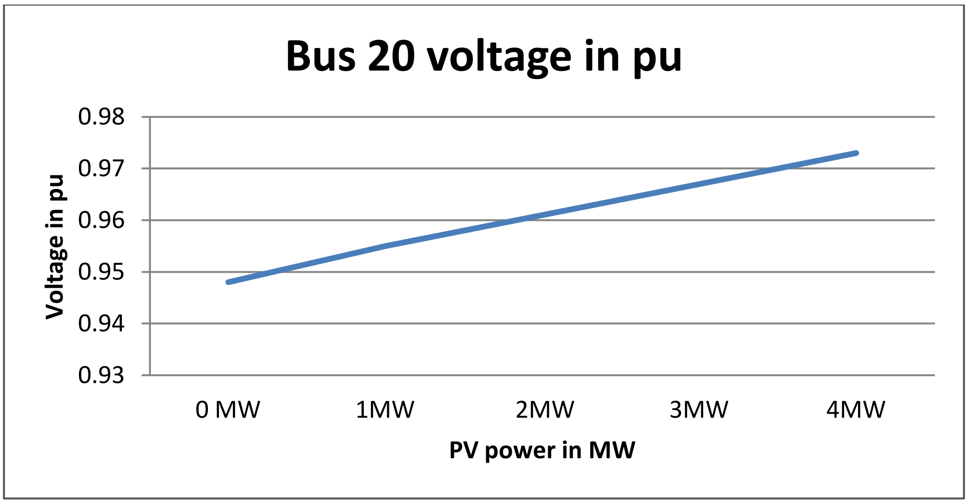

Figure 41: Voltage at Bus 20 during Scenario 10

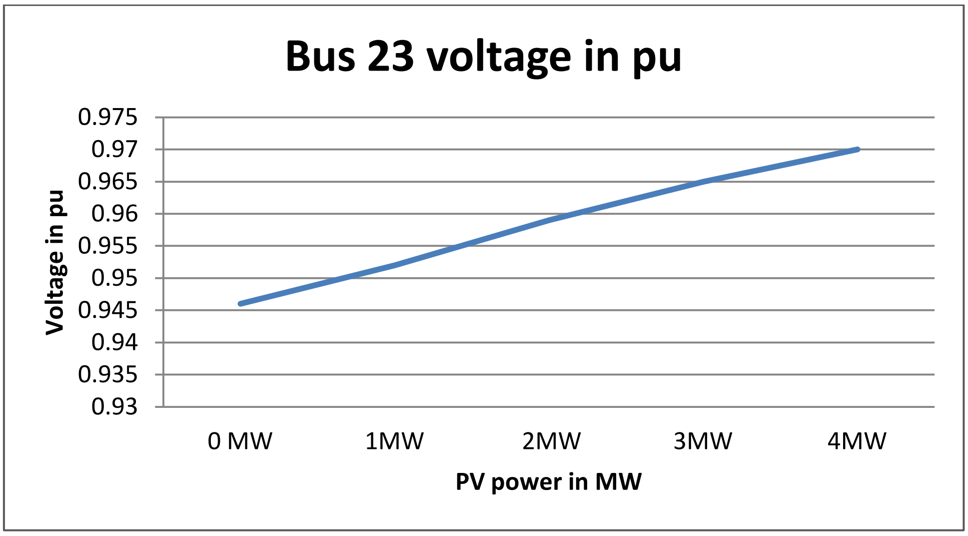

Figure 42: Voltage at Bus 23 during Scenario 10

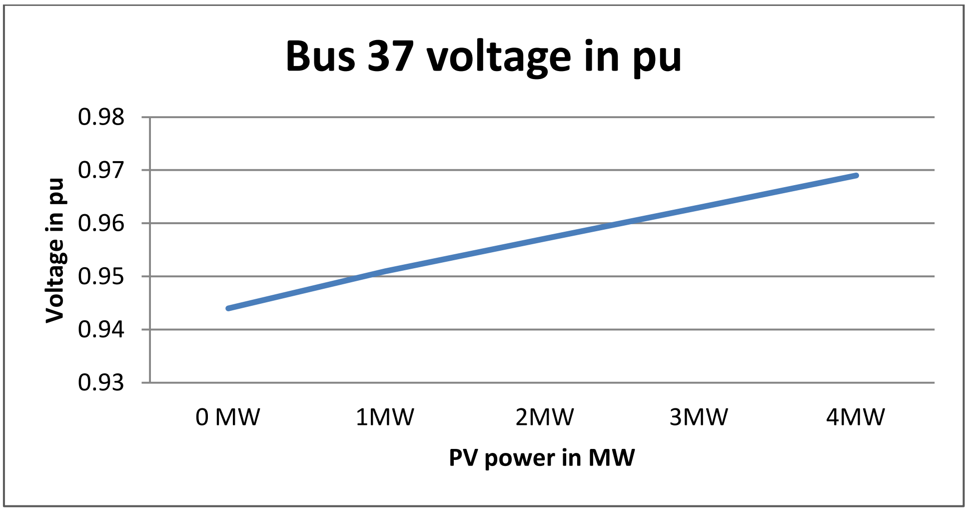

Figure 43: Voltage at Bus 3 during Scenario 10

4.2.4 Wind Farm grid integration

Scenario 11: The wind farm integrated to the industrial system at Mill-2, the maximum output of WF considered in this case is 5 MW

The utility grid supply power at 1.00 pu, and the power factor of the supplied power by the WF is 0.9 considering that all the system equipments running at the normal conditions. Results in Table 17 indicate Buses voltages for this scenario.

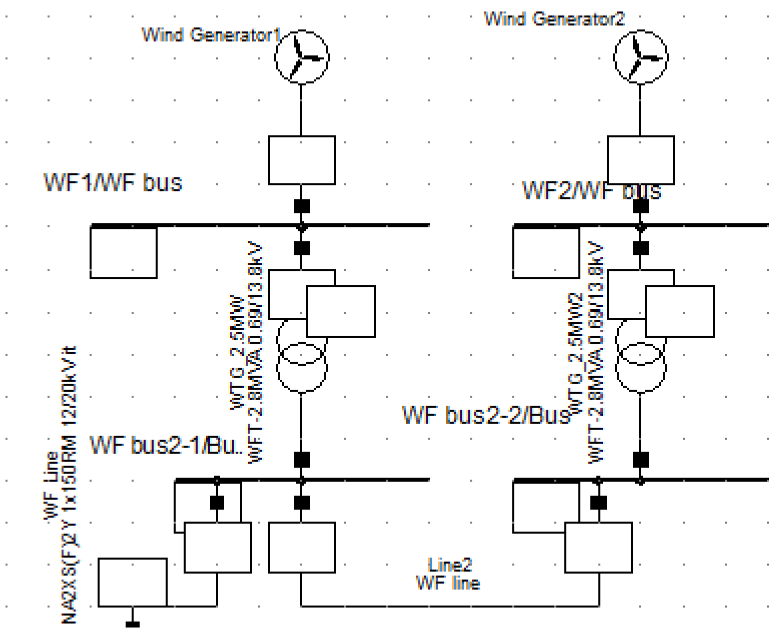

Figure 44: Wind Farm Generators

Table 17: Voltages in pu at the Buses during WF Integration to the System at Mill-2

Bus no/Wind Power in MW	0MW	1MW	2MW	3MW	4MW	5MW
Bus 4	1	1.001	1.001	0.999	0.997	0.994
Bus 18	0.971	0.971	0.972	0.97	0.968	0.964
Bus 20	0.972	0.973	0.974	0.972	0.969	0.966
Bus 21	0.971	0.972	0.972	0.97	0.968	0.965
Bus 23	0.97	0.971	0.972	0.97	0.967	0.964
Bus 35	0.976	0.977	0.977	0.976	0.973	0.97
Bus 36	0.971	0.971	0.972	0.97	0.968	0.964

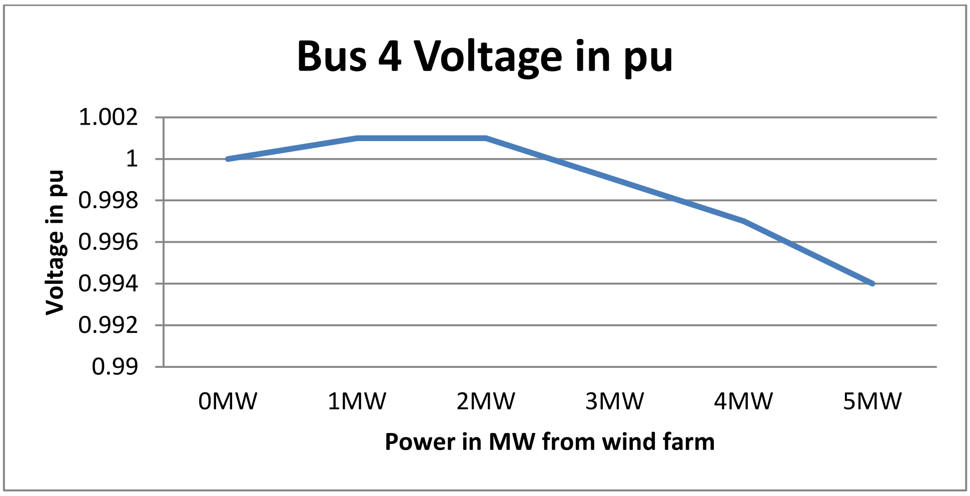

Figure 45: Voltage in pu at Bus 4 during Scenario 11

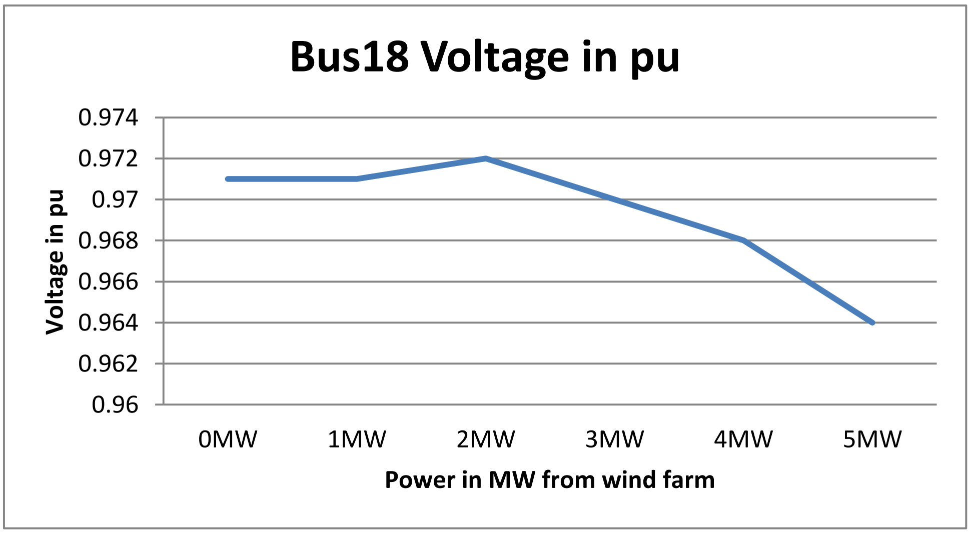

Figure 46: Voltage in pu at Bus 18 during Scenario 11

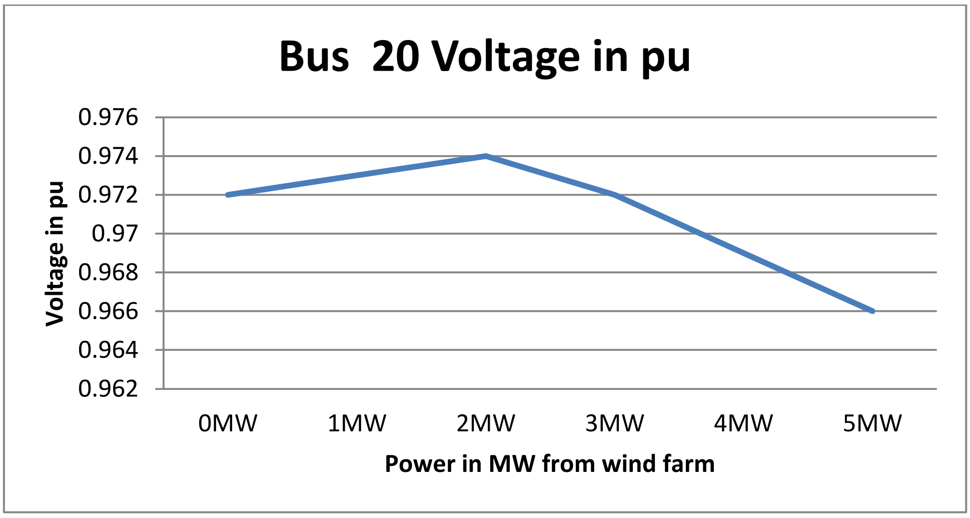

Figure 47: Voltage in pu at Bus 20 during Scenario 11

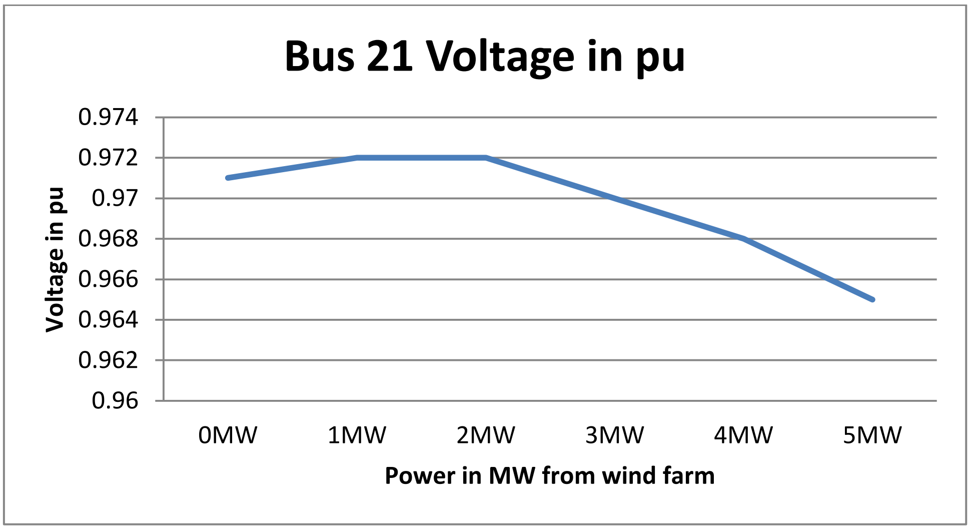

Figure 48: Voltage in pu at Bus 21 during Scenario 11

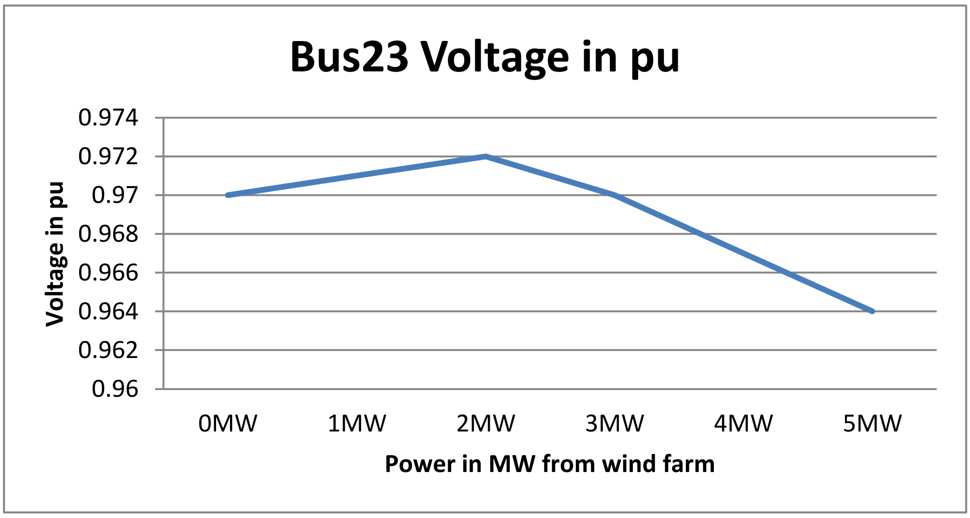

Figure 49: Voltage in pu at Bus 23 during Scenario 11

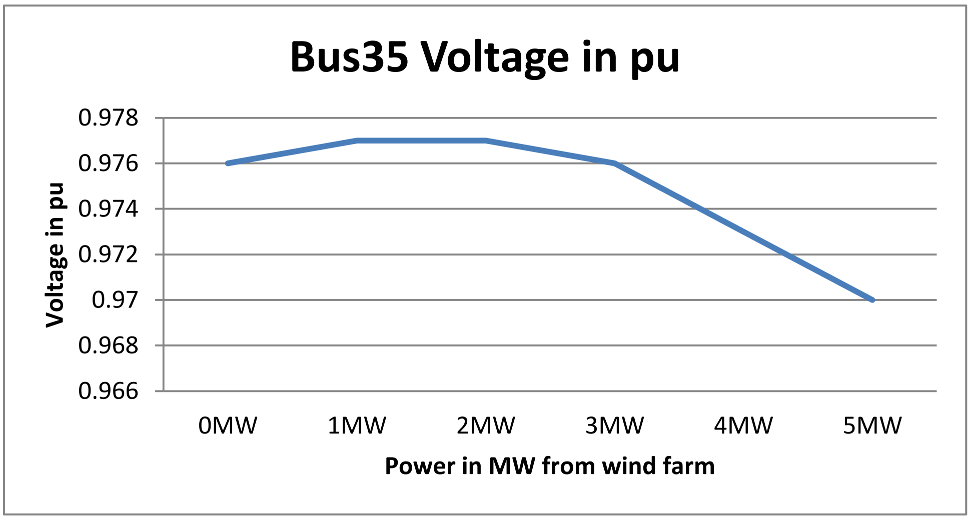

Figure 50: Voltage in pu at Bus 35 during Scenario 11

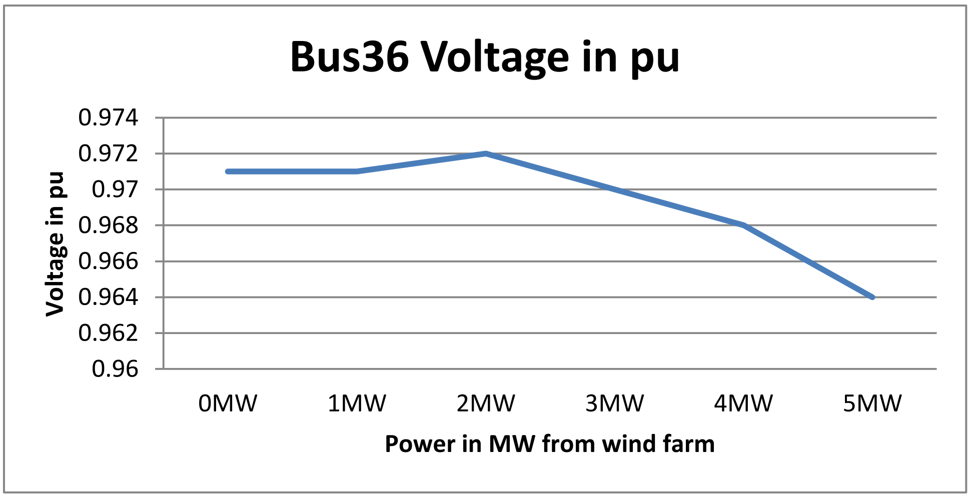

Figure 51: Voltage in pu at Bus 36 during Scenario 11

In Figure 45-51 the results show that the Buses voltage increases only when the supplied power from wind farm is below 40 % of the rated capacity of generator, and the buses voltage reduced by increasing the amount of power produced by the wind generators. The wind generators are induction generators type which consume reactive power that affect on the system voltages. The voltage level at Bus 4 reduced from 1 pu to 0.994 pu when the power generated by the wind generator increased up to 5 MW.

Scenario 12: The WF is integrated to the grid system at Mill-2 with the outage of GEN-2

In this scenario the system is being investigated when the GEN-2 is out of service and all the system equipments are running at the normal conditions. Refer to Table 18 and Figure 52-58 for Buses voltage.

Table 18: Voltages in pu at the Buses during WF to the System at Mill-2 with Outage of GEN-2

Bus no/Wind Power in MW	0MW	1MW	2MW	3MW	4MW	5MW
Bus 4 Voltage in pu	0.964	0.965	0.965	0.964	0.961	0.958
Bus 18 Voltage in pu	0.933	0.934	0.935	0.934	0.931	0.928
Bus 20 Voltage in pu	0.935	0.936	0.937	0.935	0.933	0.93
Bus 21 Voltage in pu	0.933	0.934	0.935	0.934	0.931	0.928
Bus 23 Voltage in pu	0.933	0.934	0.935	0.933	0.93	0.927
Bus 35 Voltage in pu	0.939	0.94	0.941	0.939	0.936	0.933
Bus 36 Voltage in pu	0.933	0.934	0.935	0.933	0.931	0.928

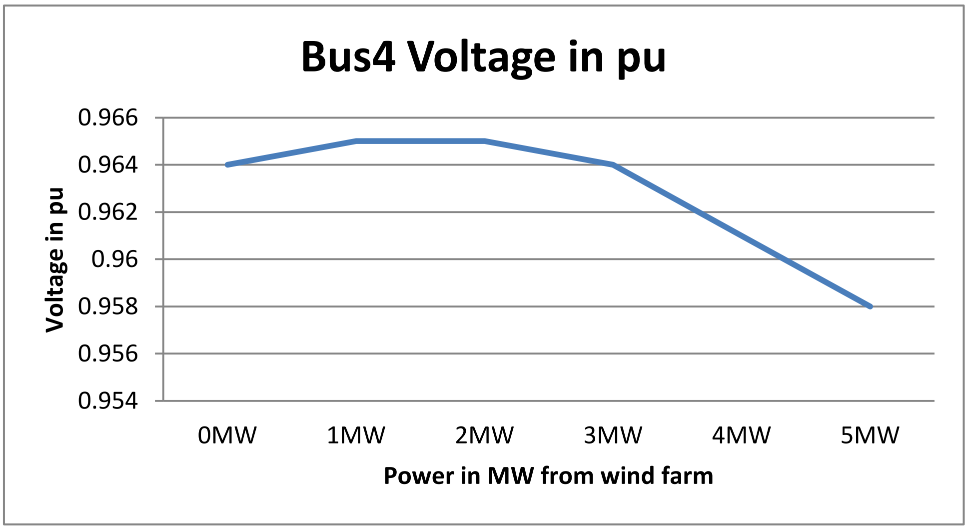

Figure 52: Voltage in pu at Bus 4 during Scenario 12

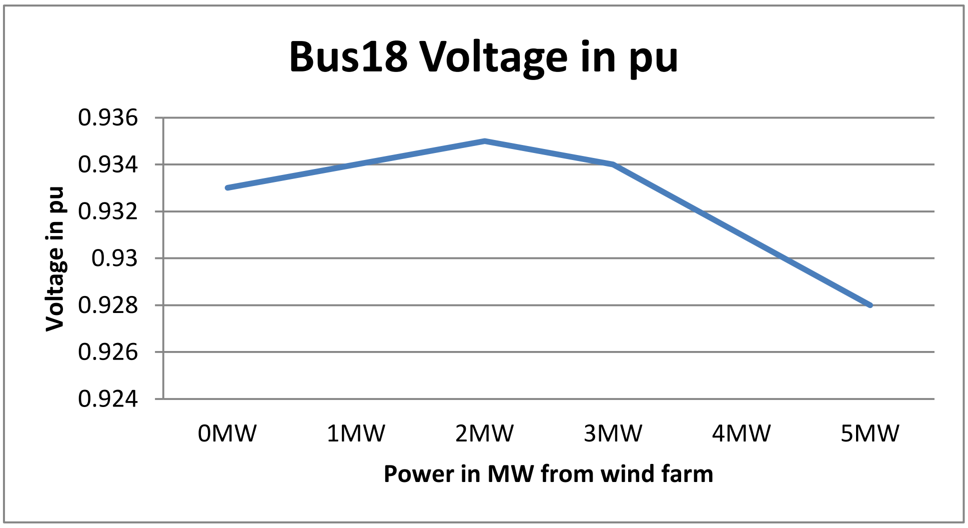

Figure 53: Voltage in pu at Bus 18 during Scenario 12

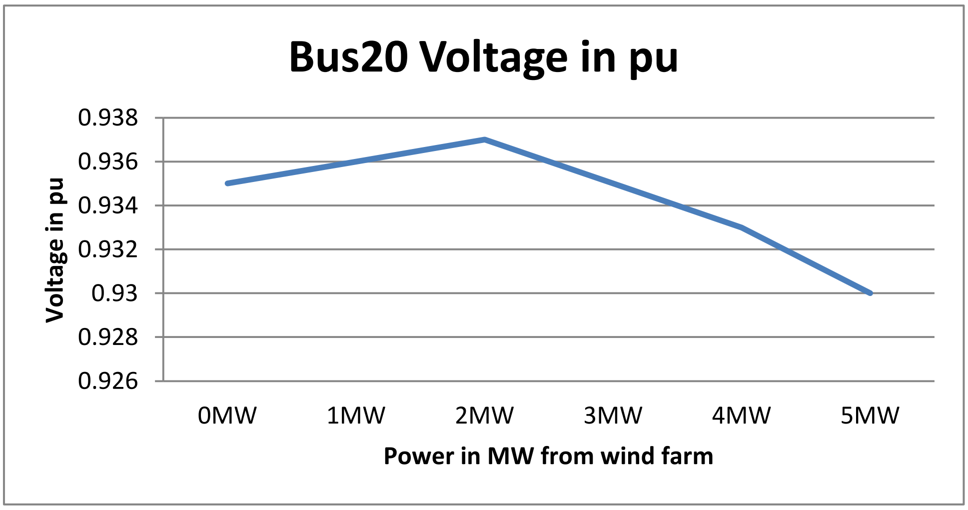

Figure 54: Voltage in pu at Bus 20 during Scenario 12

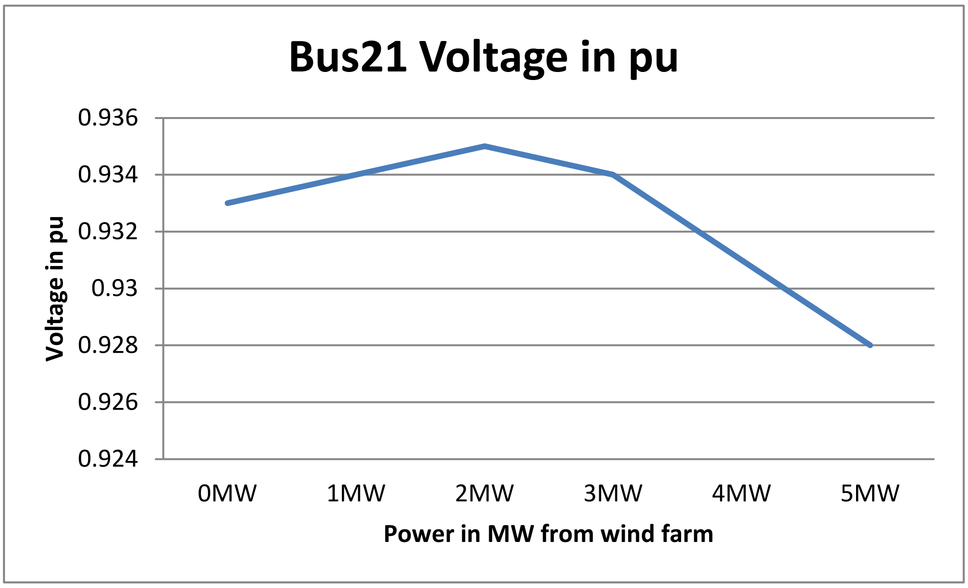

Figure 55: Voltage in pu at Bus 21 during Scenario 12

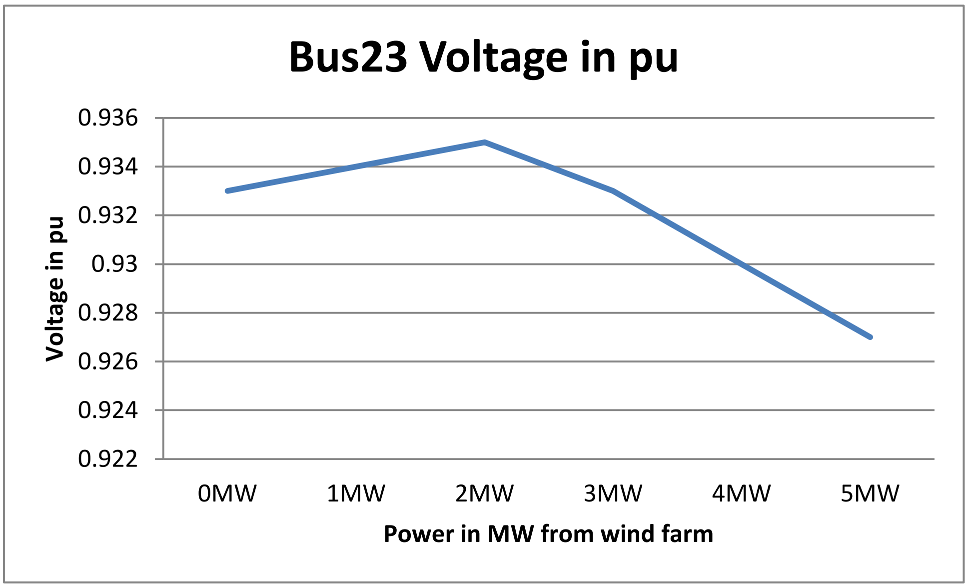

Figure 56: Voltage in pu at Bus 23 during Scenario 12

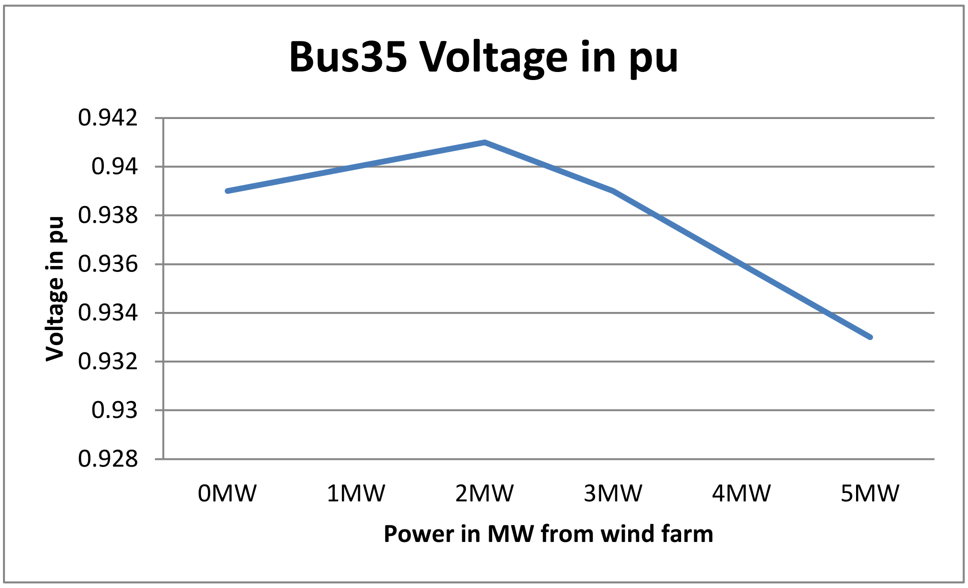

Figure 57: Voltage in pu at Bus 35 during Scenario 12

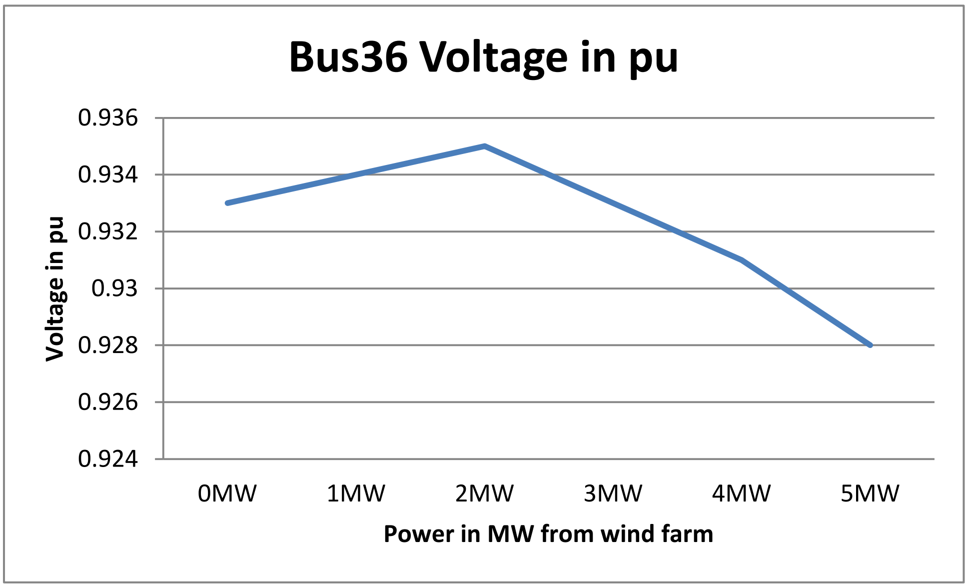

Figure 58: Voltage in pu at Bus 36 during Scenario 12

In the above scenario it shows that the Buses voltage reduced by increasing the amount of power produced by the wind generators, the wind generators are induction generators type which consume reactive power that affect on the system voltages.

The voltage level at Bus 4 reduced from 0.964 pu to 0.958 pu when the power generated by the wind generator increased up to 5 MW.

Scenario 13: When the over-head line length increased from 3.048 km to 100 km

The over-head line increased to 100 km and the GEN-2 is supplying electric power to the system. See Table 19 and Figure 59-65 for the Buses voltage.

Table 19: Voltages in pu at the Buses during WF to the System at Mill-2 with OHL of 100 km

Bus no/Wind Power in MW	0MW	1MW	2MW	3MW	4MW	5MW
Bus 4 Voltage in pu	0.976	0.983	0.989	0.988	0.985	0.981
Bus 18 Voltage in pu	0.946	0.953	0.959	0.959	0.955	0.951
Bus 20 Voltage in pu	0.948	0.955	0.961	0.96	0.957	0.952
Bus 21 Voltage in pu	0.946	0.953	0.959	0.959	0.956	0.951
Bus 23 Voltage in pu	0.946	0.952	0.959	0.958	0.955	0.95
Bus 35 Voltage in pu	0.952	0.958	0.964	0.964	0.961	0.956
Bus 36 Voltage in pu	0.946	0.953	0.959	0.959	0.955	0.951

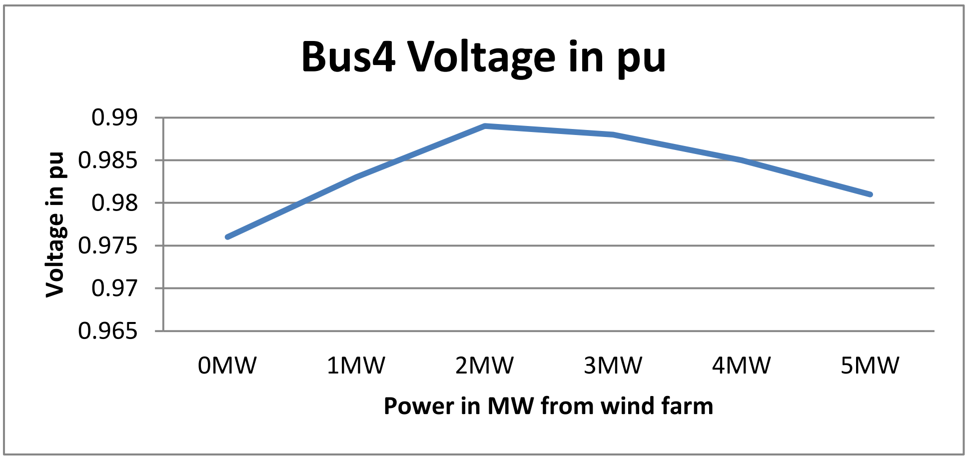

Figure 59: Voltage in pu at Bus 4 during Scenario 13

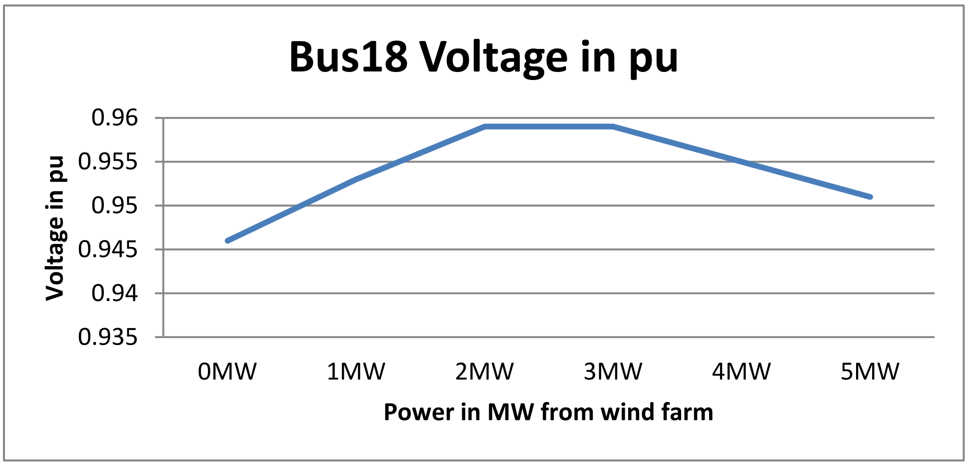

Figure 60: Voltage in pu at Bus 18 during Scenario 13

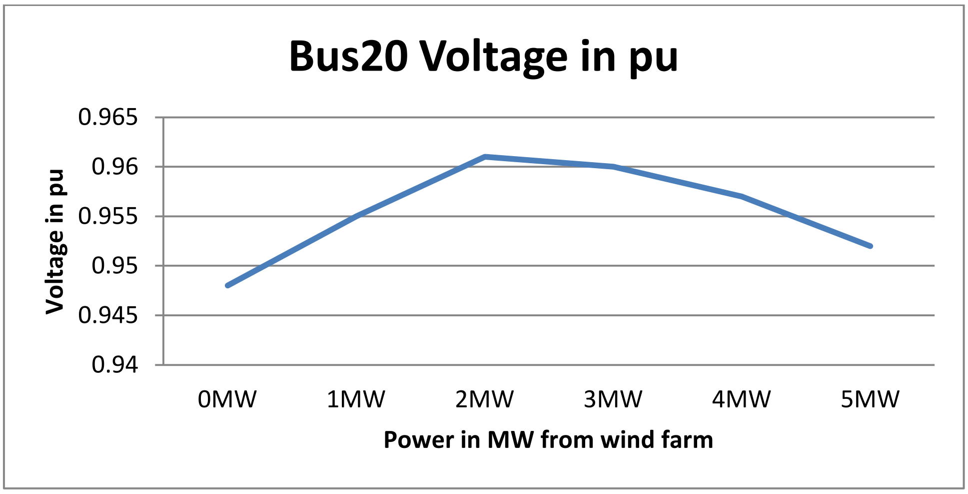

Figure 61: Voltage in pu at Bus 20 during Scenario 13

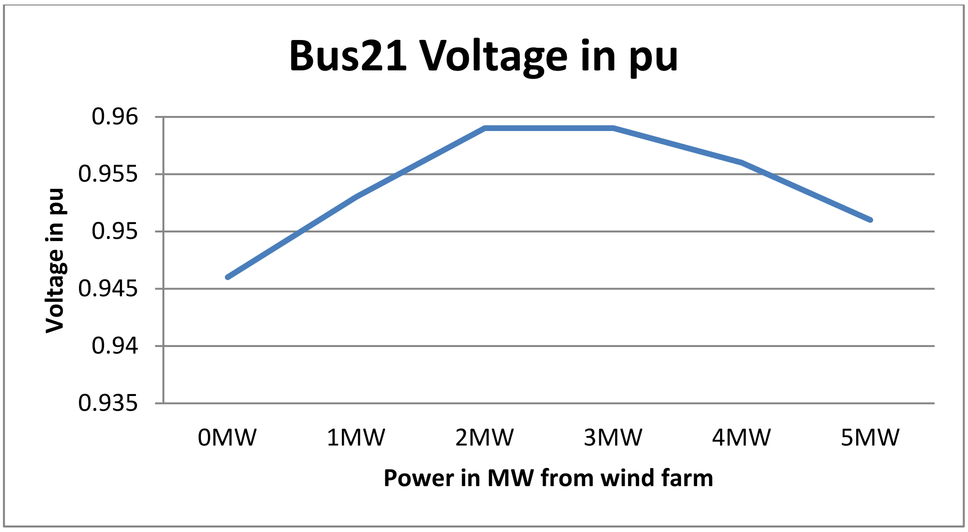

Figure 62: Voltage in pu at Bus 21 during Scenario 13

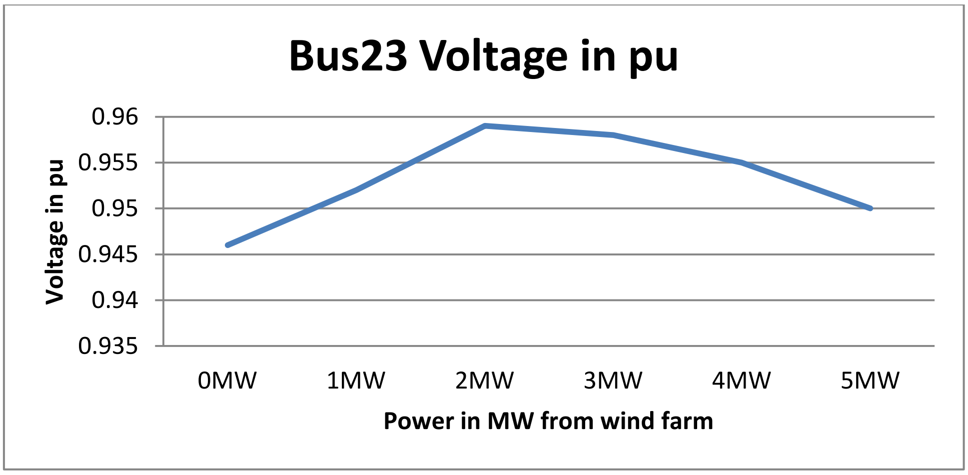

Figure 63: Voltage in pu at Bus 23 during Scenario 13

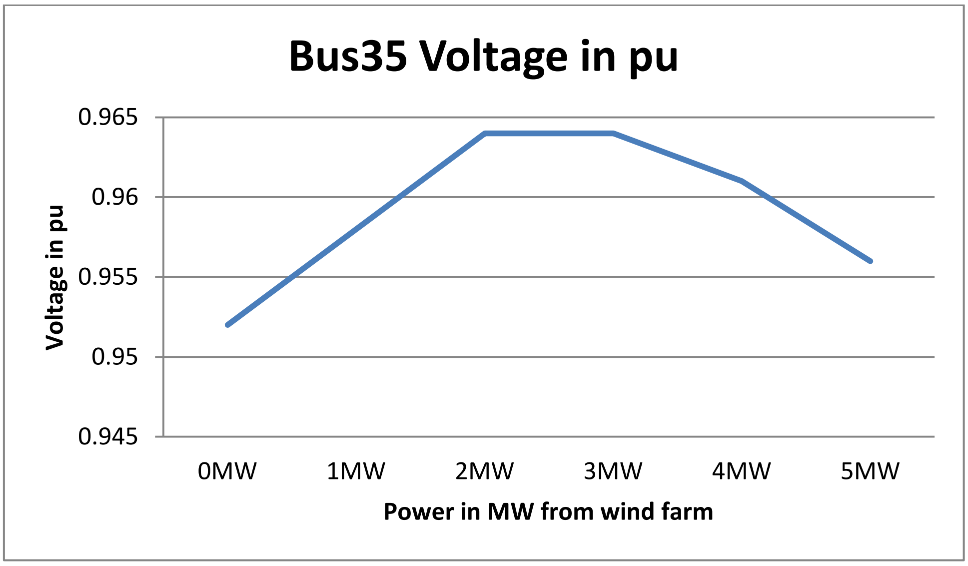

Figure 64: Voltage in pu at Bus 35 during Scenario 13

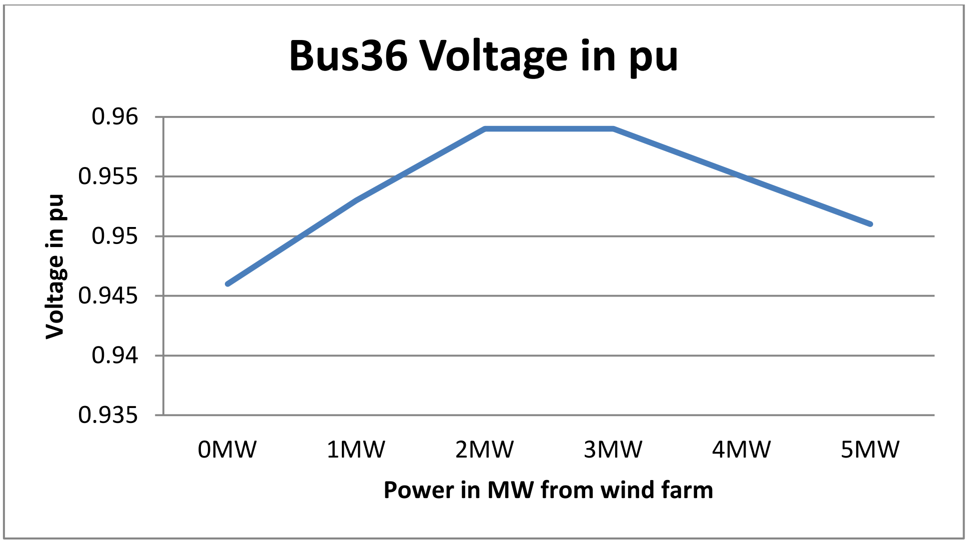

Figure 65: Voltage in pu at Bus 36 during Scenario 13

As shown in Figure 59-65, the voltage level at Buses have increased when the supply power from wind generators increased from 0 MW to 2 MW, this is due to the long distance power transmission cables of 100 km. But when the wind power generated are more than 2 MW the Bus voltages reduced due to reactive power consumption by induction generators. The reactive power consumption can be compensated by capacitor bank to reduce the reactive power compensated from the industrial grid system.

4.2.5 Integrating both PV power & Wind power to the industrial grid system

Scenario 14: Integrating 2 MW PV power with variable power from wind farm at Bus 4

The system is operating under normal operating conditions, the generators supplying the power to the industrial grid system, some of the power needed by the grid are supplied by the utility in case that the power generated is not enough to supply the grid and if all the generators including the wind farms are generating power more than the power needed, the remaining power will be supplied to the grid. The Buses voltage has been tabulated in Table 20.

Table 20: Voltage level in pu at Buses During the Integration of 2 MW PV power and variable Wind Power at Bus 4

Bus No/Wind Power	1 MW	2 MW	3 MW	4 MW	5 MW
Bus 4	1.002	1.002	1	0.998	0.995
Bus 8	1.001	1.002	1	0.997	0.994
Bus 18	0.973	0.973	0.971	0.969	0.965
Bus 20	0.974	0.975	0.973	0.97	0.967
Bus 21	0.973	0.973	0.971	0.969	0.966
Bus 30	0.979	0.979	0.978	0.975	0.972
Bus 37	0.971	0.971	0.969	0.967	0.963

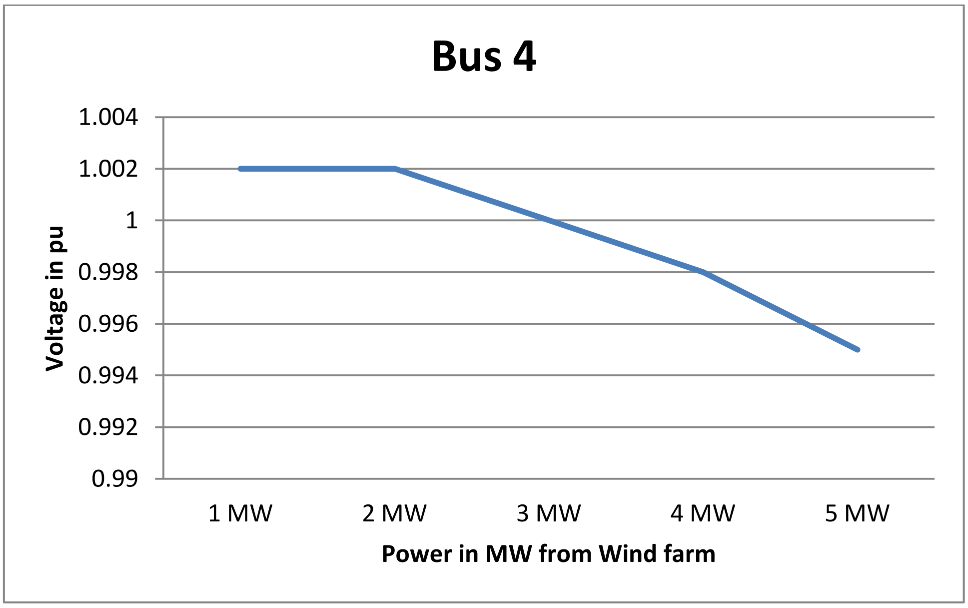

Figure 66: Voltage in pu at Bus 4 during Scenario 14

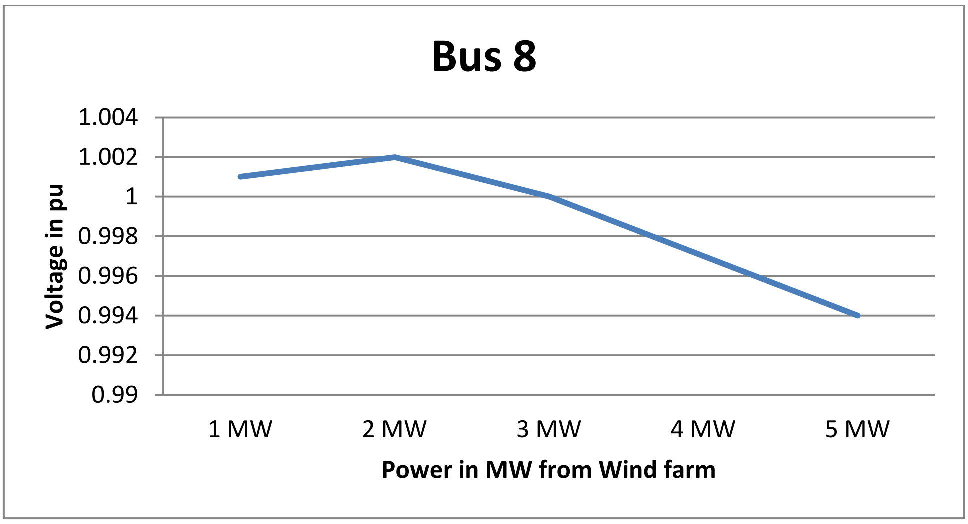

Figure 67: Voltage in pu at Bus 8 during Scenario 14

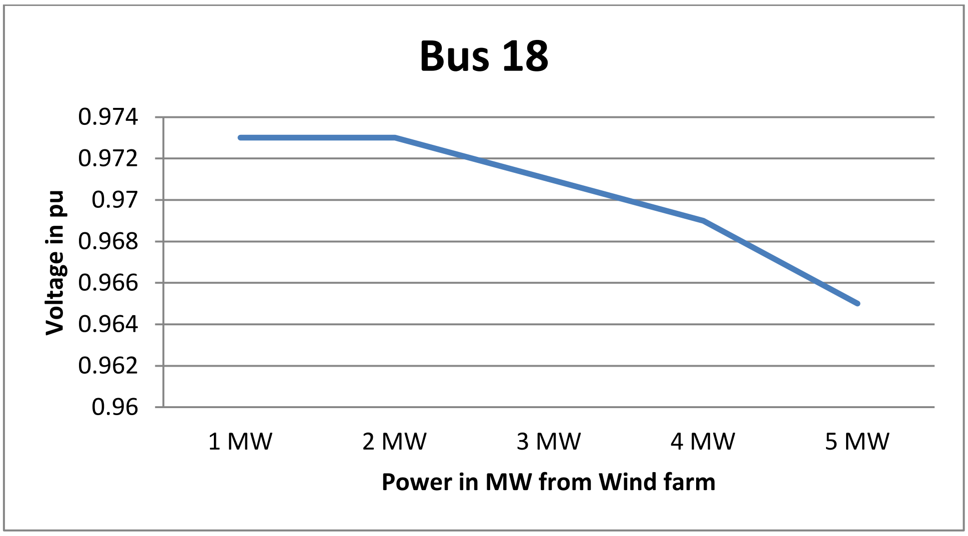

Figure 68: Voltage in pu at Bus 18 during Scenario 14

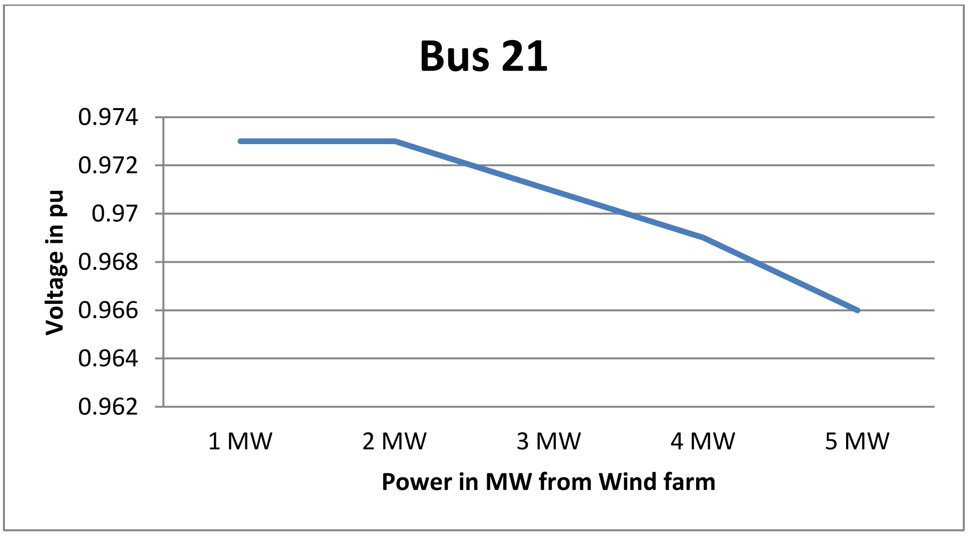

Figure 69: Voltage in pu at Bus 21 during Scenario 14

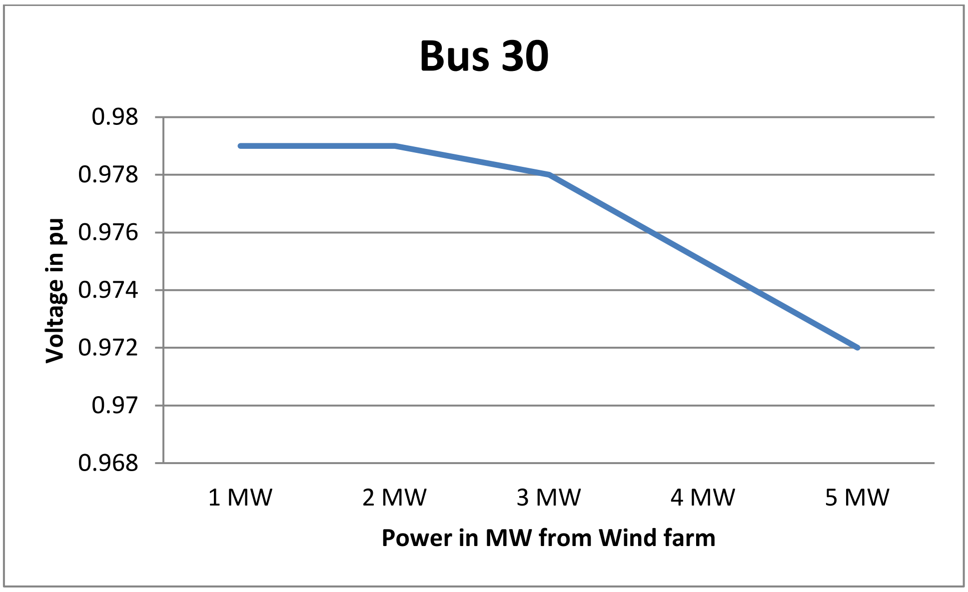

Figure 70: Voltage in pu at Bus 30 during Scenario 14

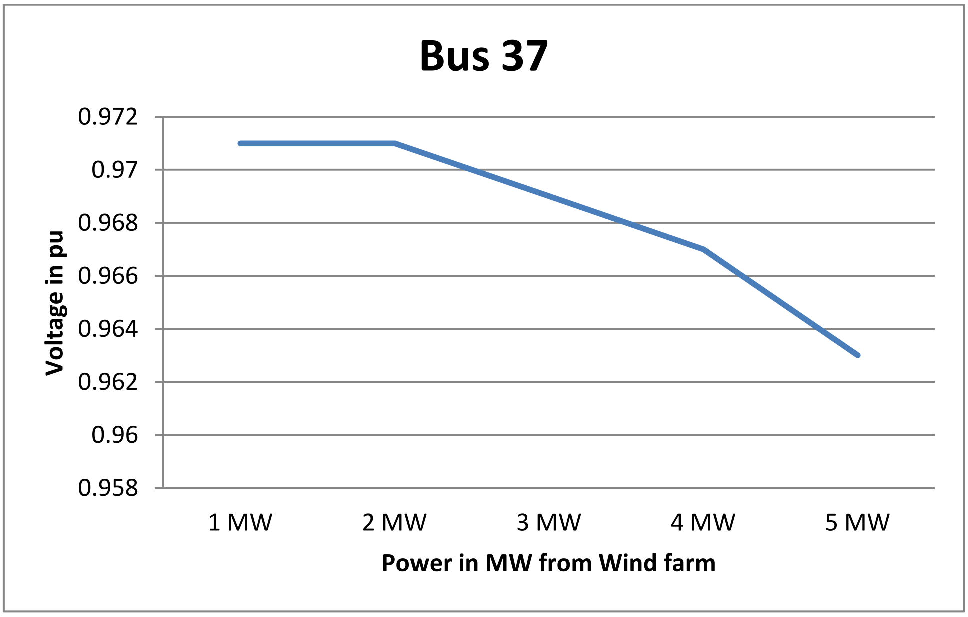

Figure 71: Voltage in pu at Bus 37 during Scenario 14

In this scenario the PV farm supply fixed amount of power of 2 MW, the power supplied by the wind farm increased from 0 MW up to 5 MW. In Figure 66-71, the Buses voltage levels reduced with the increased amount of power supplied by the wind generators. The grid Buses voltage are still in the acceptable ranges between 0.95-1.00 pu.

Scenario 15: Integrating 5 MW wind farm with variable power from PV farm at Bus 4

The system is operating under normal operating conditions, the generators supplying the power to the industrial grid system, some of the power needed by the grid are supplied by the utility in case that the power generated is not enough to supply the grid and if all the generators including the wind farms are generating power more than the power needed, the remaining power will be supplied to the utility. Table 21 shows the voltage profile at the Buses .

Table 21: Voltage level in pu at Buses During the Integration of 5 MW Wind power and variable PV Power at Bus 4

Bus No/PV Power	1 MW	2 MW	3 MW	4 MW	5 MW
Bus 4	0.994	0.995	0.995	0.996	0.996
Bus 8	0.994	0.994	0.995	0.995	0.995
Bus 18	0.965	0.965	0.966	0.966	0.967
Bus 20	0.967	0.967	0.967	0.968	0.968
Bus 21	0.965	0.966	0.966	0.966	0.967
Bus 30	0.971	0.972	0.972	0.972	0.973
Bus 37	0.963	0.963	0.964	0.964	0.965

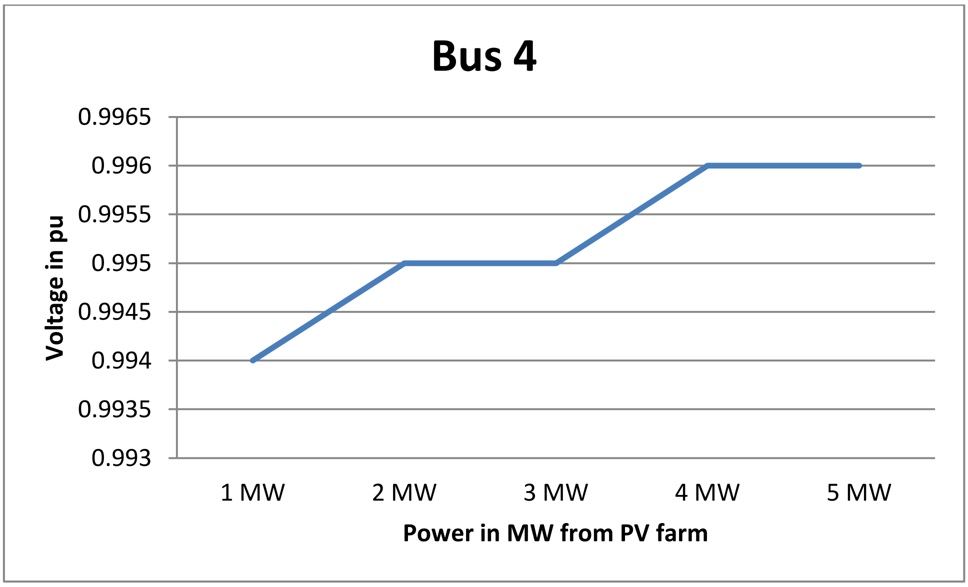

Figure 72: Voltage in pu at Bus 4 during Scenario 15

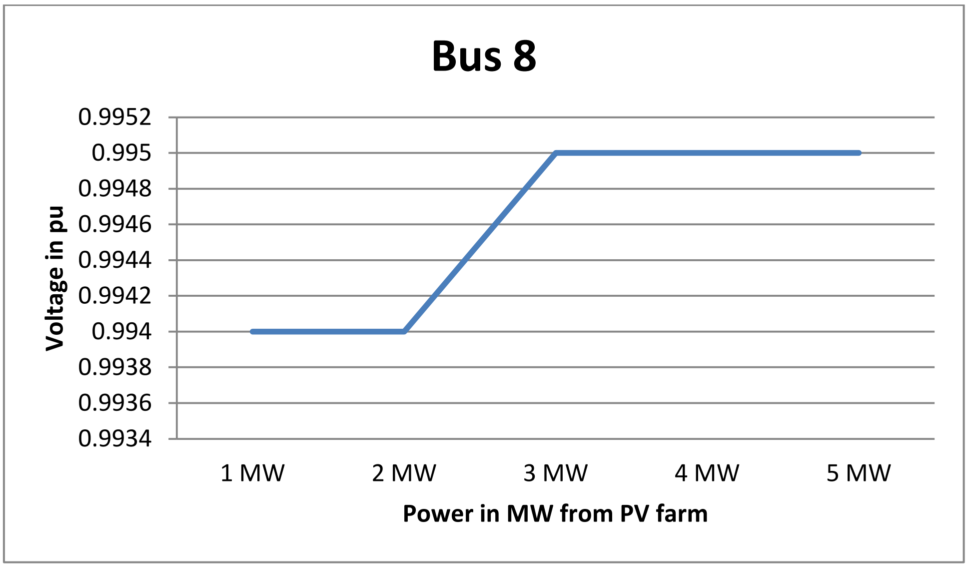

Figure 73: Voltage in pu at Bus 8 during Scenario 15

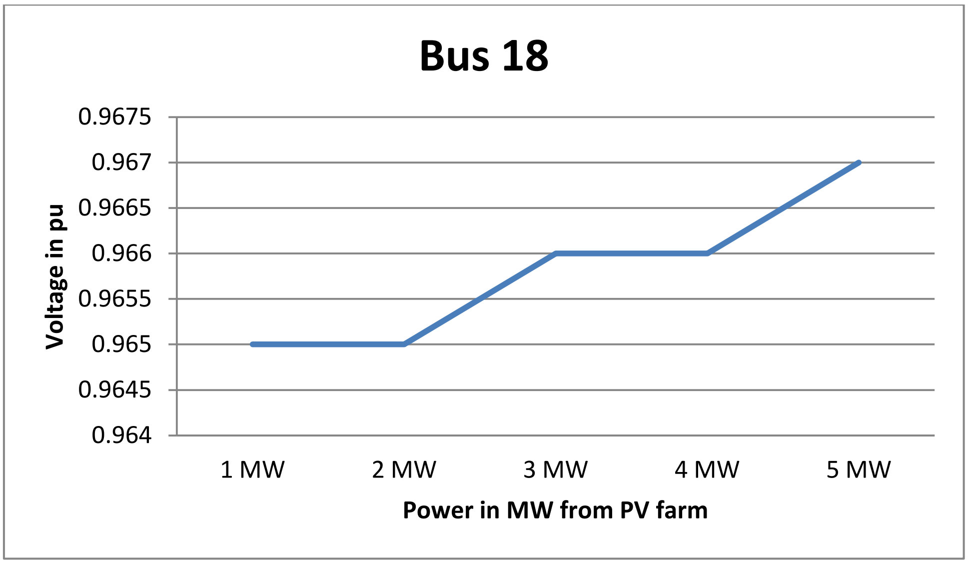

Figure 74: Voltage in pu at Bus 18 during Scenario 15

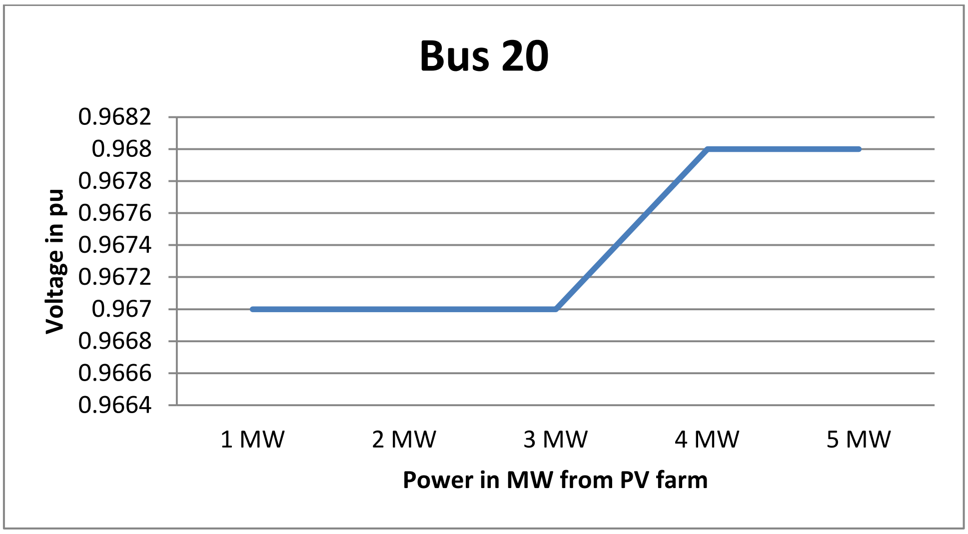

Figure 75: Voltage in pu at Bus 20 during Scenario 15

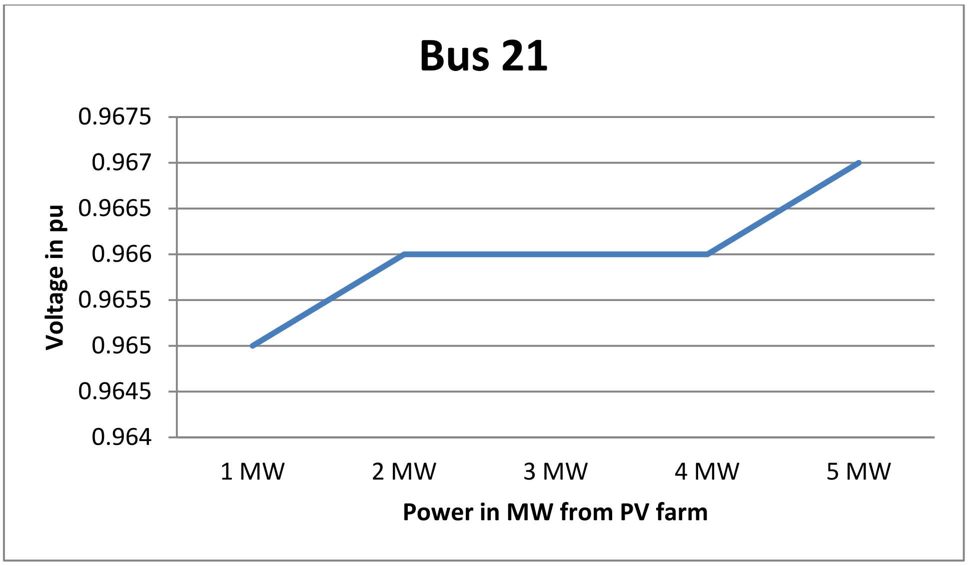

Figure 76: Voltage in pu at Bus 21 during Scenario 15

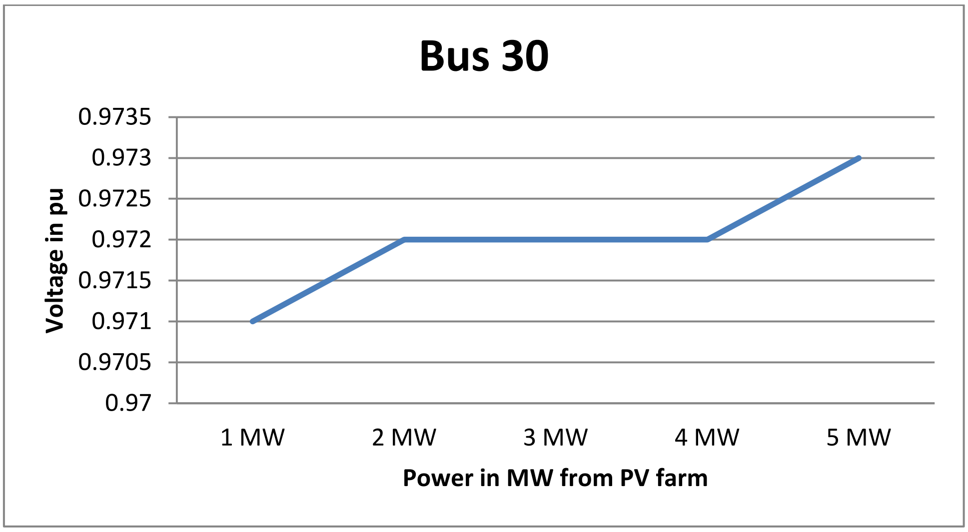

Figure 77: Voltage in pu at Bus 30 during Scenario 15

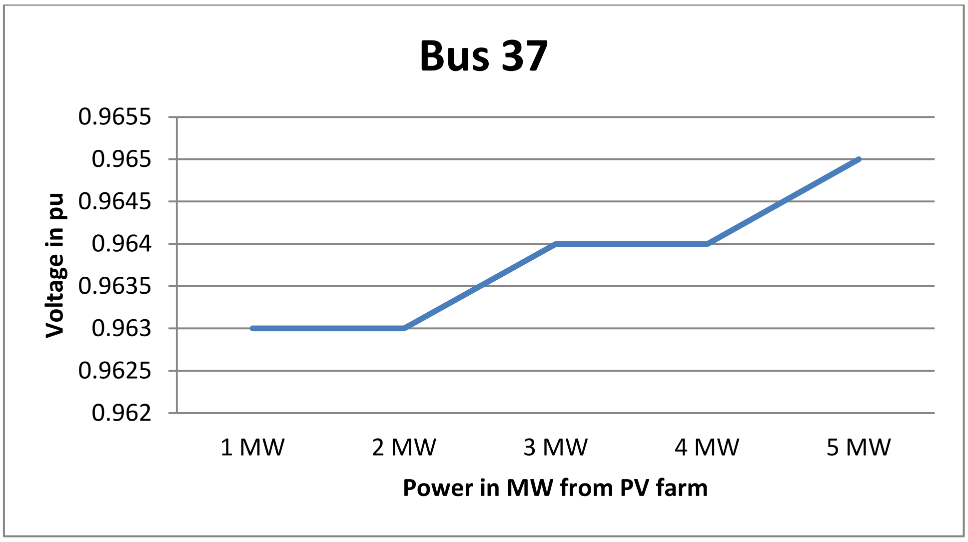

Figure 78: Voltage in pu at Bus 37 during Scenario 15

In this scenario the Buses voltages increased when the power supplied by the PV farm increased keeping the wind farm power generated at 5 MW. (See Table 21 and Figure 72-78). There is some improvement in the voltage of the grid Buses.

4.3 Short Circuit Studies

The short circuit analysis have succefully being executed for base case in order to know the fault currents at system Buses, Figure 79 show the industrial system under short circuit analysis. Refer to Appendix 10 short circuit results for the base case.

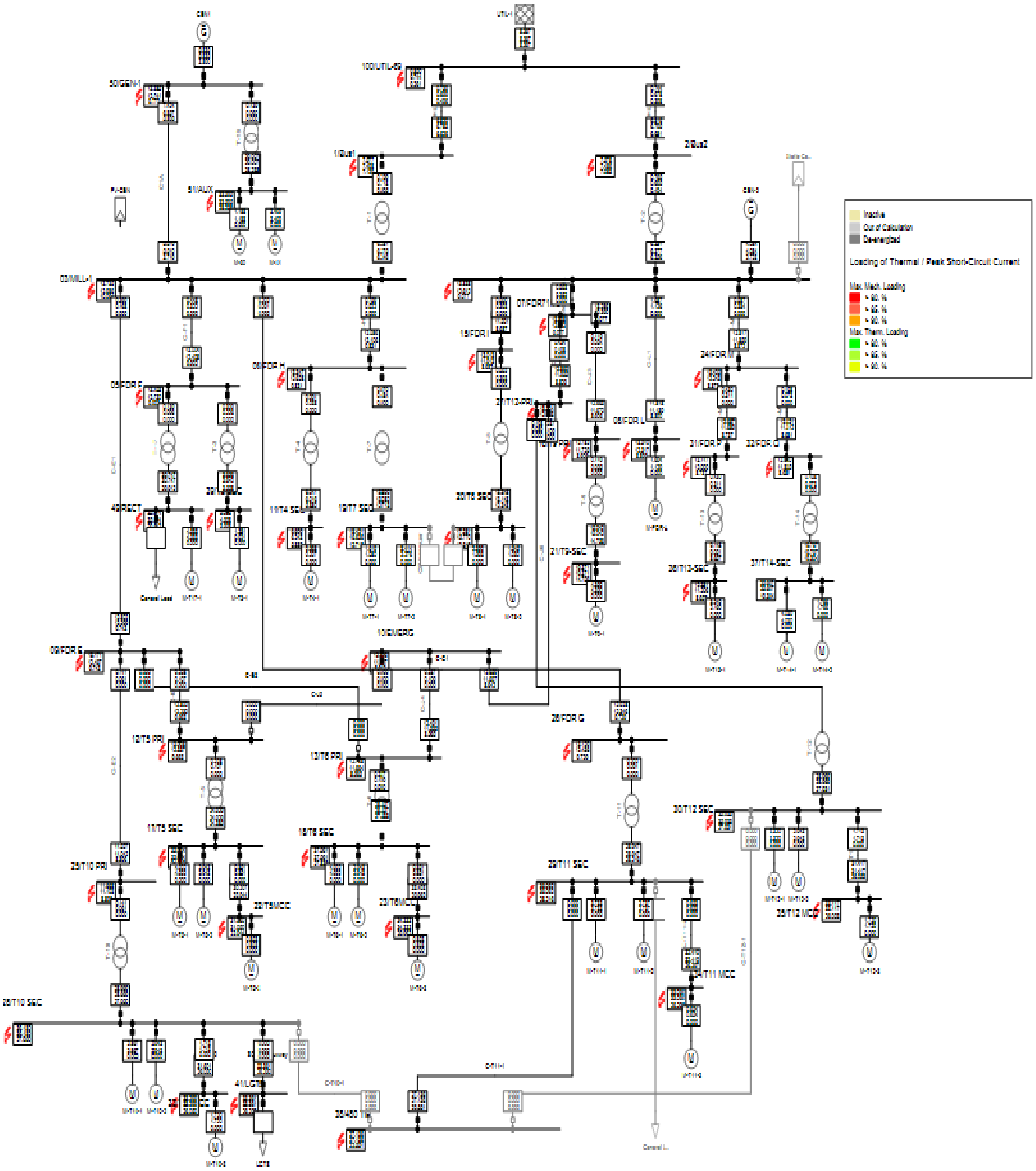

Figure 79: Short Circuit results for base case

4.3.1 Short circuit analysis on PV plant integration to the grid system

The PV plant is a combination of static generators, the static generator contributes to the faults currents of momentary and interrupting current only, but there is no contribution in the 30-cycle short circuit current. The results of short circuit analysis are given in Table 22-24 and Figure 80-82.

Table 22: Momentary fault currents of PV grid connected system

Momentary fault current (in kA)		
Bus no	Base Case	System integrated with PV
Bus 2	7.578	7.824
Bus 4	13.838	20.584
Bus 8	13.51	19.785
Bus 20	17.281	18.114
Bus 21	19.371	19.559
Bus 23	34.333	34.918
Bus 30	35.933	36.652
Bus 35	33.117	33.712
Bus 36	12.381	12.758
Bus 37	25.607	25.936
Bus 100	9.85	10.08

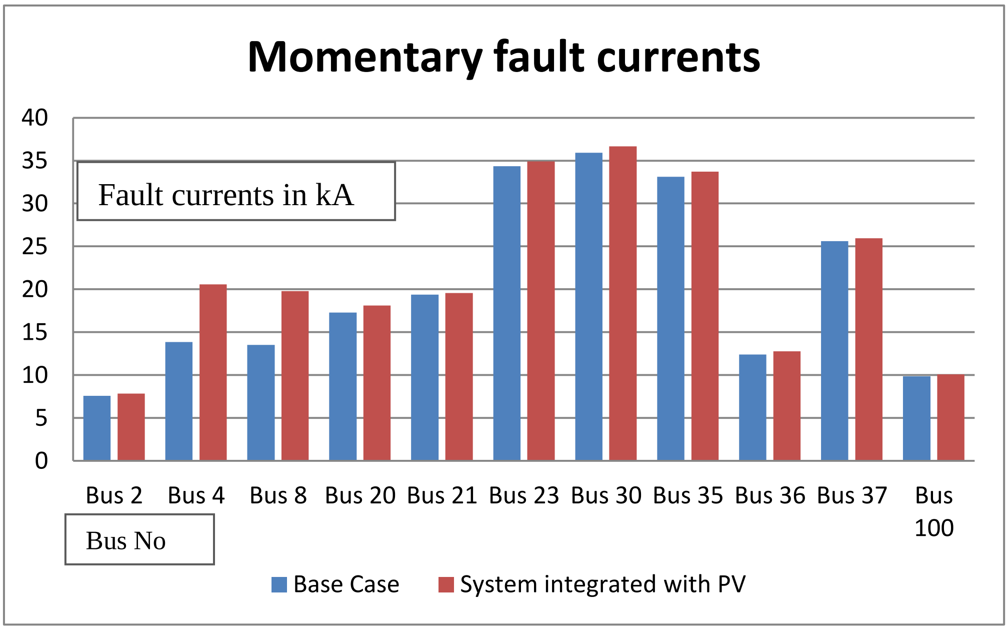

Figure 80: Momentary Fault Currents of PV grid connected system

Table 23: Interrupting fault currents of PV grid connected system

	Interrupting fault current (in kA)	
Bus no	Base Case	System integrated with PV
Bus 2	7.486	7.769
Bus 4	12.612	19.358
Bus 8	12.317	18.612
Bus 20	15.77	16.705
Bus 21	19.371	19.559
Bus 23	34.333	34.918
Bus 30	35.933	36.652
Bus 35	33.117	33.712
Bus 36	11.206	11.634
Bus 37	25.607	25.936
Bus 100	9.744	10.01

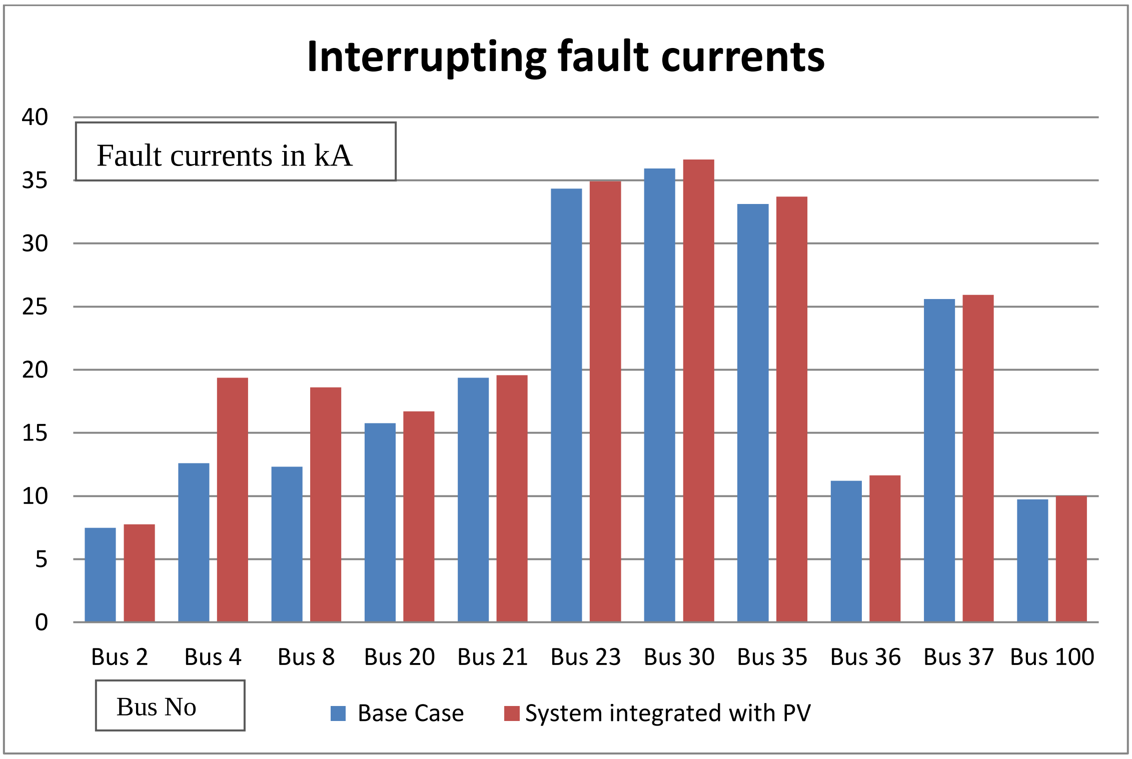

Figure 81: Interrupting Fault Currents of PV grid connected system

Table 24: 30-cycle short circuit currents of PV grid connected system

30-cycle short circuit current (in kA)		
Bus no	Base Case	System integrated with PV
Bus 2	7.083	7.083
Bus 4	9.077	9.077
Bus 8	8.89	8.89
Bus 20	12.348	12.348
Bus 21	14.756	14.756
Bus 23	25.962	25.962
Bus 30	27.931	27.931
Bus 35	26.053	26.053
Bus 36	8.657	8.657
Bus 37	19.304	19.304
Bus 100	9.261	9.261

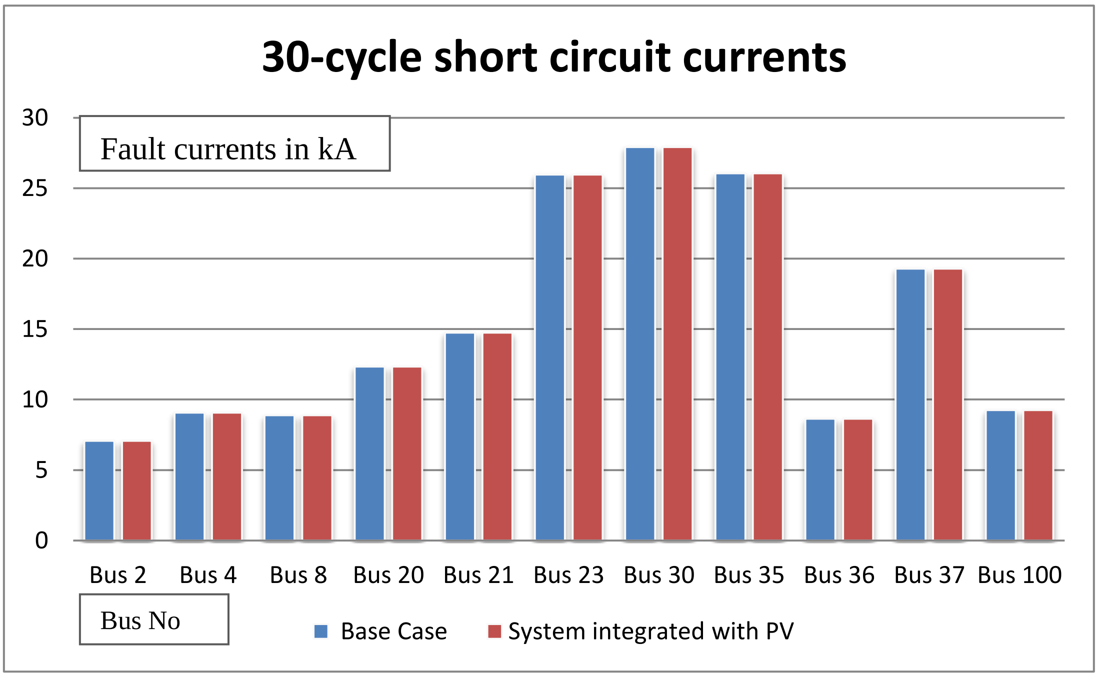

Figure 82: 30 Cycle fault currents of PV grid connected system

Integrating the PV farm to the grid system will increase the momentary and interrupting faults currents of the grid system. This will affect on the equipments protection devices and fault currents rating. The rating of the equipments needs to meet the changes in the fault currents. However there is no contribution to the 30-cycle short circuit currents.

4.3.2 Short circuit analysis on Wind Farm integration to the grid system

The wind farm is a combination of wind turbine generators, these generators contribute to the faults currents of momentary and interrupting current only, but there is no contribution in the 30-cycle short circuit current. The results of short circuit analysis are given in Table 25-27, and Figure 83-85.

Table 25: Momentary fault currents of Wind farm grid connected system

Momentary fault currents (in kA)		
Bus no	Base Case	Wind farm grid connected system
Bus 2	7.578	7.59
Bus 4	13.838	14.071
Bus 8	13.51	13.73
Bus 20	17.281	17.321
Bus 21	19.371	19.38
Bus 23	34.333	34.362
Bus 30	35.933	35.969
Bus 35	33.117	33.147
Bus 36	12.381	12.4
Bus 37	25.607	25.623
Bus 100	9.85	9.861

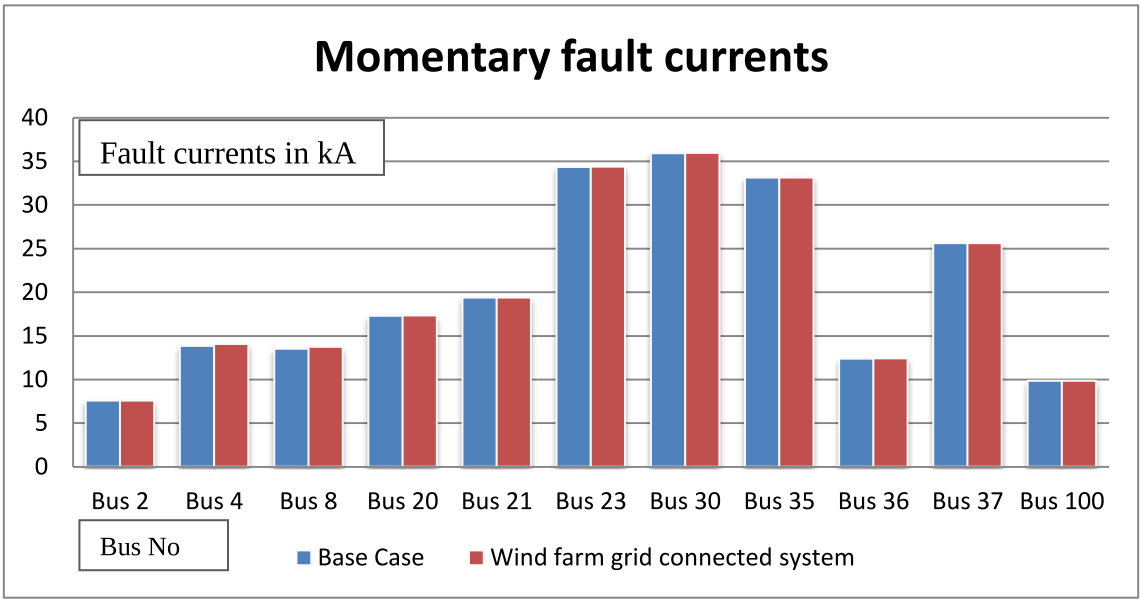

Figure 83: Momentary fault currents of Wind farm grid connected system

Table 26: Interrupting fault current of Wind farm grid connected system

Interrupting fault current (in kA)		
Bus no	Base Case	Wind farm grid connected system
Bus 2	7.486	7.501
Bus 4	12.612	12.845
Bus 8	12.317	12.538
Bus 20	15.77	15.816
Bus 21	19.371	19.38
Bus 23	34.333	34.362
Bus 30	35.933	35.969
Bus 35	33.117	33.147
Bus 36	11.206	11.228
Bus 37	25.607	25.623
Bus 100	9.744	9.758

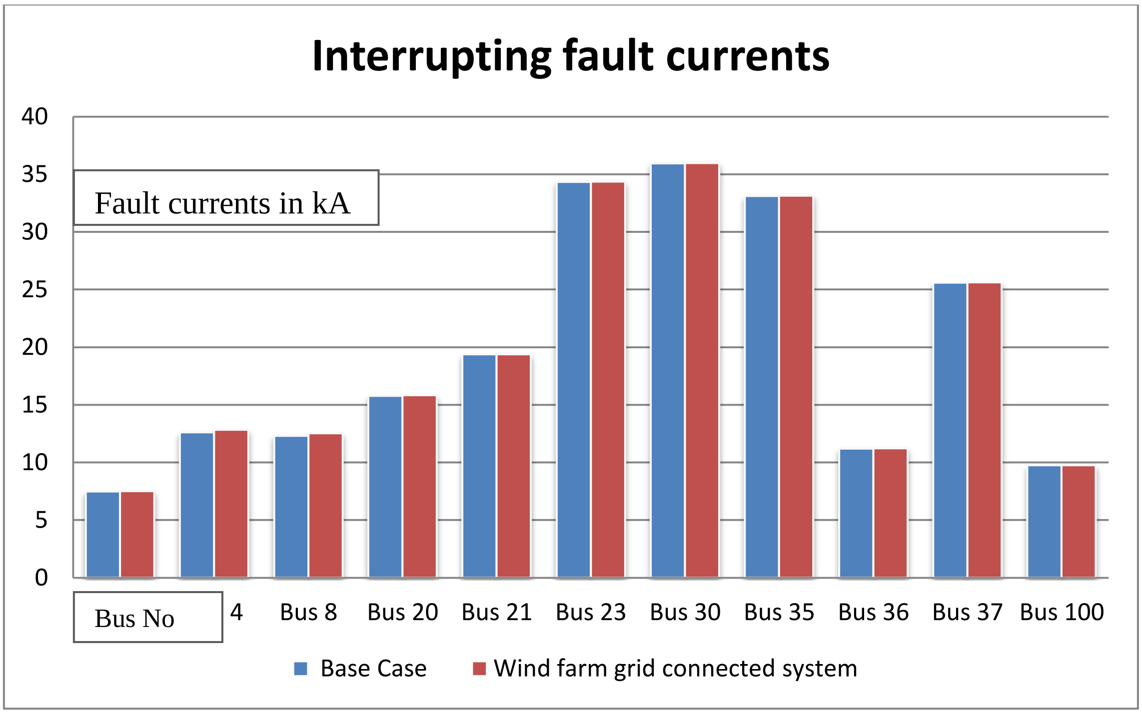

Figure 84: Interrupting fault current of Wind farm grid connected system

Table 27: 30-cycle short circuit currents of Wind farm grid connected system

30-cycle short circuit (in kA)		
Bus no	Base Case	Wind farm grid connected system
Bus 2	7.083	7.083
Bus 4	9.077	9.077
Bus 8	8.89	8.89
Bus 20	12.348	12.348
Bus 21	14.756	14.756
Bus 23	25.962	25.962
Bus 30	27.931	27.931
Bus 35	26.053	26.053
Bus 36	8.657	8.657
Bus 37	19.304	19.304
Bus 100	9.261	9.261

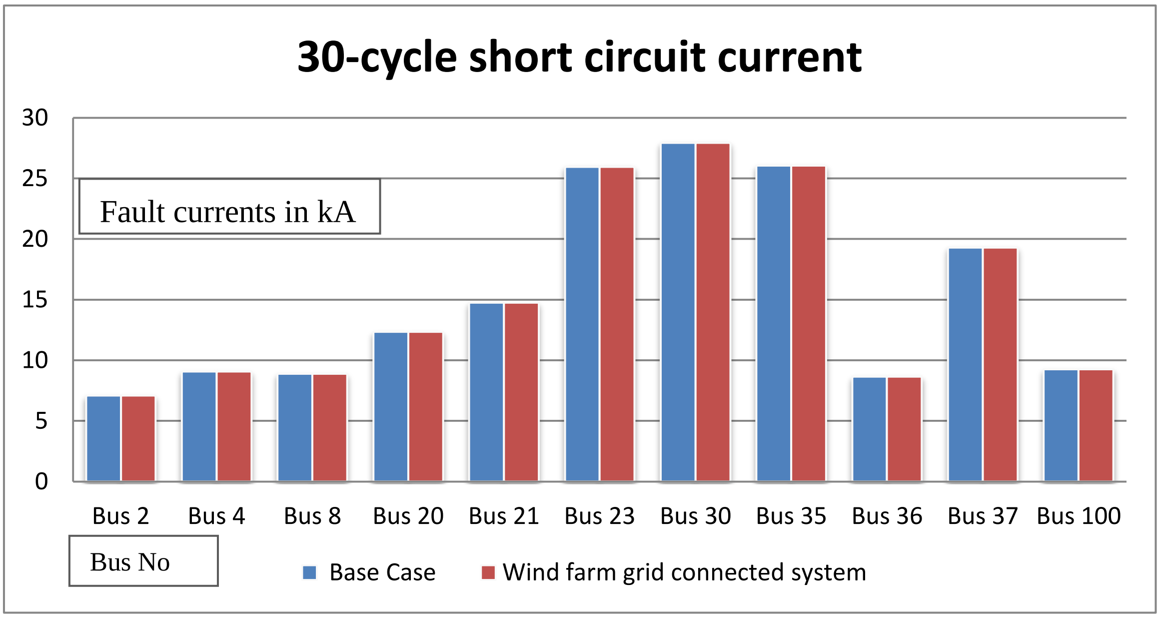

Figure 85: 30-cycle short circuit currents of Wind farm grid connected system

Similarly, this will affect on the equipments protection devices and fault currents rating. The rating of the equipments needs to meet the changes in the fault currents.

4.3.3 Short circuit analysis on grid integrated with PV & Wind Farms

The study of short circuit analysis is carried out base on ANSI and IEEE standards. The momentary and interrupting fault currents of the PV & wind farms affect on the grid system fault currents, the fault currents increased by very small values of fault currents. Refer Table 28-30, and Figure 86-88 for the short circuit currents.

Table 28: Momentary fault currents of grid system integrated with PV & Wind Farms

Momentary fault currents (in kA)		
Bus no	Base Case	Grid integrated with PV & Wind Farms
Bus 2	7.578	7.597
Bus 4	13.838	14.212
Bus 8	13.51	13.863
Bus 20	17.281	17.345
Bus 21	19.371	19.386
Bus 23	34.333	34.379
Bus 30	35.933	35.99
Bus 35	33.117	33.164
Bus 36	12.381	12.411
Bus 37	25.607	25.633
Bus 100	9.85	9.868

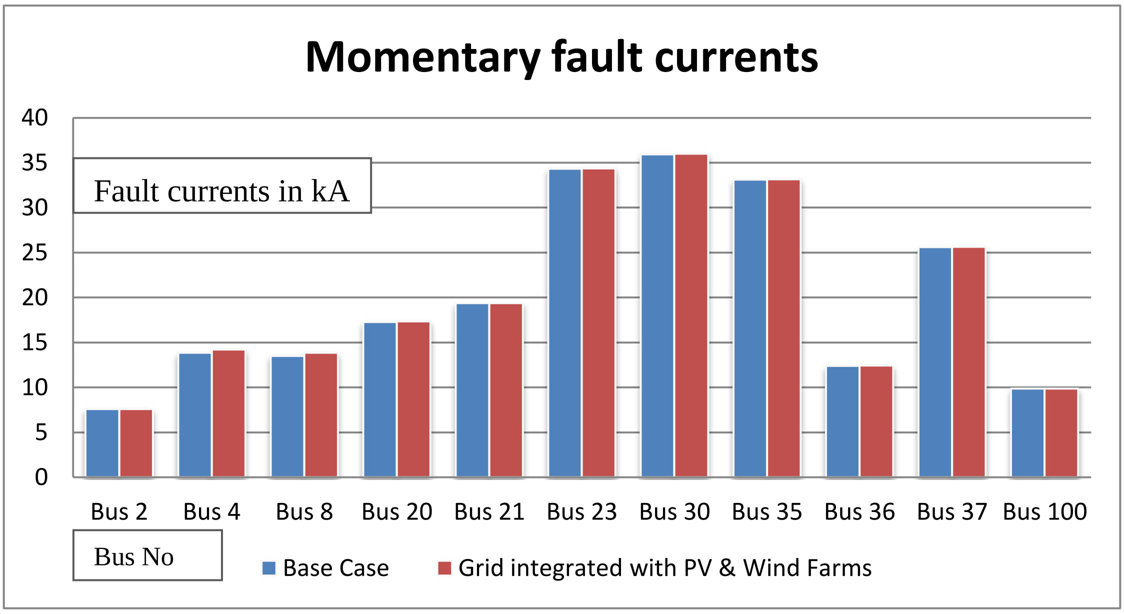

Figure 86: Momentary fault currents of grid system integrated with PV & Wind Farms

Table 29: Interrupting fault currents of grid system integrated with PV & Wind Farms

Interrupting fault currents (in kA)		
Bus no	Base Case	Grid integrated with PV & Wind Farms
Bus 2	7.486	7.509
Bus 4	12.612	12.986
Bus 8	12.317	12.671
Bus 20	15.77	15.843
Bus 21	19.371	19.386
Bus 23	34.333	34.379
Bus 30	35.933	35.99
Bus 35	33.117	33.164
Bus 36	11.206	11.24
Bus 37	25.607	25.633
Bus 100	9.744	9.766

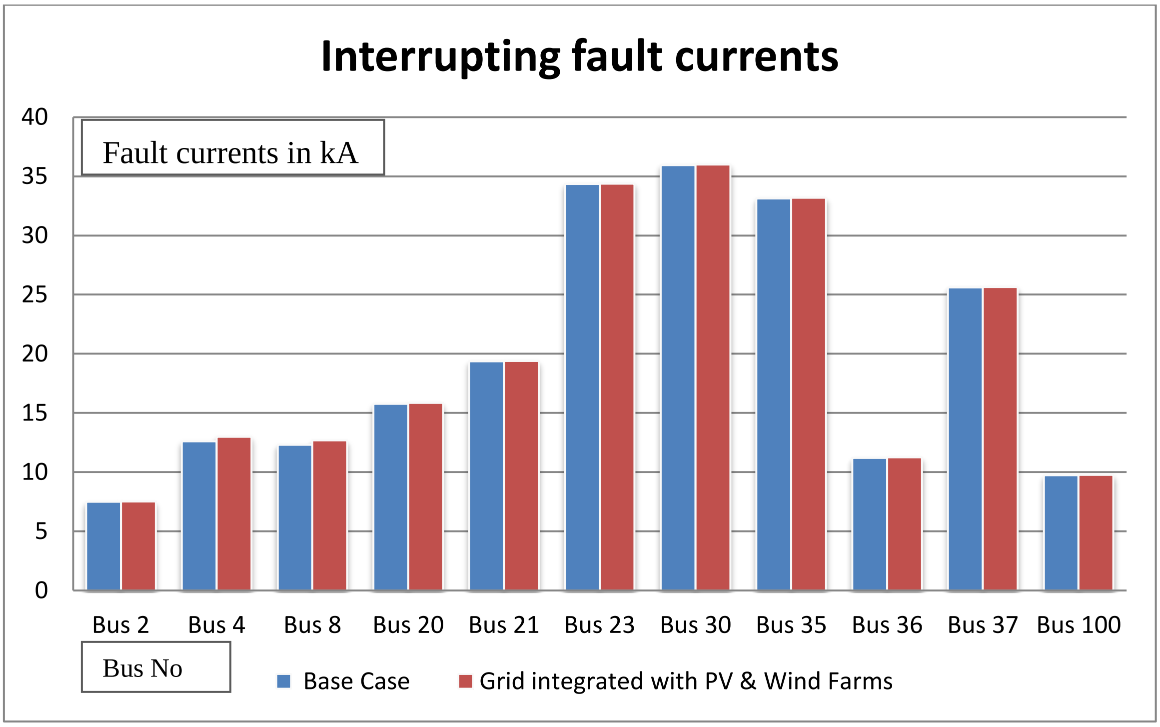

Figure 87: Interrupting fault currents of grid system integrated with PV & Wind Farms

Table 30: 30-cycle short circuit current of integrated with PV & Wind Farms

30-cycle short circuit Currents (in kA)		
Bus no	Base Case	Grid integrated with PV & Wind Farms
Bus 2	7.083	7.083
Bus 4	9.077	9.077
Bus 8	8.89	8.89
Bus 20	12.348	12.348
Bus 21	14.756	14.756
Bus 23	25.962	25.962
Bus 30	27.931	27.931
Bus 35	26.053	26.053
Bus 36	8.657	8.657
Bus 37	19.304	19.304
Bus 100	9.261	9.261

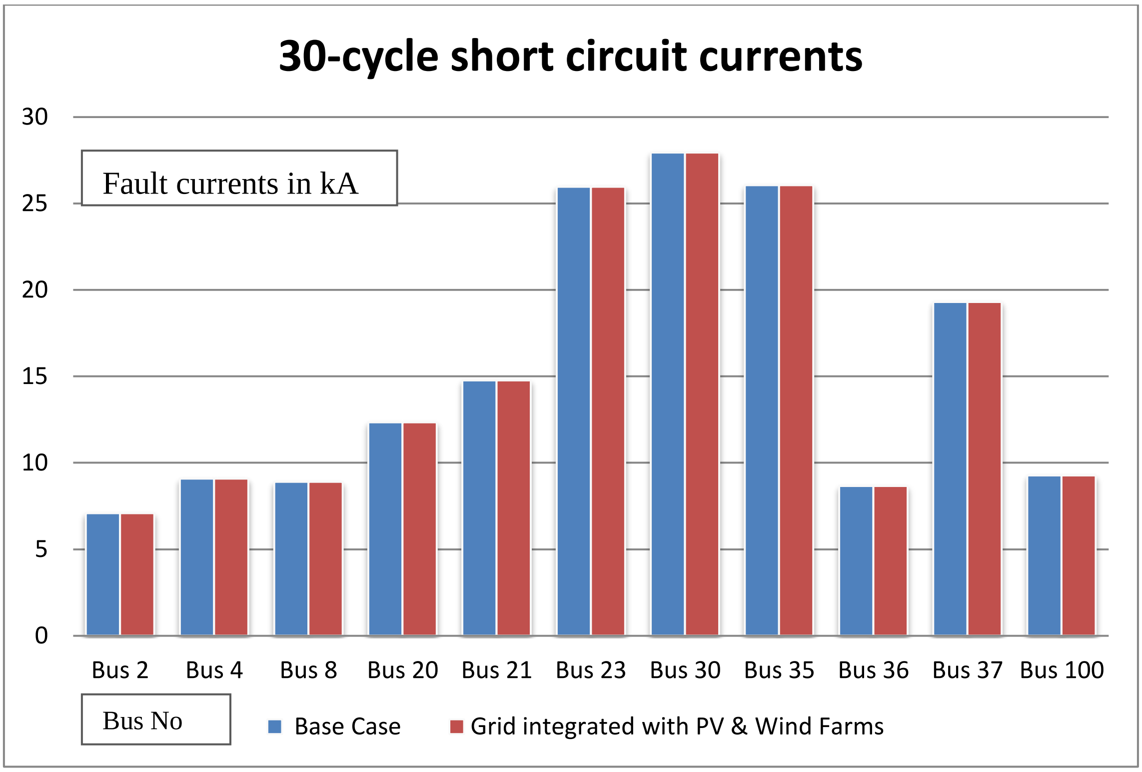

Figure 88: 30-cycle shot circuit current of integrated with PV & Wind Farms

The study of short circuit analysis of wind & PV farms grid connected system shows that the momentary and interrupting faults currents of the grid increases slightly, however no change on the 30-cycle short circuit currents.

Comparison between the fault currents contribution of PV grid connected and wind grid connected system showed that the contribution of PV farm is higher than wind farm. The contribution is higher on the Buses near to the point of interconnection.

It’s recommended that the rating of equipments fault currents is enough to meet the change in fault current due to the integration of wind and PV farms to the grid system. This analysis is very important to make sure that the cables, transformers, Buses, are adequately rated so that it could withstand short-circuit currents until the faults are cleared by the protection devices.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Wind and PV solar power are the most promising RES in the world comparing to other renewable energy systems such as biomass, hydropower, and geothermal power plants. WFs and PV solar power have high impacts on the grid power system causing some issues such as power losses, voltage instability and fault currents. The research concentrates in this area on these issues by analyzing the effects of wind and PV solar on industrial grid system.

From load flow analysis of PV integration to the industrial system, it's clear that that voltage is improved at the Buses. The far the industrial system from utility power supply the more effective the improvement of Buses voltages by PV. Integrating Wind farm to the grid system will affect on the voltage levels, increasing the power from the wind farm decreases the voltage on the system Buses. The wind farm generators are induction type which consumes reactive power that affect directly on the system voltage levels.

The study of short circuit analysis is carried out base on ANSI and IEEE standards. The momentary and interrupting fault currents of the PV & wind farms affect on the grid system fault currents, the fault currents increased by very small value. Comparison between the fault currents contribution of PV grid connected and wind grid connected system showed that the contribution of PV farm is higher than wind farm. The contribution is higher on the Buses near to the point of interconnection.

5.2 Recommendations

This research has very good outcomes, which will help in better understanding the effects of wind and PV solar power on the quality of power in grid system in order to enhance the design of the wind and PV solar power system to contribute toward the power quality in grid system. I recommend further studies on their effect on the power quality of the grid system.

Integrating PV and wind farms to an existing grid system need to be studied carefully and the design have to be carried in a professional manner to overcome the expected problems in the future. The equipments rating and protection devices have to meet the change in voltages and fault currents due to the integration of PV and wind farms.

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APPENDICES

APPENDIX A

TRANSFORMERS IMPEDANCES [17]

Transformers Impedances						
Transformer Identifier	Transformer MVA	Pu Resistance	Pu Reactance	Base MVA	Updated Resistance(P.u)	Reactance(P.u)
T-1	15	0.00313	0.05324	10	0.004695	0.07986
T-2	15	0.00313	0.05324	10	0.004695	0.07986
T-3	1.725	0.04314	0.34514	10	0.00744165	0.05953665
T-4	1.5	0.05575	0.3624	10	0.0083625	0.05436
T-5	1.5	0.06843	0.44477	10	0.0102645	0.0667155
T-6	1.5	0.05829	0.37888	10	0.0087435	0.056832
T-7	3.75	0.01218	0.14616	10	0.0045675	0.05481
T-8	3.75	0.01218	0.14616	10	0.0045675	0.05481
T-9	0.75	0.15036	0.75178	10	0.011277	0.0563835
T-10	1.5	0.05829	0.37888	10	0.0087435	0.056832
T-11	1.5	0.05829	0.37888	10	0.0087435	0.056832
T-12	1.5	0.05829	0.37888	10	0.0087435	0.056832
T-13	2.5	0.02289	0.22886	10	0.0057225	0.057215
T-14	1	0.10286	0.56573	10	0.010286	0.056573
T-17	1.25	0.05918	0.3551	10	0.0073975	0.0443875
T-18	1.5	0.06391	0.37797	10	0.0095865	0.0566955

APPENDIX B

BUSES DATA [17]

Bus Data (Total Bus Load Shown - All Loads Modeled as Constant MVA Load)				
Bus Number	**Load MW**	**Load MVAR**	**Bus Name**	**Base KV**
1	0	0	69-1	69
2	0	0	69-2	69
3	0	0	MILL-1	13.8
4	0	0	MILL-2	13.8
5	0	0	FDR F	13.8
6	0	0	FDR H	13.8
7	0	0	FDR71/72	13.8
8	6.361	0.000	FDR L	13.8
9	0	0	FDR E	0.48
10	0	0	EMERG	13.8
11	0.353	0.200	T4 SEC	2.4
12	0	0	T5 PRI	13.8
13	0	0	T6 PRI	13.8
15	0	0	FDR I	13.8
16	0	0	T9 PRI	13.8
17	0.831	0.521	T5 SEC	0.48
18	0.831	0.521	T6 SEC	0.48
19	2.650	1.502	T7 SEC	2.4
20	2.650	1.502	T8 SEC	2.4
21	0.421	0.283	T9 SEC	0.48
22	0.084	0.057	T5MCC	0.48
23	0.084	0.057	T6MCC	0.48
24	0	0	FDR M	0.48
25	0	0	T10 PRI	13.8
26	0	0	FDR G	13.8
27	0	0	T12 PRI	13.8
28	0.578	0.351	T10 SEC	0.48
29	0.703	0.426	T11 SEC	0.48
30	0.563	0.349	T12 SEC	0.48
31	0	0	FDR P	13.8
32	0	0	FDR Q	13.8
33	0.168	0.113	T10MCC	0.48
34	0.062	0.042	T11MCC	0.48
35	0.168	0.113	T12MCC	0.48
36	1.767	1.001	T13 SEC	2.4
37	0.663	0.394	T14 SEC	0.48
38	0	0	480 TIE	0.48
39	1.237	0.701	T3 SEC	4.16
41	0.150	0.049	LGTS	0.48
49	0.963	0.520	RECT	0.48
50	0	0	GEN1	13.8
51	0.478	0.307	AUX	0.48
100	0	0	UTIL-69	69

APPENDIX C

GENERATORS AND CABLES DATA [17]

Generator Data

Bus Number	Unit ID	Real Power (MW)	Reactive Power Upper Limit (MVAR)	Reactive Power Lower Limit (MVAR)	Scheduled Voltage (pu)
100	1	2.0	99.0	-99.0	1.0
4	1	8.0	8.0	-2.0	1.0
50	1	11.0	8.0	-2.0	1.0

CABLE DATA

From Bus	To Bus	Circuit	Resistance	Per Unit Data Reactance	Per Unit Data Susceptance	Cables/Phase and Size	Material	Length (ft)	Length (m)	kV	Rating (MVA)	Rating (Amps)
3	9	1	0.00150	0.00125	0.0	1-3/C-250kcmil CU	PVC	650	198.1	13.8	7.529	315
9	25	1	0.00424	0.00353	0.0	1-3/C-250kcmil CU	PVC	1833	558.7	13.8	7.529	315
9	13	1	0.00017	0.00014	0.0	1-3/C-250kcmil CU	PVC	75	22.9	13.8	7.529	315
9	12	1	0.00038	0.00032	0.0	1-3/C-250kcmil CU	PVC	165	50.3	13.8	7.529	315
3	5	1	0.00075	0.00063	0.0	1-3/C-250kcmil CU	PVC	325	99.1	13.8	7.529	315
3	26	1	0.00157	0.00131	0.0	1-3/C-250kcmil CU	PVC	680	207.3	13.8	7.529	315
3	6	1	0.00109	0.00091	0.0	1-3/C-250kcmil CU	PVC	471	143.6	13.8	7.529	315
4	15	1	0.00227	0.00189	0.0	1-3/C-250kcmil CU	PVC	980	298.7	13.8	7.529	315
4	7	1	0.00000	0.00010	0.0	breaker				13.8	7.529	315
7	27	1	0.00143	0.00119	0.0	1-3/C-250kcmil CU	PVC	619	188.7	13.8	7.529	315
7	16	1	0.00275	0.00229	0.0	1-3/C-250kcmil CU	PVC	1187	361.8	13.8	7.529	315
10	13	1	0.00046	0.00039	0.0	1-3/C-250kcmil CU	PVC	200	61.0	13.8	7.529	315
10	12	1	0.00002	0.00002	0.0	1-3/C-250kcmil CU	Steel	10	3.0	13.8	7.529	315
10	27	1	0.00110	0.00091	0.0	1-3/C-250kcmil CU	PVC	475	144.8	13.8	7.529	315
4	8	1	0.00076	0.00092	0.0	1-3/C-400kcmil CU	PVC	510	155.4	13.8	9.919	415
4	24	1	0.00118	0.00098	0.0	1-3/C-250kcmil CU	PVC	510	155.4	13.8	7.529	315
24	31	1	0.00079	0.00065	0.0	1-3/C-250kcmil CU	PVC	340	103.6	13.8	7.529	315
24	32	1	0.00112	0.00093	0.0	1-3/C-250kcmil CU	PVC	485	147.8	13.8	7.529	315
28	38	1	0.03039	0.02929	0.0	2-3/C-400kcmil CU	PVC	50	15.2	0.48	0.443	535
33	28	1	0.03813	0.02450	0.0	1-3/C-250kcmil CU	PVC	20	6.1	0.48	0.212	255
29	38	1	0.04012	0.03866	0.0	2-3/C-400kcmil CU	PVC	66	20.1	0.48	0.445	535
34	29	1	0.03813	0.02450	0.0	1-3/C-250kcmil CU	PVC	20	6.1	0.48	0.212	255
38	30	1	0.06079	0.05858	0.0	1-3/C-400kcmil CU	PVC	50	15.2	0.48	0.278	335
35	30	1	0.03813	0.02450	0.0	1-3/C-250kcmil CU	PVC	20	6.1	0.48	0.212	255
22	17	1	0.03813	0.02450	0.0	1-3/C-250kcmil CU	PVC	20	6.1	0.48	0.212	255
23	18	1	0.03813	0.02450	0.0	1-3/C-250kcmil CU	PVC	20	6.1	0.48	0.212	255
50	3	1	0.00122	0.00243	0.0	2-1/C-500kcmil CU	PVC	2000	609.6	13.8	18.350	768

APPENDIX D

MOTORS LIST IN GRID SYSTEM

Name	Bus type	Active power MW	Reactive power	Apparent power	Power factor
M-30	PQ	0.1241558	0.07974026	0.1475573	0.8414071
M-31	PQ	0.029487	0.01893831	0.03504487	0.8414071
M-T10-1	PQ	0.025688	0.0156	0.03005384	0.8547327
M-T10-2	PQ	0.06422	0.039	0.0751346	0.8547327
M-T10-3	PQ	0.028	0.018833	0.03374436	0.8297683
M-T11-1	PQ	0.080619	0.0488532	0.09426589	0.8552299
M-T11-2	PQ	0.2999036	0.18173	0.3506679	0.8552354
M-T11-3	PQ	0.062	0.042	0.07488658	0.8279186
M-T12-1	PQ	0.0307449	0.019058	0.03617259	0.8499502
M-T12-2	PQ	0.031704	0.0196531	0.03730131	0.8499433
M-T12-3	PQ	0.028	0.018833	0.03374436	0.8297683
M-T13-1	PQ	1.767	1.001	2.030835	0.8700855
M-T14-1	PQ	0.03284	0.0195171	0.03820187	0.8596438
M-T14-2	PQ	0.033868	0.0201266	0.03939697	0.85966
M-T17-1	PQ	0.963	0.52	1.094426	0.8799131
M-T3-1	PQ	1.237	0.701	1.421819	0.8700122
M-T4-1	PQ	0.0353	0.02	0.04057204	0.8700574
M-T5-1	PQ	0.030425	0.019075	0.03591011	0.8472543
M-T5-2	PQ	0.06275	0.039344	0.07406425	0.8472373
M-T5-3	PQ	0.028	0.019	0.03383785	0.8274758
M-T6-1	PQ	0.030425	0.019075	0.03591011	0.8472543
M-T6-2	PQ	0.06275	0.039344	0.07406425	0.8472373
M-T6-3	PQ	0.028	0.019	0.03383785	0.8274758
M-T7-1	PQ	0.85178	0.48278	0.9790841	0.8699763
M-T7-2	PQ	1.79821	1.01921	2.066966	0.8699756
M-T8-1	PQ	1.27238	0.721176	1.462548	0.8699751
M-T8-2	PQ	1.377617	0.780823	1.583513	0.8699752
M-T9-1	PQ	0.028066	0.018866	0.03381754	0.8299242

APPENDIX E

CABLES IMPEDANCE DATA

Cable ID	from Bus	To Bus	KV	R1	X1	R0	X0	Length Km
C-E1	3	9	13.8	0.144488	0.120341	0.265092	0.240682	0.19812
C-E2	9	25	13.8	0.144488	0.120341	0.288976	0.240682	0.5586984
C-E3	9	13	13.8	0.144488	0.120341	0.288976	0.240682	0.02286
C-E4	9	12	13.8	0.144488	0.120341	0.288976	0.240682	0.050292
C-F1	3	5	13.8	0.144488	0.120341	0.288976	0.240682	0.09906
C-G1	3	26	13.8	0.144488	0.120341	0.288976	0.240682	0.207264
C-H1	3	6	13.8	0.144488	0.120341	0.288976	0.240682	0.1435608
C-I1	4	15	13.8	0.144488	0.120341	0.288976	0.240682	0.298704
C-J2	4	27	13.8	0.144488	0.120341	0.288976	0.240682	0.1886712
C-J3	16	4	13.8	0.144488	0.120341	0.288976	0.240682	0.3617976
C-J4	10	13	13.8	0.144488	0.120341	0.288976	0.240682	0.06096
C-J5	10	12	13.8	0.144488	0.138255	0.288976	0.276542	0.003048
C-J6	10	27	13.8	0.144488	0.120341	0.288976	0.240682	0.14478
C-L1	4	8	13.8	0.092881	0.112336	0.185728	0.224639	0.155448
C-M1	4	24	13.8	0.144488	0.120341	0.288976	0.240682	0.155448
C-M2	24	31	13.8	0.144488	0.120341	0.288976	0.240682	0.103632
C-M3	24	32	13.8	0.144488	0.120341	0.288976	0.240682	0.147828
C-T10-1	28	38	0.48	0.091896	0.08855	0.183793	0.177133	0.01524
C-T10-2	33	28	0.48	0.144127	0.092618	0.288255	0.185203	0.006096
C-T11-1	29	38	0.48	0.144127	0.08855	0.183793	0.177133	0.0201168
C-T11-2	34	29	0.48	0.144127	0.092618	0.288255	0.185203	0.006096
C-T12-1	38	30	0.48	0.091896	0.08855	0.183793	0.177133	0.01524
C-T12-2	35	30	0.48	0.144127	0.092618	0.288255	0.185203	0.006096
C-T5-1	22	17	0.48	0.144127	0.092618	0.288255	0.185203	0.006096
C-T6-1	23	18	0.48	0.144127	0.092618	0.288255	0.185203	0.006096
C1A	50	3	13.8	0.075919	0.15164	0.06834	1.364665	0.6096

APPENDIX F

SHORT CIRCUIT DATA OF GENERATORS, BUS WAY, UTILITY INTERCONNECTION AND OVER HEAD LINES

System Generators Data						
GEN-ID	Rated kV	Rated MVA	X"d (%)	X/R ratio	X0 (%)	X0/R0 ratio
GEN-1	13.8	15.625	0.112	37.4	5.7	37.4
GEN-2	13.8	12.5	12.8	35.7	5.8	35.7

Bus way Data							
Bus way ID	Rated kV	Size (A)	R1	X1	Length	From Bus	To Bus
SQD-I-Li	0.48	1000	0.0524934	0.0328084	0.01524	28	41

Utility Interconnection Data					
Connection point		3PH-MVA	X/R ratio	L-G MVA level	X/R ratio
UTIL-1		1000	22	765	9.7

Overhead line Data					
LINE-ID	Rated kV	Conductor Size	R1 (ohm/km)	X1 (ohm/km)	Length (km)
OHL-1	69	266.8 MCM	0.217107095	0.462337449	3.048097536
OHL-2	69	266.8 MCM	0.217107095	0.462337449	3.048097536

APPENDIX G

SHORT CIRCUIT DATA OF INDUSTRIAL PLANT TRANSFORMERS

		Primary		Secondary						
TR-ID	Rated MVA	kV	Bus	kV	Bus	Z1 (%)	X1/R1 ratio	Z0 (%)	X0/R0 ratio	Resistive part ukr0
T-1	15	69	1	13.8	3	8	17	7.2	17	0.4227985
T-2	15	69	2	13.8	4	8	17	7.4	17	0.434543
T-3	1.725	13.8	5	4.16	39	6	8	6	8	0.7442084
T-4	1.5	13.8	6	2.4	11	5.5	6.5	5.5	6.5	0.8363145
T-5	1.5	13.8	12	0.48	17	6.75	6.5	6.75	6.5	1.026386
T-6	1.5	13.8	13	0.48	18	5.75	6.5	5.75	6.5	0.8743288
T-7	3.75	13.8	6	2.4	19	5.5	12	5.5	12	0.4567501
T-8	3.75	13.8	15	2.4	20	5.5	12	5.5	12	0.4567501
T-9	0.75	13.8	16	0.48	21	5.75	5	5.5	5	1.078639
T-10	1.5	13.8	25	0.48	28	5.75	6.5	5.75	6.5	0.8469585
T-11	1.5	13.8	26	0.48	29	5.75	6.5	5.5	6.5	0.8363145
T-12	1.5	13.8	27	0.48	30	5.75	6.5	5.5	6.5	0.8363145
T-13	2.5	13.8	31	2.4	36	5.75	10	50	10	0.5472705
T-14	1	13.8	32	0.48	37	5.75	5.5	50	5.5	8.944272
T-17	1.25	13.8	5	0.48	49	4.5	6	4.5	6	0.7397954
T-18	1.5	13.8	50	0.48	51	5.75	5.914	5.75	5.91	0.9292617

APPENDIX H
LOAD FLOW RESULTS

```
------------------------------------------------------------------------------------------------------------------------------------
|                  |                                                                                  |  DIgSILENT    | Project:         |
|                  |                                                                                  | PowerFactory  |------------------
|                  |                                                                                  |    14.1.6     | Date:  4/18/2013 |
------------------------------------------------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------------------------------------------------
| Load Flow Calculation                                      Complete System Report: Substations, Voltage Profiles, Grid Interchange |
------------------------------------------------------------------------------------------------------------------------------------
|     AC Load Flow, balanced, positive sequence                |   Automatic Model Adaptation for Convergence           No       |
|     Automatic Tap Adjust of Transformers         Yes         |   Max. Acceptable Load Flow Error for                           |
|     Consider Reactive Power Limits               Yes         |      Nodes                                           1.00 kVA   |
|                                                              |      Model Equations                                 0.10 %     |
------------------------------------------------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------------------------------------------------
| Grid: IPS Draft           System Stage: IPS Draft       | Study Case: Study Case                 | Annex:                   / 7  |
------------------------------------------------------------------------------------------------------------------------------------
|          rated                               Active Reactive Power                   |                                          |
|         Voltage     Bus-voltage              Power   Power   Factor Current Loading|              Additional Data              |
|           [kV]  [p.u.]    [kV]    [deg]     [MW]   [Mvar]    [-]    [kA]     [%]   |                                          |
------------------------------------------------------------------------------------------------------------------------------------
|02                                                                                   |                                          |
|  69-1     69.00    1.00   69.00     0.00                                           |                                          |
|   Cubicle/Coup       CBS                                                           |                                          |
|   Cub_1   /Lne       OHL1                     11.15    -0.99    1.00    0.09    9.36 |Pv:      0.11 kW   cLod: -0.00 Mvar L:    3.05 km|
|   Cub_1   /Tr2       T-1                     -11.15     0.99   -1.00    0.09   74.61 |Tap:     0.00      Min:      0      Max:    0   |
|  69-2     69.00    1.00   69.00    -0.00                                           |                   |                      |
|   Cubicle/Coup       CBS                                                           |                                          |
|   Cub_1   /Lne       Line                     -5.57     0.37   -1.00    0.05    4.67 |Pv:      0.03 kW   cLod: -0.00 Mvar L:    3.05 km|
|   Cub_1   /Tr2       T-2                       5.57    -0.37    1.00    0.05   37.22 |Tap:     0.00      Min:      0      Max:    0   |
|                                                                                   |                                          |
|04                                                                                   |                                          |
|  MILL-1  13.80    1.00   13.80     3.42                                           |                                          |
|   Cub_1   /Genstat  Static Generator          8.50     0.27    1.00    0.36   85.04 |                                          |
|   Cubicle/Coup       CBS                                                           |                                          |
|   Cub_1   /Lne       L3-26                     0.77     0.50    0.84    0.04   12.20 |Pv:      0.18 kW   cLod: -0.00 Mvar L:    0.21 km|
|   Cub_1   /Lne       L3-5                      2.22     1.34    0.86    0.11   34.42 |Pv:      0.67 kW   cLod: -0.00 Mvar L:    0.10 km|
|   Cub_1   /Lne       L3-6                      3.02     1.85    0.85    0.15   47.03 |Pv:      1.82 kW   cLod: -0.00 Mvar L:    0.14 km|
|   Cub_1   /Lne       L3-9                      1.82     1.19    0.84    0.09   28.86 |Pv:      0.92 kW   cLod: -0.00 Mvar L:    0.20 km|
|   Cub_1   /Lne       L50-3                   -10.51    -4.29   -0.93    0.47   61.85 |Pv:      8.57 kW   cLod: -0.00 Mvar L:    0.61 km|
|   Cub_1   /Tr2       T-1                      11.19    -0.32    1.00    0.47   74.61 |Tap:     0.00      Min:      0      Max:    0   |
|  MILL-2  13.80    1.00   13.81    -1.71                                           |                                          |
|   Cub_1   /Svs       Static Var System         0.00     0.00    1.00    0.00         |Qtcr:  -0.00 Mvar Qtsc:  0.00 Mvar nCap:   0   |
|   Cub_1   /Sym       GEN-2                     8.00     5.14    0.84    0.40   76.06 |Typ:    PQ                                 |
|   Cubicle/Coup       CB.R6                     2.08     1.42    0.83    0.11    0.00 |                                          |
|   Cubicle/Coup       CBS                                                           |                                          |
|   Cub_1   /Lne       L4-15                     2.66     1.65    0.85    0.13   41.57 |Pv:      2.21 kW   cLod:  0.00 Mvar L:    0.30 km|
|   Cub_1   /Lne       L4-24                     2.45     1.53    0.85    0.12   38.34 |Pv:      1.31 kW   cLod:  0.00 Mvar L:    0.16 km|
|   Cub_1   /Lne       L4-8                      6.36     0.00    1.00    0.27   64.12 |Pv:      1.61 kW   cLod:  0.00 Mvar L:    0.08 km|
|   Cub_1   /Sind      Series Reactor           -0.00    -0.00   -1.00    0.00    0.00 |X:       0.00 Ohm  R:      0.00 Ohm           |
|   Cub_1   /Tr2       T-2                      -5.56     0.53   -1.00    0.23   37.22 |Tap:     0.00      Min:      0      Max:    0   |
|                                                                                   |                                          |

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|          rated                               Active Reactive Power                   |                                          |
|         Voltage     Bus-voltage              Power   Power   Factor Current Loading|              Additional Data              |
|           [kV]  [p.u.]    [kV]    [deg]     [MW]   [Mvar]    [-]    [kA]     [%]   |                                          |
------------------------------------------------------------------------------------------------------------------------------------
|05                                                                                   |                                          |
|  FDR F   13.80    1.00   13.80     3.42                                           |                                          |
|   Cub_1   /Lne       L3-5                     -2.22    -1.34   -0.86    0.11   34.42 |Pv:      0.67 kW   cLod: -0.00 Mvar L:    0.10 km|
|   Cub_1   /Tr2       T-17                      0.97     0.56    0.86    0.05   89.86 |Tap:     0.00      Min:      0      Max:    0   |
|   Cub_1   /Tr2       T-3                       1.25     0.78    0.85    0.06   85.12 |Tap:     0.00      Min:      0      Max:    0   |
|                                                                                   |                                          |
|06                                                                                   |                                          |
|  FDR H   13.80    1.00   13.79     3.42                                           |                                          |
|   Cub_1   /Lne       L3-6                     -3.02    -1.85   -0.85    0.15   47.03 |Pv:      1.82 kW   cLod: -0.00 Mvar L:    0.14 km|
|   Cub_1   /Tr2       T-4                       0.35     0.21    0.86    0.02   27.32 |Tap:     0.00      Min:      0      Max:    0   |
|   Cub_1   /Tr2       T-7                       2.66     1.65    0.85    0.13   83.51 |Tap:     0.00      Min:      0      Max:    0   |
|                                                                                   |                                          |
|07                                                                                   |                                          |
|  FDR71/7213.80    1.00   13.81    -1.71                                           |                                          |
|   Cubicle/Coup       CB3                      -2.08    -1.42   -0.83    0.11    0.00 |                                          |
|   Cub_1   /Lne       L7-16                     0.43     0.30    0.81    0.02    6.93 |Pv:      0.10 kW   cLod:  0.00 Mvar L:    0.36 km|
|   Cub_1   /Lne       L7-27                     1.66     1.12    0.83    0.08   26.55 |Pv:      0.76 kW   cLod:  0.00 Mvar L:    0.19 km|
|                                                                                   |                                          |
|08                                                                                   |                                          |
|  FDR L   13.80    1.00   13.80    -1.74                                           |                                          |
|   Cub_1   /Asm       M-FDR-L                   6.36     0.00    1.00    0.27   88.02 |Slip:    0.89 %    xm:     4.00 p.u.          |
|   Cub_1   /Lne       L4-8(1)                  -6.36     0.00   -1.00    0.27   64.12 |Pv:      1.61 kW   cLod:  0.00 Mvar L:    0.08 km|
|                                                                                   |                                          |
|09                                                                                   |                                          |
|  FDR E   13.80    1.00   13.79     3.42                                           |                                          |
|   Cub_1   /Lne       L3-9                     -1.82    -1.19   -0.84    0.09   28.86 |Pv:      0.92 kW   cLod: -0.00 Mvar L:    0.20 km|
|   Cub_1   /Lne       L9-12                     0.00    -0.00    1.00    0.00    0.00 |Pv:      0.00 kW   cLod: -0.00 Mvar L:    0.05 km|
|   Cub_1   /Lne       L9-12                     0.92     0.63    0.82    0.05   14.89 |Pv:      0.06 kW   cLod: -0.00 Mvar L:    0.05 km|
|   Cub_1   /Lne       L9-13                     0.00    -0.00    1.00    0.00    0.00 |Pv:      0.00 kW   cLod: -0.00 Mvar L:    0.02 km|
|   Cub_1   /Lne       L9-13                     0.00    -0.00    1.00    0.00    0.00 |Pv:      0.00 kW   cLod: -0.00 Mvar L:    0.02 km|
|   Cub_1   /Lne       L9-25                     0.00     0.00    1.00    0.00    0.00 |Pv:      0.00 kW   cLod: -0.00 Mvar L:    0.56 km|
|   Cub_1   /Lne       L9-25                     0.90     0.55    0.85    0.04   13.98 |Pv:      0.61 kW   cLod: -0.00 Mvar L:    0.56 km|
|                                                                                   |                                          |
|10                                                                                   |                                          |
|  EMERG   13.80    1.00   13.80    -1.71                                           |                                          |
|   Cub_1   /Lne       L10-12                    0.00     0.00    1.00    0.00    0.00 |Pv:      0.00 kW   cLod:  0.00 Mvar L:    0.00 km|
|   Cub_1   /Lne       L10-13                    0.92     0.63    0.83    0.05   14.80 |Pv:      0.08 kW   cLod:  0.00 Mvar L:    0.06 km|
|   Cub_1   /Lne       L10-27                   -0.92    -0.63   -0.83    0.05   14.80 |Pv:      0.18 kW   cLod:  0.00 Mvar L:    0.14 km|
|                                                                                   |                                          |
|100                                                                                  |                                          |
|  UTIL-69 69.00    1.00   69.00     0.00                                           |                                          |
|   Cub_1   /Xnet      UTIL-1                   -5.58     0.62   -0.99    0.05         |Sk":  1000.00 MVA                          |
|   Cub_1   /Lne       Line                      5.57    -0.37    1.00    0.05    4.67 |Pv:      0.03 kW   cLod: -0.00 Mvar L:    3.05 km|
|   Cub_1   /Lne       OHL1                    -11.15     0.99   -1.00    0.09    9.36 |Pv:      0.11 kW   cLod: -0.00 Mvar L:    3.05 km|
|                                                                                   |                                          |
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|            rated                        Active Reactive Power                     |                                              |
|           Voltage     Bus-voltage         Power   Power   Factor Current Loading  |                 Additional Data              |
|             [kV]  [p.u.]    [kV]   [deg]   [MW]   [Mvar]   [-]    [kA]    [%]    |                                              |
-----------------------------------------------------------------------------------------------------------------------------------
|11                                                                                 |                                              |
| T4 SEC   2.40    0.88    2.12    2.74                                             |                                              |
|  Cub_1  /Asm     M-T4-1                   0.35     0.20   0.87    0.11  101.02   |Slip:     1.15 %     xm:    4.00 p.u.         |
|  Cub_1  /Tr2     T-4                     -0.35    -0.20  -0.87    0.11   27.32   |Tap:      0.00       Min:      0       Max:      0 |
|                                                                                   |                                              |
|12                                                                                 |                                              |
| T5 PRI  13.80    1.00   13.79    3.42                                             |                                              |
|  Cub_1  /Lne     L10-12                  -0.00    -0.00  -1.00    0.00    0.00   |Pv:       0.00 kW    cLod:  0.00 Mvar L:     0.00 km|
|  Cub_1  /Lne     L9-12                   -0.92    -0.63  -0.82    0.05   14.89   |Pv:       0.06 kW    cLod: -0.00 Mvar L:     0.05 km|
|  Cub_1  /Tr2     T-5                      0.92     0.63   0.82    0.05   74.73   |Tap:      0.00       Min:      0       Max:      0 |
|                                                                                   |                                              |
|13                                                                                 |                                              |
| T6 PRI  13.80    1.00   13.80   -1.71                                             |                                              |
|  Cub_1  /Lne     L10-13                  -0.92    -0.63  -0.83    0.05   14.80   |Pv:       0.08 kW    cLod:  0.00 Mvar L:     0.06 km|
|  Cub_1  /Lne     L9-13                   -0.00     0.00  -1.00    0.00    0.00   |Pv:       0.00 kW    cLod: -0.00 Mvar L:     0.02 km|
|  Cub_1  /Tr2     T-6                      0.92     0.63   0.83    0.05   74.28   |Tap:      0.00       Min:      0       Max:      0 |
|                                                                                   |                                              |
|15                                                                                 |                                              |
| FDR I   13.80    1.00   13.80   -1.71                                             |                                              |
|  Cub_1  /Lne     L4-15                   -2.66    -1.65  -0.85    0.13   41.57   |Pv:       2.21 kW    cLod:  0.00 Mvar L:     0.30 km|
|  Cub_1  /Tr2     T-8                      2.66     1.65   0.85    0.13   83.47   |Tap:      0.00       Min:      0       Max:      0 |
|                                                                                   |                                              |
|16                                                                                 |                                              |
| T9 PRI  13.80    1.00   13.81   -1.71                                             |                                              |
|  Cub_1  /Lne     L7-16                   -0.43    -0.30  -0.81    0.02    6.93   |Pv:       0.10 kW    cLod:  0.00 Mvar L:     0.36 km|
|  Cub_1  /Tr2     T-9                      0.43     0.30   0.81    0.02   69.61   |Tap:      0.00       Min:      0       Max:      0 |
|                                                                                   |                                              |
|17                                                                                 |                                              |
| T5 SEC   0.48    0.97    0.46    1.24                                             |                                              |
|  Cub_1  /Asm     M-T5-1                   0.52     0.33   0.85    0.77   90.48   |Slip:     0.83 %     xm:    4.00 p.u.         |
|  Cub_1  /Asm     M-T5-2                   0.31     0.19   0.85    0.45   90.69   |Slip:     0.84 %     xm:    4.00 p.u.         |
|  Cub_1  /Lne     L22-17                   0.08     0.06   0.83    0.13   49.59   |Pv:       0.00 kW    cLod: -0.00 Mvar L:     0.01 km|
|  Cub_1  /Tr2     T-5                     -0.91    -0.58  -0.85    1.35   74.73   |Tap:      0.00       Min:      0       Max:      0 |
|                  Total                  -------  -------                          |                                              |
|                  Motor Load:               0.83     0.52                          |                                              |
|                                                                                   |                                              |
|18                                                                                 |                                              |
| T6 SEC   0.48    0.97    0.47   -3.56                                             |                                              |
|  Cub_1  /Asm     M-T6-1                   0.52     0.33   0.85    0.76   90.48   |Slip:     0.82 %     xm:    4.00 p.u.         |
|  Cub_1  /Asm     M-T6-2                   0.31     0.19   0.85    0.45   90.69   |Slip:     0.83 %     xm:    4.00 p.u.         |
|  Cub_1  /Lne     L23-18                   0.08     0.06   0.83    0.13   49.30   |Pv:       0.00 kW    cLod:  0.00 Mvar L:     0.01 km|
|  Cub_1  /Tr2     T-6                     -0.91    -0.58  -0.85    1.34   74.28   |Tap:      0.00       Min:      0       Max:      0 |
|                  Total                  -------  -------                          |                                              |
|                  Motor Load:               0.83     0.52                          |                                              |
|                                                                                   |                                              |
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|            rated                        Active Reactive Power                     |                                              |
|           Voltage     Bus-voltage         Power   Power   Factor Current Loading  |                 Additional Data              |
|             [kV]  [p.u.]    [kV]   [deg]   [MW]   [Mvar]   [-]    [kA]    [%]    |                                              |
-----------------------------------------------------------------------------------------------------------------------------------
|19                                                                                 |                                              |
| T7 SEC   2.40    0.97    2.33    1.24                                             |                                              |
|  Cub_1  /Asm     M-T7-1                   0.88     0.50   0.87    0.25  101.07   |Slip:     0.94 %     xm:    4.00 p.u.         |
|  Cub_1  /Asm     M-T7-2                   1.77     1.00   0.87    0.50   71.17   |Slip:     0.66 %     xm:    4.00 p.u.         |
|  Cubicle/Coup    CB4                                                              |                                              |
|  Cub_1  /Tr2     T-7                     -2.65    -1.50  -0.87    0.75   83.51   |Tap:      0.00       Min:      0       Max:      0 |
|                  Total                  -------  -------                          |                                              |
|                  Motor Load:               2.65     1.50                          |                                              |
|                                                                                   |                                              |
|20                                                                                 |                                              |
| T8 SEC   2.40    0.97    2.34   -3.89                                             |                                              |
|  Cub_1  /Asm     M-T8-1                   1.24     0.70   0.87    0.35  101.16   |Slip:     0.94 %     xm:    4.00 p.u.         |
|  Cub_1  /Asm     M-T8-2                   1.41     0.80   0.87    0.40   56.93   |Slip:     0.53 %     xm:    4.00 p.u.         |
|  Cubicle/Coup    CB4                                                              |                                              |
|  Cub_1  /Tr2     T-8                     -2.65    -1.50  -0.87    0.75   83.47   |Tap:      0.00       Min:      0       Max:      0 |
|                  Total                  -------  -------                          |                                              |
|                  Motor Load:               2.65     1.50                          |                                              |
|                                                                                   |                                              |
|21                                                                                 |                                              |
| T9-SEC   0.48    0.97    0.47   -3.32                                             |                                              |
|  Cub_1  /Asm     M-T9-1                   0.42     0.28   0.83    0.63   84.13   |Slip:     0.75 %     xm:    4.00 p.u.         |
|  Cub_1  /Tr2     T-9                     -0.42    -0.28  -0.83    0.63   69.61   |Tap:      0.00       Min:      0       Max:      0 |
|                                                                                   |                                              |
|22                                                                                 |                                              |
| T5MCC    0.48    0.97    0.46    1.24                                             |                                              |
|  Cub_1  /Asm     M-T5-3                   0.08     0.06   0.83    0.13  112.23   |Slip:     1.01 %     xm:    4.00 p.u.         |
|  Cub_1  /Lne     L22-17                  -0.08    -0.06  -0.83    0.13   49.59   |Pv:       0.00 kW    cLod: -0.00 Mvar L:     0.01 km|
|                                                                                   |                                              |
|23                                                                                 |                                              |
| T6MCC    0.48    0.97    0.47   -3.56                                             |                                              |
|  Cub_1  /Asm     M-T6-3                   0.08     0.06   0.83    0.13  112.23   |Slip:     1.00 %     xm:    4.00 p.u.         |
|  Cub_1  /Lne     L23-18                  -0.08    -0.06  -0.83    0.13   49.30   |Pv:       0.00 kW    cLod:  0.00 Mvar L:     0.01 km|
|                                                                                   |                                              |
|24                                                                                 |                                              |
| FDR M   13.80    1.00   13.80   -1.71                                             |                                              |
|  Cub_1  /Lne     L24-31                   1.78     1.10   0.85    0.09   27.77   |Pv:       0.46 kW    cLod:  0.00 Mvar L:     0.10 km|
|  Cub_1  /Lne     L24-32                   0.67     0.43   0.84    0.03   10.57   |Pv:       0.09 kW    cLod:  0.00 Mvar L:     0.15 km|
|  Cub_1  /Lne     L4-24                   -2.45    -1.53  -0.85    0.12   38.34   |Pv:       1.31 kW    cLod:  0.00 Mvar L:     0.16 km|
|                                                                                   |                                              |
|25                                                                                 |                                              |
| T10 PRI 13.80    1.00   13.78    3.41                                             |                                              |
|  Cub_1  /Lne     L9-25                   -0.89    -0.55  -0.85    0.04   13.98   |Pv:       0.61 kW    cLod: -0.00 Mvar L:     0.56 km|
|  Cub_1  /Tr2     T-10                     0.89     0.55   0.85    0.04   70.17   |Tap:      0.00       Min:      0       Max:      0 |
|                                                                                   |                                              |
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```

	rated Voltage [kV]	Bus-voltage [p.u.]	Bus-voltage [kV]	[deg]	Active Power [MW]	Reactive Power [Mvar]	Power Factor [-]	Current [kA]	Loading [%]	Additional Data
26										
FDR G	13.80	1.00	13.80	3.42						
Cub_1	/Lne	L3-26			-0.77	-0.50	-0.84	0.04	12.20	Pv: 0.18 kW cLod: -0.00 Mvar L: 0.21 km
Cub_1	/Tr2	T-11			0.00	0.00	1.00	0.00	0.00	Tap: 0.00 Min: 0 Max: 0
Cub_1	/Tr2	T-11			0.77	0.50	0.84	0.04	61.21	Tap: 0.00 Min: 0 Max: 0
27										
T12-PRI	13.80	1.00	13.80	-1.71						
Cub_1	/Lne	L10-27			0.00	0.00	1.00	0.00	0.00	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.14 km
Cub_1	/Lne	L10-27			0.92	0.63	0.83	0.05	14.80	Pv: 0.18 kW cLod: 0.00 Mvar L: 0.14 km
Cub_1	/Lne	L7-27			-1.66	-1.12	-0.83	0.08	26.55	Pv: 0.76 kW cLod: 0.00 Mvar L: 0.19 km
Cub_1	/Tr2	T-12			0.00	0.00	1.00	0.00	0.00	Tap: 0.00 Min: 0 Max: 0
Cub_1	/Tr2	T-12			0.74	0.49	0.83	0.04	58.97	Tap: 0.00 Min: 0 Max: 0
28										
T10 SEC	0.48	0.97	0.47	1.60						
Cub_1	/Asm	M-T10-1			0.26	0.16	0.85	0.37	93.35	Slip: 0.85 % xm: 4.00 p.u.
Cub_1	/Asm	M-T10-2			0.32	0.19	0.85	0.46	93.54	Slip: 0.86 % xm: 4.00 p.u.
Cub_1	/Lne	Busway1			0.14	0.05	0.95	0.18	18.46	Pv: 0.05 kW cLod: -0.00 Mvar L: 0.01 km
Cub_1	/Lne	L28-38			0.00	0.00	1.00	0.00	0.00	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.02 km
Cub_1	/Lne	L33-28			0.17	0.11	0.83	0.25	98.15	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.01 km
Cub_1	/Tr2	T-10			-0.89	-0.51	-0.87	1.27	70.17	Tap: 0.00 Min: 0 Max: 0
		Total Motor Load:			0.58	0.35				
29										
T11 SEC	0.48	0.98	0.47	1.88						
Cub_1	/Asm	M-T11-1			0.33	0.20	0.86	0.48	103.33	Slip: 0.94 % xm: 4.00 p.u.
Cub_1	/Asm	M-T11-2			0.37	0.23	0.86	0.54	103.41	Slip: 0.94 % xm: 4.00 p.u.
Cub_1	/Lne	L29-28			0.00	0.00	1.00	0.00	0.00	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.02 km
Cub_1	/Lne	L34-29			0.06	0.04	0.83	0.09	36.17	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.01 km
Cub_1	/Tr2	T-11			-0.77	-0.47	-0.85	1.10	61.21	Tap: 0.00 Min: 0 Max: 0
		Total Motor Load:			0.70	0.43				
30										
T12 SEC	0.48	0.98	0.47	-3.17						
Cub_1	/Asm	M-T12-1			0.25	0.16	0.85	0.36	91.44	Slip: 0.82 % xm: 4.00 p.u.
Cub_1	/Asm	M-T12-2			0.31	0.19	0.85	0.45	91.63	Slip: 0.83 % xm: 4.00 p.u.
Cub_1	/Lne	L35-30			0.17	0.11	0.83	0.25	97.69	Pv: 0.00 kW cLod: 0.00 Mvar L: 0.01 km
Cub_1	/Lne	L38-30			0.00	0.00	1.00	0.00	0.00	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.02 km
Cub_1	/Tr2	T-12			-0.73	-0.46	-0.85	1.06	58.97	Tap: 0.00 Min: 0 Max: 0
		Total Motor Load:			0.56	0.35				

| Grid: IPS Draft System Stage: IPS Draft | Study Case: Study Case | Annex: / 12 |

	rated Voltage [kV]	Bus-voltage [p.u.]	Bus-voltage [kV]	[deg]	Active Power [MW]	Reactive Power [Mvar]	Power Factor [-]	Current [kA]	Loading [%]	Additional Data
31										
FDR P	13.80	1.00	13.80	-1.71						
Cub_1	/Lne	L24-31			-1.78	-1.10	-0.85	0.09	27.77	Pv: 0.46 kW cLod: 0.00 Mvar L: 0.10 km
Cub_1	/Tr2	T-13			1.78	1.10	0.85	0.09	83.64	Tap: 0.00 Min: 0 Max: 0
32										
FDR Q	13.80	1.00	13.80	-1.71						
Cub_1	/Lne	L24-32			-0.67	-0.43	-0.84	0.03	10.57	Pv: 0.09 kW cLod: 0.00 Mvar L: 0.15 km
Cub_1	/Tr2	T-14			0.67	0.43	0.84	0.03	79.57	Tap: 0.00 Min: 0 Max: 0
33										
T10 MCC	0.48	0.97	0.47	1.60						
Cub_1	/Asm	M-T10-3			0.17	0.11	0.83	0.25	28.36	Slip: 0.25 % xm: 4.00 p.u.
Cub_1	/Lne	L33-28			-0.17	-0.11	-0.83	0.25	98.15	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.01 km
34										
T11 MCC	0.48	0.98	0.47	1.88						
Cub_1	/Asm	M-T11-3			0.06	0.04	0.83	0.09	84.79	Slip: 0.74 % xm: 4.00 p.u.
Cub_1	/Lne	L34-29			-0.06	-0.04	-0.83	0.09	36.17	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.01 km
35										
T12 MCC	0.48	0.98	0.47	-3.17						
Cub_1	/Asm	M-T12-3			0.17	0.11	0.83	0.25	83.94	Slip: 0.74 % xm: 4.00 p.u.
Cub_1	/Lne	L35-30			-0.17	-0.11	-0.83	0.25	97.69	Pv: 0.00 kW cLod: 0.00 Mvar L: 0.01 km
36										
T13-SEC	2.40	0.97	2.33	-3.96						
Cub_1	/Asm	M-T13-1			1.77	1.00	0.87	0.50	106.74	Slip: 1.00 % xm: 4.00 p.u.
Cub_1	/Tr2	T-13			-1.77	-1.00	-0.87	0.50	83.64	Tap: 0.00 Min: 0 Max: 0
37										
T14-SEC	0.48	0.97	0.47	-3.69						
Cub_1	/Asm	M-T14-1			0.46	0.28	0.86	0.67	96.05	Slip: 0.89 % xm: 4.00 p.u.
Cub_1	/Asm	M-T14-2			0.20	0.12	0.86	0.29	32.41	Slip: 0.30 % xm: 4.00 p.u.
Cub_1	/Tr2	T-14			-0.66	-0.39	-0.86	0.96	79.57	Tap: 0.00 Min: 0 Max: 0
		Total Motor Load:			0.66	0.39				
38										
480 TIE	0.48	0.98	0.47	1.88						
Cub_1	/Lne	L28-38			0.00	0.00	1.00	0.00	0.00	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.02 km
Cub_1	/Lne	L29-28			-0.00	-0.00	-1.00	0.00	0.00	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.02 km
Cub_1	/Lne	L38-30			0.00	0.00	1.00	0.00	0.00	Pv: 0.00 kW cLod: -0.00 Mvar L: 0.02 km

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| Grid: IPS Draft              System Stage: IPS Draft       | Study Case: Study Case                    | Annex:                / 13 |
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|            rated                                         Active Reactive Power                      |                                           |
|           Voltage     Bus-voltage                       Power    Power   Factor Current Loading     |              Additional Data              |
|            [kV]  [p.u.]     [kV]    [deg]               [MW]    [Mvar]    [-]    [kA]     [%]     |                                           |
-----------------------------------------------------------------------------------------------------------------------------------
|39                                                                                                   |                                           |
|  T3 SEC   4.16    0.97    4.03     1.07                                                            |                                           |
|   Cub_1  /Asm      M-T3-1                              1.24     0.70   0.87    0.20  101.18   |Slip:      0.95 %     xm:    4.00 p.u.                    |
|   Cub_1  /Tr2      T-3                                -1.24    -0.70  -0.87    0.20   85.12   |Tap:       0.00       Min:      0       Max:     0        |
|                                                                                                     |                                           |
|41                                                                                                   |                                           |
|  LGTS     0.48    0.97    0.47     1.60                                                            |                                           |
|   Cub_1  /Lod      LGTS                                0.14     0.05   0.95    0.18           |Pl0:       0.15 MW    Ql0:   0.05 Mvar                   |
|   Cub_1  /Lne      Busway1                            -0.14    -0.05  -0.95    0.18   18.46   |Pv:        0.05 kW    cLod: -0.00 Mvar L:      0.01 km|
|                                                                                                     |                                           |
|49                                                                                                   |                                           |
|  RECT     0.48    0.97    0.47     1.59                                                            |                                           |
|   Cub_1  /Asm      M-T17-1                             0.96     0.52   0.88    1.35  113.63   |Slip:      1.07 %     xm:    4.00 p.u.                    |
|   Cub_1  /Lod      General Load                        0.00     0.00   1.00    0.00           |Pl0:       0.00 MW    Ql0:   0.00 Mvar                   |
|   Cub_1  /Tr2      T-17                               -0.96    -0.52  -0.88    1.35   89.86   |Tap:       0.00       Min:      0       Max:     0        |
|                                                                                                     |                                           |
|50                                                                                                   |                                           |
|  GEN-1   13.80    1.00   13.82     3.48                                                            |                                           |
|   Cub_1  /Sym      GEN1                               11.00     4.63   0.92    0.50   76.38   |Typ:     PQ                                            |
|   Cub_1  /Lne      L50-3                              10.52     4.31   0.93    0.47   61.85   |Pv:        8.57 kW    cLod: -0.00 Mvar L:      0.61 km|
|   Cub_1  /Tr2      T-18                                0.48     0.32   0.83    0.02   38.40   |Tap:       0.00       Min:      0       Max:     0        |
|                                                                                                     |                                           |
|51                                                                                                   |                                           |
|  AUX      0.48    0.99    0.47     2.55                                                            |                                           |
|   Cub_1  /Asm      M-30                                0.12     0.08   0.84    0.17   88.44   |Slip:      0.77 %     xm:    4.00 p.u.                    |
|   Cub_1  /Asm      M-31                                0.36     0.23   0.84    0.52   88.52   |Slip:      0.78 %     xm:    4.00 p.u.                    |
|   Cub_1  /Tr2      T-18                               -0.48    -0.31  -0.84    0.69   38.40   |Tap:       0.00       Min:      0       Max:     0        |
|                    Total                             -------  -------                          |                                           |
|                    Motor Load:                         0.48     0.31                           |                                           |
|                                                                                                     |                                           |
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| Load Flow Calculation                                   Complete System Report: Substations, Voltage Profiles, Grid Interchange |
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|     AC Load Flow, balanced, positive sequence                |    Automatic Model Adaptation for Convergence          No      |
|     Automatic Tap Adjust of Transformers           Yes       |    Max. Acceptable Load Flow Error for                         |
|     Consider Reactive Power Limits                 Yes       |       Nodes                                             1.00 kVA |
|                                                              |       Model Equations                                   0.10 %   |
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| Grid: IPS Draft              System Stage: IPS Draft       | Study Case: Study Case                    | Annex:                / 14 |
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|                      rtd.V      Bus - voltage                                    Voltage - Deviation [%]                        |
|                       [kV]  [p.u.]     [kV]  [deg]            -10         -5            0            +5           +10            |
-----------------------------------------------------------------------------------------------------------------------------------
|02                                                                                                                               |
|  69-1                69.00  1.000    69.00   0.00                                      |                                        |
|  69-2                69.00  1.000    69.00  -0.00                                      |                                        |
|04                                                                                                                               |
|  MILL-1              13.80  1.000    13.80   3.42                                      |                                        |
|  MILL-2              13.80  1.001    13.81  -1.71                                      |                                        |
|05                                                                                                                               |
|  FDR F               13.80  1.000    13.80   3.42                                      |                                        |
|06                                                                                                                               |
|  FDR H               13.80  0.999    13.79   3.42                                      |                                        |
|07                                                                                                                               |
|  FDR71/72            13.80  1.001    13.81  -1.71                                      |                                        |
|08                                                                                                                               |
|  FDR L               13.80  1.000    13.80  -1.74                                      |                                        |
|09                                                                                                                               |
|  FDR E               13.80  0.999    13.79   3.42                                      |                                        |
|10                                                                                                                               |
|  EMERG               13.80  1.000    13.80  -1.71                                      |                                        |
|100                                                                                                                              |
|  UTIL-69             69.00  1.000    69.00   0.00                                      |                                        |
|11                                                                                                                               |
|  T4 SEC               2.40  0.883     2.12   2.74            <\\\\\\\\\\\\\\\\\\\\\\\|                                        |
|12                                                                                                                               |
|  T5 PRI              13.80  0.999    13.79   3.42                                      |                                        |
|13                                                                                                                               |
|  T6 PRI              13.80  1.000    13.80  -1.71                                      |                                        |
|15                                                                                                                               |
|  FDR I               13.80  1.000    13.80  -1.71                                      |                                        |
|16                                                                                                                               |
|  T9 PRI              13.80  1.000    13.81  -1.71                                      |                                        |
|17                                                                                                                               |
|  T5 SEC               0.48  0.966     0.46   1.24                              <<<<<<<<|                                        |
|18                                                                                                                               |
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Bus	No.	rtd.V [kV]	Bus - voltage [p.u.]	Bus - voltage [kV]	[deg]	Voltage - Deviation [%] (-10 / -5 / 0 / +5 / +10)
T6 SEC	19	0.48	0.971	0.47	-3.56	<<<<<<<|
T7 SEC	20	2.40	0.973	2.33	1.24	<<<<<<|
T8 SEC	21	2.40	0.973	2.34	-3.89	<<<<<<|
T9-SEC	22	0.48	0.972	0.47	-3.32	<<<<<<<|
T5MCC	23	0.48	0.966	0.46	1.24	<<<<<<<<|
T6MCC	24	0.48	0.971	0.47	-3.56	<<<<<<<|
FDR M	25	13.80	1.000	13.80	-1.71	|
T10 PRI	26	13.80	0.999	13.78	3.41	|
FDR G	27	13.80	1.000	13.80	3.42	|
T12-PRI	28	13.80	1.000	13.80	-1.71	|
T10 SEC	29	0.48	0.973	0.47	1.60	<<<<<<|
T11 SEC	30	0.48	0.977	0.47	1.88	<<<<<|
T12 SEC	31	0.48	0.978	0.47	-3.17	<<<<<|
FDR P	32	13.80	1.000	13.80	-1.71	|
FDR Q	33	13.80	1.000	13.80	-1.71	|
T10 MCC	34	0.48	0.973	0.47	1.60	<<<<<<|
T11 MCC	35	0.48	0.977	0.47	1.88	<<<<<|
T12 MCC	36	0.48	0.978	0.47	-3.17	<<<<<|
T13-SEC	37	2.40	0.971	2.33	-3.96	<<<<<<<|
T14-SEC	38	0.48	0.969	0.47	-3.69	<<<<<<<|
480 TIE	39	0.48	0.977	0.47	1.88	<<<<<|
T3 SEC	41	4.16	0.968	4.03	1.07	<<<<<<<<|
LGTS	49	0.48	0.973	0.47	1.60	<<<<<<|

Bus	No.	rtd.V [kV]	Bus - voltage [p.u.]	Bus - voltage [kV]	[deg]	Voltage - Deviation [%] (-10 / -5 / 0 / +5 / +10)
RECT	50	0.48	0.974	0.47	1.59	<<<<<<|
GEN-1	51	13.80	1.001	13.82	3.48	|
AUX		0.48	0.986	0.47	2.55	<<<|

Load Flow Calculation — Complete System Report: Substations, Voltage Profiles, Grid Interchange

AC Load Flow, balanced, positive sequence		Automatic Model Adaptation for Convergence		No
Automatic Tap Adjust of Transformers	Yes	Max. Acceptable Load Flow Error for		
Consider Reactive Power Limits	Yes	Nodes		1.00 kVA
		Model Equations		0.10 %

Grid: IPS Draft | System Stage: IPS Draft | Study Case: Study Case | Annex: / 17

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen- sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
0.48	0.00	6.60	0.14	0.00	0.00			0.00	0.00	0.00
	0.00	4.05	0.05	0.00	0.00			0.00	0.00	0.00
						13.80 kV	-6.74	0.05	0.05	0.00
							-4.10	0.32	0.32	0.00
2.40	0.00	7.42	0.00	0.00	0.00			0.00	0.00	0.00
	0.00	4.20	0.00	0.00	0.00			0.00	0.00	0.00
						13.80 kV	-7.42	0.03	0.03	0.00
							-4.20	0.39	0.39	0.00
4.16	0.00	1.24	0.00	0.00	0.00			0.00	0.00	0.00
	0.00	0.70	0.00	0.00	0.00			0.00	0.00	0.00
						13.80 kV	-1.24	0.01	0.01	0.00
							-0.70	0.07	0.07	0.00
13.80	27.50	6.36	0.00	0.00	0.00			0.02	0.02	0.00
	10.03	0.00	0.00	0.00	0.00			0.03	0.03	0.00
						0.48 kV	6.79	0.05	0.05	0.00
							4.42	0.32	0.32	0.00
						2.40 kV	7.45	0.03	0.03	0.00
							4.60	0.39	0.39	0.00
						4.16 kV	1.25	0.01	0.01	0.00
							0.78	0.07	0.07	0.00
						69.00 kV	5.63	0.05	0.05	0.00
							0.21	0.83	0.83	0.00
69.00	0.00	0.00	0.00	0.00	-5.58			0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.62			0.00	0.00	0.00
						13.80 kV	-5.58	0.05	0.05	0.00
							0.62	0.83	0.83	0.00

Grid: IPS Draft	System Stage: IPS Draft	Study Case: Study Case	Annex: / 18

Volt. Level [kV]	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Interchange to	Power Interchange [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
Total:	27.50 10.03	21.61 8.96	0.14 0.05	0.00 0.00	-5.58 0.62		0.00 -0.00	0.17 1.65	0.17 1.65	0.00 0.00

	DIgSILENT PowerFactory 14.1.6	Project:
		Date: 4/18/2013

Load Flow Calculation	Complete System Report: Substations, Voltage Profiles, Grid Interchange

AC Load Flow, balanced, positive sequence		Automatic Model Adaptation for Convergence	No
Automatic Tap Adjust of Transformers	Yes	Max. Acceptable Load Flow Error for	
Consider Reactive Power Limits	Yes	Nodes	1.00 kVA
		Model Equations	0.10 %

Total System Summary	Study Case: Study Case	Annex: / 19

	Generation [MW]/ [Mvar]	Motor Load [MW]/ [Mvar]	Load [MW]/ [Mvar]	Compen-sation [MW]/ [Mvar]	External Infeed [MW]/ [Mvar]	Inter Area Flow [MW]/ [Mvar]	Total Losses [MW]/ [Mvar]	Load Losses [MW]/ [Mvar]	Noload Losses [MW]/ [Mvar]
\moh\IEEE Typical Power System\Network Model\Network Data\IPS Draft	27.50 10.03	21.61 8.96	0.14 0.05	0.00 0.00	-5.58 0.62	0.00 -0.00	0.17 1.65	0.17 1.65	0.00 0.00
Total:	27.50 10.03	21.61 8.96	0.14 0.05	0.00 0.00	-5.58 0.62		0.17 1.65	0.17 1.65	0.00 0.00

APPENDIX I

GRID SUMMARY OF LOAD FLOW

Load Flow Calculation			Grid Summary
AC Load Flow, balanced, positive sequence		Automatic Model Adaptation for Convergence	No
Automatic Tap Adjust of Transformers	Yes	Max. Acceptable Load Flow Error for	
Consider Reactive Power Limits	No	Nodes	1.00 kVA
		Model Equations	0.10 %

Grid: Grid	System Stage: Grid	Study Case: Study Case	Annex: / 1

Grid: Grid Summary

No. of Substations	42	No. of Busbars	43	No. of Terminals	573	No. of Lines	29
No. of 2-w Trfs.	16	No. of 3-w Trfs.	0	No. of syn. Machines	2	No. of asyn.Machines	29
No. of Loads	3	No. of Shunts	0	No. of SVS	0		

Generation	=	19.00 MW	9.77 Mvar	21.36 MVA
External Infeed	=	2.92 MW	0.32 Mvar	2.93 MVA
Inter Grid Flow	=	0.00 MW	0.00 Mvar	
Load P(U)	=	0.15 MW	0.05 Mvar	0.16 MVA
Load P(Un)	=	0.15 MW	0.05 Mvar	0.16 MVA
Load P(Un-U)	=	0.00 MW	0.00 Mvar	
Motor Load	=	21.61 MW	8.96 Mvar	23.39 MVA
Grid Losses	=	0.16 MW	1.08 Mvar	
Line Charging	=		0.00 Mvar	
Compensation ind.	=		0.00 Mvar	
Compensation cap.	=		0.00 Mvar	

Installed Capacity	=	23.91 MW
Spinning Reserve	=	4.91 MW

Total Power Factor:

Generation	=	0.89 [-]
Load/Motor	=	0.95 / 0.92 [-]

APPENDIX J

SHORT CIRCUIT RESULTS FOR BASE CASE

Fault Locations with Feeders -- Complete Report --
Short-Circuit Calculation according to ANSI — 3-Phase Short-Circuit

Pre-fault Voltage	1.00 p.u.	Fault Impedance		NACD Mode	Interpolated
Consider Transformer Taps	No	Resistance, Rf	0.00 Ohm	Currents/Voltages for	LV/Interrupting
		Reactance, Xf	0.00 Ohm		

Grid: Grid — System Stage: Grid — Annex: / 1

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	Symmetrical Current (E/Z) [deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]			
03													
MILL-1	13.80											Sym.Base	Tot.Base
		Mom.Duty	0.041	0.579	13.735	-85.91	328.309	14.794	20.867	35.133		[kA]	[kA]
		Int.Duty	0.042	0.612	12.986	-86.07	310.406	15.117			2 cycles	12.986	17.318
		30-cycle	0.051	0.790	10.064	-86.28	240.559				3 cycles	12.986	14.878
											5 cycles	12.986	13.509
											8 cycles	13.241	13.137
C-E1		Mom.Duty			0.369	98.33	8.809	6.829	20.867	35.133			
		Int.Duty			0.168	98.13	4.019	7.004			2 cycles	12.986	17.318
		30-cycle			0.000	0.00	0.000				3 cycles	12.986	14.878
											5 cycles	12.986	13.509
											8 cycles	13.241	13.137
C-F1		Mom.Duty			0.448	94.20	10.706	13.610	20.867	35.133			
		Int.Duty			0.322	93.87	7.691	14.800			2 cycles	12.986	17.318
		30-cycle			0.000	0.00	0.000				3 cycles	12.986	14.878
											5 cycles	12.986	13.509
											8 cycles	13.241	13.137
C-G1		Mom.Duty			0.202	98.25	4.818	6.895	20.867	35.133			
		Int.Duty			0.091	98.16	2.169	6.975			2 cycles	12.986	17.318
		30-cycle			0.000	0.00	0.000				3 cycles	12.986	14.878
											5 cycles	12.986	13.509
											8 cycles	13.241	13.137
C-H1		Mom.Duty			0.759	93.92	18.150	14.603	20.867	35.133			
		Int.Duty			0.522	93.72	12.477	15.400			2 cycles	12.986	17.318
		30-cycle			0.000	0.00	0.000				3 cycles	12.986	14.878
											5 cycles	12.986	13.509
											8 cycles	13.241	13.137
C1A		Mom.Duty			5.579	93.39	133.346	16.886	20.867	35.133			
		Int.Duty			5.510	93.31	131.706	17.298			2 cycles	12.986	17.318
		30-cycle			3.719	92.70	88.890				3 cycles	12.986	14.878
											5 cycles	12.986	13.509
											8 cycles	13.241	13.137

Grid: Grid — System Stage: Grid — Annex: / 2

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	Symmetrical Current (E/Z) [deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]			
T-1		Mom.Duty			6.381	94.33	152.528	13.205	20.867	35.133			
		Int.Duty			6.375	94.33	152.372	13.222			2 cycles	12.986	17.318
		30-cycle			6.346	94.31	151.692				3 cycles	12.986	14.878
											5 cycles	12.986	13.509
											8 cycles	13.241	13.137
MILL-2	13.80											Sym.Base	Tot.Base
		Mom.Duty	0.033	0.575	13.838	-86.68	330.750	22.078	21.899	36.543		[kA]	[kA]
		Int.Duty	0.036	0.631	12.612	-86.77	301.452	22.389			2 cycles	12.815	17.995
		30-cycle	0.054	0.876	9.077	-86.49	216.959				3 cycles	13.188	15.610
											5 cycles	13.049	14.027
											8 cycles	13.314	13.183
CB.R6		Mom.Duty			0.553	97.51	13.217	7.581	21.899	36.543			
		Int.Duty			0.252	97.18	6.033	7.943			2 cycles	12.815	17.995
		30-cycle			0.000	0.00	0.000				3 cycles	13.188	15.610
											5 cycles	13.049	14.027
											8 cycles	13.314	13.183
C-I1		Mom.Duty			0.550	93.65	13.157	15.680	21.899	36.543			
		Int.Duty			0.393	93.51	9.383	16.280			2 cycles	12.815	17.995
		30-cycle			0.000	0.00	0.000				3 cycles	13.188	15.610
											5 cycles	13.049	14.027
											8 cycles	13.314	13.183
C-L1		Mom.Duty			1.687	91.85	40.329	30.900	21.899	36.543			
		Int.Duty			1.126	91.80	26.920	31.866			2 cycles	12.815	17.995
		30-cycle			0.000	0.00	0.000				3 cycles	13.188	15.610
											5 cycles	13.049	14.027
											8 cycles	13.314	13.183
C-M1		Mom.Duty			0.587	94.11	14.032	13.916	21.899	36.543			
		Int.Duty			0.384	93.40	9.168	16.851			2 cycles	12.815	17.995
		30-cycle			0.000	0.00	0.000				3 cycles	13.188	15.610
											5 cycles	13.049	14.027
											8 cycles	13.314	13.183
T-2		Mom.Duty			6.381	94.34	152.514	13.181	21.899	36.543			
		Int.Duty			6.377	94.33	152.422	13.193			2 cycles	12.815	17.995
		30-cycle			6.356	94.32	151.932				3 cycles	13.188	15.610
											5 cycles	13.049	14.027
											8 cycles	13.314	13.183
Static Generator		Mom.Duty			0.000	0.00	0.000	0.000	0.000	0.000			
		Int.Duty			0.000	0.00	0.000	0.000			2 cycles	0.000	0.000
		30-cycle			0.000	0.00	0.000				3 cycles	0.000	0.000
											5 cycles	0.000	0.000
											8 cycles	0.000	0.000
GEN-2		Mom.Duty			4.084	-88.40	97.618	35.700	21.899	36.543			
		Int.Duty			4.084	-88.40	97.618	35.700			2 cycles	12.815	17.995
		30-cycle			2.723	-88.40	65.079				3 cycles	13.188	15.610
											5 cycles	13.049	14.027
											8 cycles	13.314	13.183

| Grid: Grid | System Stage: Grid | Annex: / 3 |

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
05												
FDR F	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.055	0.590	13.453	-84.70	321.546	11.270	19.703	33.421	[kA]	[kA]
		Int.Duty	0.056	0.623	12.730	-84.90	304.271	11.566		2 cycles	12.730	16.154
		30-cycle	0.066	0.802	9.902	-85.32	236.691			3 cycles	12.730	13.865
										5 cycles	12.730	12.892
										8 cycles	12.754	12.730
C-F1		Mom.Duty			13.004	95.34	310.834	10.703	19.703	33.421		
		Int.Duty			12.408	95.14	296.578	11.124		2 cycles	12.730	16.154
		30-cycle			9.902	94.68	236.691			3 cycles	12.730	13.865
										5 cycles	12.730	12.892
										8 cycles	12.754	12.730
T-17		Mom.Duty			0.139	96.16	3.320	9.267	19.703	33.421		
		Int.Duty			0.096	96.02	2.305	9.480		2 cycles	12.730	16.154
		30-cycle			0.000	0.00	0.000			3 cycles	12.730	13.865
										5 cycles	12.730	12.892
										8 cycles	12.754	12.730
T-3		Mom.Duty			0.309	93.26	7.397	17.546	19.703	33.421		
		Int.Duty			0.226	92.90	5.393	19.742		2 cycles	12.730	16.154
		30-cycle			0.000	0.00	0.000			3 cycles	12.730	13.865
										5 cycles	12.730	12.892
										8 cycles	12.754	12.730
06												
FDR H	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.060	0.594	13.347	-84.26	319.014	10.441	19.321	32.846	[kA]	[kA]
		Int.Duty	0.061	0.628	12.628	-84.44	301.835	10.642		2 cycles	12.628	15.762
		30-cycle	0.072	0.807	9.831	-84.90	234.973			3 cycles	12.628	13.558
										5 cycles	12.628	12.727
										8 cycles	12.628	12.628
C-H1		Mom.Duty			12.586	95.86	300.843	9.748	19.321	32.846		
		Int.Duty			12.106	95.64	289.351	10.124		2 cycles	12.628	15.762
		30-cycle			9.831	95.10	234.973			3 cycles	12.628	13.558
										5 cycles	12.628	12.727
										8 cycles	12.628	12.628
T-4		Mom.Duty			0.091	95.08	2.174	11.247	19.321	32.846		
		Int.Duty			0.038	94.90	0.913	11.672		2 cycles	12.628	15.762
		30-cycle			0.000	0.00	0.000			3 cycles	12.628	13.558
										5 cycles	12.628	12.727
										8 cycles	12.628	12.628
T-7		Mom.Duty			0.670	93.64	16.009	15.727	19.321	32.846		
		Int.Duty			0.484	93.54	11.579	16.153		2 cycles	12.628	15.762
		30-cycle			0.000	0.00	0.000			3 cycles	12.628	13.558
										5 cycles	12.628	12.727
										8 cycles	12.628	12.628

| Grid: Grid | System Stage: Grid | Annex: / 4 |

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
07												
FDR71/72	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.033	0.575	13.838	-86.68	330.750	22.078	21.899	36.543	[kA]	[kA]
		Int.Duty	0.036	0.631	12.612	-86.77	301.452	22.389		2 cycles	12.815	17.995
		30-cycle	0.054	0.876	9.077	-86.49	216.959			3 cycles	13.188	15.610
										5 cycles	13.049	14.027
										8 cycles	13.314	13.183
CB3		Mom.Duty			13.286	93.14	317.569	18.204	21.899	36.543		
		Int.Duty			12.360	93.15	295.434	18.191		2 cycles	12.815	17.995
		30-cycle			9.077	93.51	216.959			3 cycles	13.188	15.610
										5 cycles	13.049	14.027
										8 cycles	13.314	13.183
C-J2		Mom.Duty			0.434	97.87	10.386	7.237	21.899	36.543		
		Int.Duty			0.198	97.65	4.731	7.440		2 cycles	12.815	17.995
		30-cycle			0.000	0.00	0.000			3 cycles	13.188	15.610
										5 cycles	13.049	14.027
										8 cycles	13.314	13.183
C-J3		Mom.Duty			0.119	96.22	2.833	9.170	21.899	36.543		
		Int.Duty			0.054	95.43	1.303	10.510		2 cycles	12.815	17.995
		30-cycle			0.000	0.00	0.000			3 cycles	13.188	15.610
										5 cycles	13.049	14.027
										8 cycles	13.314	13.183
08												
FDR L	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.044	0.588	13.510	-85.72	322.923	17.076	20.861	35.002	[kA]	[kA]
		Int.Duty	0.047	0.645	12.317	-85.81	294.405	16.916		2 cycles	12.317	16.754
		30-cycle	0.068	0.894	8.890	-85.64	212.502			3 cycles	12.409	14.426
										5 cycles	12.413	13.067
										8 cycles	12.679	12.566
C-L1		Mom.Duty			11.818	94.66	282.488	12.279	20.861	35.002		
		Int.Duty			11.189	94.44	267.445	12.865		2 cycles	12.317	16.754
		30-cycle			8.890	94.36	212.502			3 cycles	12.409	14.426
										5 cycles	12.413	13.067
										8 cycles	12.679	12.566
M-FDR-L		Mom.Duty			1.694	91.68	40.483	34.000	20.861	35.002		
		Int.Duty			1.129	91.68	26.988	34.000		2 cycles	12.317	16.754
		30-cycle			0.000	0.00	0.000			3 cycles	12.409	14.426
										5 cycles	12.413	13.067
										8 cycles	12.679	12.566
09												
FDR E	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.068	0.601	13.171	-83.50	314.813	9.017	18.609	31.773	[kA]	[kA]
		Int.Duty	0.070	0.635	12.467	-83.71	297.985	9.262		2 cycles	12.467	15.262
		30-cycle	0.080	0.814	9.743	-84.39	232.883			3 cycles	12.467	13.131
										5 cycles	12.467	12.475
										8 cycles	12.467	12.467

| Grid: Grid | System Stage: Grid | Annex: / 5 |

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	Symmetrical Current (E/Z) [deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
C-E1		Mom.Duty			12.802	96.45	305.997	8.850	18.609	31.773		
		Int.Duty			12.299	96.26	293.966	9.112		2 cycles	12.467	15.262
		30-cycle			9.743	95.61	232.883			3 cycles	12.467	13.131
										5 cycles	12.467	12.475
										8 cycles	12.467	12.467
C-E2		Mom.Duty			0.141	99.05	3.362	6.281	18.609	31.773		
		Int.Duty			0.061	98.96	1.460	6.341		2 cycles	12.467	15.262
		30-cycle			0.000	0.00	0.000			3 cycles	12.467	13.131
										5 cycles	12.467	12.475
										8 cycles	12.467	12.467
C-E3		Mom.Duty			0.000	0.00	0.000	0.000	18.609	31.773		
		Int.Duty			0.000	0.00	0.000	0.000		2 cycles	12.467	15.262
		30-cycle			0.000	0.00	0.000			3 cycles	12.467	13.131
										5 cycles	12.467	12.475
										8 cycles	12.467	12.467
C-E4		Mom.Duty			0.228	97.78	5.459	7.316	18.609	31.773		
		Int.Duty			0.107	97.60	2.562	7.493		2 cycles	12.467	15.262
		30-cycle			0.000	0.00	0.000			3 cycles	12.467	13.131
										5 cycles	12.467	12.475
										8 cycles	12.467	12.467
1												
Bus1	69.00										Sym.Base	Tot.Base
		Mom.Duty	0.735	5.206	7.577	-81.96	905.497	7.669	10.393	17.829	[kA]	[kA]
		Int.Duty	0.739	5.261	7.498	-82.00	896.148	7.694		2 cycles	7.498	8.755
		30-cycle	0.770	5.535	7.129	-82.08	851.967			3 cycles	7.498	7.726
										5 cycles	7.498	7.498
										8 cycles	7.498	7.498
OHL-1		Mom.Duty			6.820	98.53	815.067	6.670	10.393	17.829		
		Int.Duty			6.783	98.47	810.686	6.712		2 cycles	7.498	8.755
		30-cycle			6.626	98.30	791.912			3 cycles	7.498	7.726
										5 cycles	7.498	7.498
										8 cycles	7.498	7.498
T-1		Mom.Duty			0.759	93.63	90.727	15.770	10.393	17.829		
		Int.Duty			0.718	93.47	85.757	16.493		2 cycles	7.498	8.755
		30-cycle			0.505	92.92	60.303			3 cycles	7.498	7.726
										5 cycles	7.498	7.498
										8 cycles	7.498	7.498
10												
EMERG	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.079	0.613	12.896	-82.64	308.240	8.434	18.006	30.803	[kA]	[kA]
		Int.Duty	0.083	0.670	11.807	-82.97	282.203	8.862		2 cycles	11.807	14.376
		30-cycle	0.102	0.916	8.642	-83.66	206.574			3 cycles	11.807	12.387
										5 cycles	11.807	11.807
										8 cycles	11.807	11.807

| Grid: Grid | System Stage: Grid | Annex: / 6 |

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	Symmetrical Current (E/Z) [deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
C-J4		Mom.Duty			0.237	97.75	5.665	7.348	18.006	30.803		
		Int.Duty			0.109	97.58	2.606	7.512		2 cycles	11.807	14.376
		30-cycle			0.000	0.00	0.000			3 cycles	11.807	12.387
										5 cycles	11.807	11.807
										8 cycles	11.807	11.807
C-J5		Mom.Duty			0.000	0.00	0.000	0.000	18.006	30.803		
		Int.Duty			0.000	0.00	0.000	0.000		2 cycles	11.807	14.376
		30-cycle			0.000	0.00	0.000			3 cycles	11.807	12.387
										5 cycles	11.807	11.807
										8 cycles	11.807	11.807
C-J6		Mom.Duty			12.659	97.35	302.575	7.753	18.006	30.803		
		Int.Duty			11.697	97.02	279.597	8.120		2 cycles	11.807	14.376
		30-cycle			8.642	96.34	206.574			3 cycles	11.807	12.387
										5 cycles	11.807	11.807
										8 cycles	11.807	11.807
100												
UTIL-69	69.00										Sym.Base	Tot.Base
		Mom.Duty	0.197	4.040	9.850	-87.21	1177.170	21.063	15.525	25.929	[kA]	[kA]
		Int.Duty	0.196	4.084	9.744	-87.25	1164.566	21.221		2 cycles	9.832	13.902
		30-cycle	0.198	4.297	9.261	-87.37	1106.837			3 cycles	10.323	12.146
										5 cycles	10.239	11.019
										8 cycles	10.586	10.414
OHL-1		Mom.Duty			0.739	94.24	88.286	13.504	15.525	25.929		
		Int.Duty			0.699	94.05	83.575	14.130		2 cycles	9.832	13.902
		30-cycle			0.496	93.34	59.220			3 cycles	10.323	12.146
										5 cycles	10.239	11.019
										8 cycles	10.586	10.414
OHL-2		Mom.Duty			0.744	93.53	88.925	16.229	15.525	25.929		
		Int.Duty			0.678	93.24	81.019	17.671		2 cycles	9.832	13.902
		30-cycle			0.398	92.41	47.622			3 cycles	10.323	12.146
										5 cycles	10.239	11.019
										8 cycles	10.586	10.414
UTIL-1		Mom.Duty			8.367	-87.40	1000.000	22.000	15.525	25.929		
		Int.Duty			8.367	-87.40	1000.000	22.000		2 cycles	9.832	13.902
		30-cycle			8.367	-87.40	1000.000			3 cycles	10.323	12.146
										5 cycles	10.239	11.019
										8 cycles	10.586	10.414
11												
T4 SEC	2.40										Sym.Base	Tot.Base
		Mom.Duty	0.030	0.208	6.609	-81.81	27.471	7.154	8.942	15.370	[kA]	[kA]
		Int.Duty	0.032	0.220	6.243	-81.65	25.952	6.909		2 cycles	6.243	7.097
		30-cycle	0.034	0.233	5.880	-81.63	24.441			3 cycles	6.243	6.376
										5 cycles	6.243	6.243
										8 cycles	6.243	6.243

Grid: Grid	System Stage: Grid	Annex: / 7

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
T-4		Mom.Duty			6.041	98.51	25.114	6.684	8.942	15.370		
		Int.Duty			6.016	98.48	25.009	6.706		2 cycles	6.243	7.097
		30-cycle			5.880	98.37	24.441			3 cycles	6.243	6.376
										5 cycles	6.243	6.243
										8 cycles	6.243	6.243
M-T4-1		Mom.Duty			0.568	94.76	2.362	12.000	8.942	15.370		
		Int.Duty			0.227	94.76	0.945	12.000		2 cycles	6.243	7.097
		30-cycle			0.000	0.00	0.000			3 cycles	6.243	6.376
										5 cycles	6.243	6.243
										8 cycles	6.243	6.243
12												
T5 PRI	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.075	0.607	13.028	-82.91	311.402	8.235	18.111	31.006	[kA]	[kA]
		Int.Duty	0.077	0.641	12.337	-83.14	294.883	8.466		2 cycles	12.337	14.946
		30-cycle	0.087	0.820	9.663	-83.93	230.974			3 cycles	12.337	12.910
										5 cycles	12.337	12.337
										8 cycles	12.337	12.337
C-E4		Mom.Duty			12.800	97.08	305.942	8.055	18.111	31.006		
		Int.Duty			12.230	96.85	292.321	8.320		2 cycles	12.337	14.946
		30-cycle			9.663	96.07	230.974			3 cycles	12.337	12.910
										5 cycles	12.337	12.337
										8 cycles	12.337	12.337
C-J5		Mom.Duty			0.000	0.00	0.000	0.000	0.000	0.000		
		Int.Duty			0.000	0.00	0.000	0.000		2 cycles	0.000	0.000
		30-cycle			0.000	0.00	0.000			3 cycles	0.000	0.000
										5 cycles	0.000	0.000
										8 cycles	0.000	0.000
T-5		Mom.Duty			0.228	97.77	5.460	7.326	18.111	31.006		
		Int.Duty			0.107	97.60	2.562	7.498		2 cycles	12.337	14.946
		30-cycle			0.000	0.00	0.000			3 cycles	12.337	12.910
										5 cycles	12.337	12.337
										8 cycles	12.337	12.337
13												
T6 PRI	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.088	0.620	12.728	-81.96	304.233	7.639	17.446	29.931	[kA]	[kA]
		Int.Duty	0.091	0.677	11.664	-82.33	278.796	8.038		2 cycles	11.664	14.018
		30-cycle	0.111	0.924	8.565	-83.17	204.731			3 cycles	11.664	12.166
										5 cycles	11.664	11.664
										8 cycles	11.664	11.664
C-E3		Mom.Duty			0.000	0.00	0.000	0.000	0.000	0.000		
		Int.Duty			0.000	0.00	0.000	0.000		2 cycles	0.000	0.000
		30-cycle			0.000	0.00	0.000			3 cycles	0.000	0.000
										5 cycles	0.000	0.000
										8 cycles	0.000	0.000

Grid: Grid	System Stage: Grid	Annex: / 8

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
C-J4		Mom.Duty			12.491	98.05	298.567	7.071	17.446	29.931		
		Int.Duty			11.555	97.67	276.190	7.423		2 cycles	11.664	14.018
		30-cycle			8.565	96.83	204.731			3 cycles	11.664	12.166
										5 cycles	11.664	11.664
										8 cycles	11.664	11.664
T-6		Mom.Duty			0.237	97.74	5.666	7.361	17.446	29.931		
		Int.Duty			0.109	97.58	2.606	7.518		2 cycles	11.664	14.018
		30-cycle			0.000	0.00	0.000			3 cycles	11.664	12.166
										5 cycles	11.664	11.664
										8 cycles	11.664	11.664
15												
FDR I	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.073	0.608	13.013	-83.16	311.044	9.408	18.521	31.582	[kA]	[kA]
		Int.Duty	0.076	0.664	11.913	-83.48	284.760	9.807		2 cycles	11.913	14.670
		30-cycle	0.097	0.912	8.687	-83.94	207.632			3 cycles	11.913	12.622
										5 cycles	11.913	11.957
										8 cycles	11.913	11.913
C-I1		Mom.Duty			12.462	96.98	297.876	8.164	18.521	31.582		
		Int.Duty			11.521	96.62	275.374	8.613		2 cycles	11.913	14.670
		30-cycle			8.687	96.06	207.632			3 cycles	11.913	12.622
										5 cycles	11.913	11.957
										8 cycles	11.913	11.913
T-8		Mom.Duty			0.552	93.49	13.192	16.409	18.521	31.582		
		Int.Duty			0.393	93.40	9.401	16.835		2 cycles	11.913	14.670
		30-cycle			0.000	0.00	0.000			3 cycles	11.913	12.622
										5 cycles	11.913	11.957
										8 cycles	11.913	11.913
16												
T9 PRI	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.085	0.618	12.782	-82.19	305.510	7.958	17.656	30.256	[kA]	[kA]
		Int.Duty	0.087	0.674	11.725	-82.61	280.253	8.416		2 cycles	11.725	14.182
		30-cycle	0.106	0.920	8.606	-83.43	205.715			3 cycles	11.725	12.260
										5 cycles	11.725	11.725
										8 cycles	11.725	11.725
C-J3		Mom.Duty			12.663	97.82	302.677	7.278	17.656	30.256		
		Int.Duty			11.670	97.40	278.951	7.703		2 cycles	11.725	14.182
		30-cycle			8.606	96.57	205.715			3 cycles	11.725	12.260
										5 cycles	11.725	11.725
										8 cycles	11.725	11.725
T-9		Mom.Duty			0.119	96.18	2.835	9.230	17.656	30.256		
		Int.Duty			0.055	95.42	1.303	10.547		2 cycles	11.725	14.182
		30-cycle			0.000	0.00	0.000			3 cycles	11.725	12.260
										5 cycles	11.725	11.725
										8 cycles	11.725	11.725

Grid: Grid	System Stage: Grid	Annex: / 9

	Rated Voltage [kV]	Duty	Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
17												
T5 SEC	0.48										MCCB	LV Fuse
		Mom.Duty	0.001	0.008	33.634	-81.67	27.963	7.122	45.471	78.166	[kA]	[kA]
		Int.Duty	0.001	0.008	33.634	-81.67	27.963	7.122	0-10 kA/Fuse		47.523/	36.205
		30-cycle	0.002	0.011	24.385	-81.49	20.274		10-20 kA/PwrBrk		40.276/	34.100
									>20 kA		36.205	
C-T5-1		Mom.Duty			0.851	94.23	0.708	13.511	45.471	78.166		
		Int.Duty			0.851	94.23	0.708	13.511	0-10 kA/Fuse		47.523/	36.205
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		40.276/	34.100
									>20 kA		36.205	
T-5		Mom.Duty			24.929	98.63	20.725	6.586	45.471	78.166		
		Int.Duty			24.929	98.63	20.725	6.586	0-10 kA/Fuse		47.523/	36.205
		30-cycle			24.385	98.51	20.274		10-20 kA/PwrBrk		40.276/	34.100
									>20 kA		36.205	
M-T5-1		Mom.Duty			4.922	95.71	4.092	10.000	45.471	78.166		
		Int.Duty			4.922	95.71	4.092	10.000	0-10 kA/Fuse		47.523/	36.205
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		40.276/	34.100
									>20 kA		36.205	
M-T5-2		Mom.Duty			2.943	101.31	2.447	5.000	45.471	78.166		
		Int.Duty			2.943	101.31	2.447	5.000	0-10 kA/Fuse		47.523/	36.205
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		40.276/	34.100
									>20 kA		36.205	
18												
T6 SEC	0.48										MCCB	LV Fuse
		Mom.Duty	0.001	0.007	37.561	-81.60	31.228	7.055	50.684	87.150	[kA]	[kA]
		Int.Duty	0.001	0.007	37.561	-81.60	31.228	7.055	0-10 kA/Fuse		52.986/	40.367
		30-cycle	0.001	0.010	27.833	-81.47	23.140		10-20 kA/PwrBrk		44.905/	38.019
									>20 kA		40.367	
C-T6-1		Mom.Duty			0.851	94.23	0.708	13.511	50.684	87.150		
		Int.Duty			0.851	94.23	0.708	13.511	0-10 kA/Fuse		52.986/	40.367
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		44.905/	38.019
									>20 kA		40.367	
T-6		Mom.Duty			28.857	98.69	23.991	6.542	50.684	87.150		
		Int.Duty			28.857	98.69	23.991	6.542	0-10 kA/Fuse		52.986/	40.367
		30-cycle			27.833	98.53	23.140		10-20 kA/PwrBrk		44.905/	38.019
									>20 kA		40.367	
M-T6-1		Mom.Duty			4.922	95.71	4.092	10.000	50.684	87.150		
		Int.Duty			4.922	95.71	4.092	10.000	0-10 kA/Fuse		52.986/	40.367
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		44.905/	38.019
									>20 kA		40.367	
M-T6-2		Mom.Duty			2.943	101.31	2.447	5.000	50.684	87.150		
		Int.Duty			2.943	101.31	2.447	5.000	0-10 kA/Fuse		52.986/	40.367
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		44.905/	38.019
									>20 kA		40.367	

Grid: Grid	System Stage: Grid	Annex: / 10

	Rated Voltage [kV]	Duty	Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
19												
T7 SEC	2.40										Sym.Base	Tot.Base
		Mom.Duty	0.006	0.075	18.421	-85.49	76.573	13.505	27.667	46.694	[kA]	[kA]
		Int.Duty	0.007	0.083	16.636	-85.40	69.156	13.048		2 cycles	16.636	21.676
		30-cycle	0.009	0.109	12.713	-85.16	52.847			3 cycles	16.636	18.652
										5 cycles	16.636	17.174
										8 cycles	16.878	16.705
T-7		Mom.Duty			13.390	94.96	55.660	11.515	27.667	46.694		
		Int.Duty			13.282	94.93	55.214	11.593		2 cycles	16.636	21.676
		30-cycle			12.713	94.84	52.847			3 cycles	16.636	18.652
										5 cycles	16.636	17.174
										8 cycles	16.878	16.705
M-T7-1		Mom.Duty			1.619	92.19	6.732	26.100	27.667	46.694		
		Int.Duty			1.080	92.19	4.488	26.100		2 cycles	16.636	21.676
		30-cycle			0.000	0.00	0.000			3 cycles	16.636	18.652
										5 cycles	16.636	17.174
										8 cycles	16.878	16.705
M-T7-2		Mom.Duty			3.414	93.81	14.190	15.000	27.667	46.694		
		Int.Duty			2.276	93.81	9.460	15.000		2 cycles	16.636	21.676
		30-cycle			0.000	0.00	0.000			3 cycles	16.636	18.652
										5 cycles	16.636	17.174
										8 cycles	16.878	16.705
2												
Bus2	69.00										Sym.Base	Tot.Base
		Mom.Duty	0.731	5.206	7.578	-82.01	905.625	8.180	10.521	18.015	[kA]	[kA]
		Int.Duty	0.739	5.270	7.486	-82.01	894.696	8.185		2 cycles	7.486	8.840
		30-cycle	0.785	5.570	7.083	-81.98	846.471			3 cycles	7.486	7.744
										5 cycles	7.486	7.486
										8 cycles	7.486	7.486
OHL-2		Mom.Duty			6.816	98.57	814.637	6.639	10.521	18.015		
		Int.Duty			6.795	98.53	812.035	6.666		2 cycles	7.486	8.840
		30-cycle			6.681	98.38	798.433			3 cycles	7.486	7.744
										5 cycles	7.486	7.486
										8 cycles	7.486	7.486
T-2		Mom.Duty			0.765	92.89	91.390	19.776	10.521	18.015		
		Int.Duty			0.695	92.66	83.056	21.540		2 cycles	7.486	8.840
		30-cycle			0.404	92.06	48.315			3 cycles	7.486	7.744
										5 cycles	7.486	7.486
										8 cycles	7.486	7.486
20												
T8 SEC	2.40										Sym.Base	Tot.Base
		Mom.Duty	0.007	0.080	17.281	-85.28	71.836	13.136	25.862	43.680	[kA]	[kA]
		Int.Duty	0.007	0.088	15.770	-85.19	65.553	12.727		2 cycles	15.770	20.440
		30-cycle	0.010	0.112	12.348	-84.92	51.330			3 cycles	15.770	17.576
										5 cycles	15.770	16.213
										8 cycles	15.950	15.799

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
T-8		Mom.Duty			13.348	95.18	55.489	11.037	25.862	43.680		
		Int.Duty			13.148	95.13	54.655	11.133		2 cycles	15.770	20.440
		30-cycle			12.348	95.08	51.330			3 cycles	15.770	17.576
										5 cycles	15.770	16.213
										8 cycles	15.950	15.799
M-T8-1		Mom.Duty			2.390	93.81	9.933	15.000	25.862	43.680		
		Int.Duty			1.593	93.81	6.622	15.000		2 cycles	15.770	20.440
		30-cycle			0.000	0.00	0.000			3 cycles	15.770	17.576
										5 cycles	15.770	16.213
										8 cycles	15.950	15.799
M-T8-2		Mom.Duty			1.545	92.20	6.424	26.000	25.862	43.680		
		Int.Duty			1.030	92.20	4.283	26.000		2 cycles	15.770	20.440
		30-cycle			0.000	0.00	0.000			3 cycles	15.770	17.576
										5 cycles	15.770	16.213
										8 cycles	15.950	15.799
21												
T9-SEC	0.48										MCCB	LV Fuse
		Mom.Duty	0.002	0.014	19.371	-80.27	16.105	6.612	25.795	44.429	[kA]	[kA]
		Int.Duty	0.002	0.014	19.371	-80.27	16.105	6.612	0-10 kA/Fuse		27.012/	20.579
		30-cycle	0.004	0.018	14.756	-78.97	12.268		10-20 kA/PwrBrk		22.893/	19.382
									>20 kA		20.579	
T-9		Mom.Duty			15.042	101.17	12.506	5.066	25.795	44.429		
		Int.Duty			15.042	101.17	12.506	5.066	0-10 kA/Fuse		27.012/	20.579
		30-cycle			14.756	101.03	12.268		10-20 kA/PwrBrk		22.893/	19.382
									>20 kA		20.579	
M-T9-1		Mom.Duty			4.350	94.76	3.617	12.000	25.795	44.429		
		Int.Duty			4.350	94.76	3.617	12.000	0-10 kA/Fuse		27.012/	20.579
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		22.893/	19.382
									>20 kA		20.579	
22												
T5MCC	0.48										MCCB	LV Fuse
		Mom.Duty	0.002	0.009	31.050	-76.90	25.814	4.550	38.062	65.925	[kA]	[kA]
		Int.Duty	0.002	0.009	31.050	-76.90	25.814	4.550	0-10 kA/Fuse		40.082/	31.050
		30-cycle	0.003	0.012	22.944	-77.76	19.075		10-20 kA/PwrBrk		33.969/	31.050
									>20 kA		31.050	
C-T5-1		Mom.Duty			30.207	103.35	25.114	4.213	38.062	65.925		
		Int.Duty			30.207	103.35	25.114	4.213	0-10 kA/Fuse		40.082/	31.050
		30-cycle			22.944	102.24	19.075		10-20 kA/PwrBrk		33.969/	31.050
									>20 kA		31.050	
M-T5-3		Mom.Duty			0.853	94.09	0.709	14.000	38.062	65.925		
		Int.Duty			0.853	94.09	0.709	14.000	0-10 kA/Fuse		40.082/	31.050
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		33.969/	31.050
									>20 kA		31.050	

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
23												
T6MCC	0.48										MCCB	LV Fuse
		Mom.Duty	0.002	0.008	34.333	-76.30	28.544	4.336	41.622	72.084	[kA]	[kA]
		Int.Duty	0.002	0.008	34.333	-76.30	28.544	4.336	0-10 kA/Fuse		43.826/	34.333
		30-cycle	0.002	0.010	25.962	-77.25	21.584		10-20 kA/PwrBrk		37.142/	34.333
									>20 kA		34.333	
C-T6-1		Mom.Duty			33.493	103.95	27.845	4.026	41.622	72.084		
		Int.Duty			33.493	103.95	27.845	4.026	0-10 kA/Fuse		43.826/	34.333
		30-cycle			25.962	102.75	21.584		10-20 kA/PwrBrk		37.142/	34.333
									>20 kA		34.333	
M-T6-3		Mom.Duty			0.853	94.09	0.709	14.000	41.622	72.084		
		Int.Duty			0.853	94.09	0.709	14.000	0-10 kA/Fuse		43.826/	34.333
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		37.142/	34.333
									>20 kA		34.333	
24												
FDR M	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.054	0.592	13.405	-84.80	320.411	12.752	19.982	33.776	[kA]	[kA]
		Int.Duty	0.057	0.648	12.243	-85.01	292.635	13.248		2 cycles	12.243	15.957
		30-cycle	0.076	0.895	8.872	-85.14	212.056			3 cycles	12.243	13.679
										5 cycles	12.243	12.522
										8 cycles	12.375	12.288
C-M1		Mom.Duty			12.817	95.25	306.361	10.879	19.982	33.776		
		Int.Duty			11.859	95.04	283.462	11.328		2 cycles	12.243	15.957
		30-cycle			8.872	94.86	212.056			3 cycles	12.243	13.679
										5 cycles	12.243	12.522
										8 cycles	12.375	12.288
C-M2		Mom.Duty			0.430	92.73	10.279	21.003	19.982	33.776		
		Int.Duty			0.311	92.45	7.440	23.328		2 cycles	12.243	15.957
		30-cycle			0.000	0.00	0.000			3 cycles	12.243	13.679
										5 cycles	12.243	12.522
										8 cycles	12.375	12.288
C-M3		Mom.Duty			0.158	97.54	3.784	7.553	19.982	33.776		
		Int.Duty			0.073	97.11	1.741	8.014		2 cycles	12.243	15.957
		30-cycle			0.000	0.00	0.000			3 cycles	12.243	13.679
										5 cycles	12.243	12.522
										8 cycles	12.375	12.288
25												
T10 PRI	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.147	0.667	11.668	-77.54	278.888	4.592	14.333	24.825	[kA]	[kA]
		Int.Duty	0.150	0.702	11.103	-77.94	265.379	4.731		2 cycles	11.103	12.795
		30-cycle	0.161	0.881	8.896	-79.67	212.641			3 cycles	11.103	11.427
										5 cycles	11.103	11.103
										8 cycles	11.103	11.103

Grid: Grid | System Stage: Grid | Annex: / 13

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
C-E2		Mom.Duty			11.527	102.50	275.527	4.510	14.333	24.825		
		Int.Duty			11.042	102.07	263.921	4.676		2 cycles	11.103	12.795
		30-cycle			8.896	100.33	212.641			3 cycles	11.103	11.427
										5 cycles	11.103	11.103
										8 cycles	11.103	11.103
T-10		Mom.Duty			0.141	98.98	3.366	6.331	14.333	24.825		
		Int.Duty			0.061	98.93	1.461	6.363		2 cycles	11.103	12.795
		30-cycle			0.000	0.00	0.000			3 cycles	11.103	11.427
										5 cycles	11.103	11.103
										8 cycles	11.103	11.103
26												
FDR G	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.070	0.603	13.129	-83.34	313.823	8.806	18.474	31.564	[kA]	[kA]
		Int.Duty	0.072	0.637	12.436	-83.58	297.258	9.075		2 cycles	12.436	15.191
		30-cycle	0.081	0.815	9.729	-84.31	232.535			3 cycles	12.436	13.076
										5 cycles	12.436	12.436
										8 cycles	12.436	12.436
C-G1		Mom.Duty			12.928	96.64	309.003	8.591	18.474	31.564		
		Int.Duty			12.346	96.41	295.090	8.906		2 cycles	12.436	15.191
		30-cycle			9.729	95.69	232.535			3 cycles	12.436	13.076
										5 cycles	12.436	12.436
										8 cycles	12.436	12.436
T-11		Mom.Duty			0.202	98.21	4.822	6.927	18.474	31.564		
		Int.Duty			0.091	98.14	2.169	6.989		2 cycles	12.436	15.191
		30-cycle			0.000	0.00	0.000			3 cycles	12.436	13.076
										5 cycles	12.436	12.436
										8 cycles	12.436	12.436
27												
T12-PRI	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.059	0.596	13.304	-84.35	317.996	11.384	19.515	33.092	[kA]	[kA]
		Int.Duty	0.062	0.653	12.153	-84.57	290.479	11.875		2 cycles	12.153	15.506
		30-cycle	0.081	0.899	8.829	-84.86	211.021			3 cycles	12.153	13.304
										5 cycles	12.153	12.335
										8 cycles	12.197	12.153
C-J2		Mom.Duty			12.869	95.57	307.603	10.245	19.515	33.092		
		Int.Duty			11.955	95.39	285.748	10.599		2 cycles	12.153	15.506
		30-cycle			8.829	95.14	211.021			3 cycles	12.153	13.304
										5 cycles	12.153	12.335
										8 cycles	12.197	12.153
C-J6		Mom.Duty			0.237	97.78	5.662	7.319	19.515	33.092		
		Int.Duty			0.109	97.60	2.605	7.497		2 cycles	12.153	15.506
		30-cycle			0.000	0.00	0.000			3 cycles	12.153	13.304
										5 cycles	12.153	12.335
										8 cycles	12.197	12.153

Grid: Grid | System Stage: Grid | Annex: / 14

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
T-12		Mom.Duty			0.198	97.81	4.739	7.295	19.515	33.092		
		Int.Duty			0.089	97.65	2.128	7.446		2 cycles	12.153	15.506
		30-cycle			0.000	0.00	0.000			3 cycles	12.153	13.304
										5 cycles	12.153	12.335
										8 cycles	12.197	12.153
28												
T10 SEC	0.48										MCCB	LV Fuse
		Mom.Duty	0.001	0.008	36.180	-81.20	30.080	6.697	48.306	83.174	[kA]	[kA]
		Int.Duty	0.001	0.008	36.180	-81.20	30.080	6.697	0-10 kA/Fuse		50.568/	38.525
		30-cycle	0.002	0.010	27.950	-81.08	23.237		10-20 kA/PwrBrk		42.856/	36.285
									>20 kA		38.525	
C-T10-1		Mom.Duty			0.000	0.00	0.000	0.000	0.000	0.000		
		Int.Duty			0.000	0.00	0.000	0.000	0-10 kA/Fuse		0.000/	0.000
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		0.000/	0.000
									>20 kA		0.000	
C-T10-2		Mom.Duty			1.713	95.06	1.424	11.300	48.306	83.174		
		Int.Duty			1.713	95.06	1.424	11.300	0-10 kA/Fuse		50.568/	38.525
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		42.856/	36.285
									>20 kA		38.525	
SQD-I-Li busway		Mom.Duty			0.000	0.00	0.000	0.000	48.306	83.174		
		Int.Duty			0.000	0.00	0.000	0.000	0-10 kA/Fuse		50.568/	38.525
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		42.856/	36.285
									>20 kA		38.525	
T-10		Mom.Duty			28.669	99.07	23.835	6.264	48.306	83.174		
		Int.Duty			28.669	99.07	23.835	6.264	0-10 kA/Fuse		50.568/	38.525
		30-cycle			27.950	98.92	23.237		10-20 kA/PwrBrk		42.856/	36.285
									>20 kA		38.525	
M-T10-1		Mom.Duty			2.867	95.71	2.383	10.000	48.306	83.174		
		Int.Duty			2.867	95.71	2.383	10.000	0-10 kA/Fuse		50.568/	38.525
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		42.856/	36.285
									>20 kA		38.525	
M-T10-2		Mom.Duty			2.943	101.31	2.447	5.000	48.306	83.174		
		Int.Duty			2.943	101.31	2.447	5.000	0-10 kA/Fuse		50.568/	38.525
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		42.856/	36.285
									>20 kA		38.525	
29												
T11 SEC	0.48										MCCB	LV Fuse
		Mom.Duty	0.001	0.008	36.062	-81.51	29.981	6.861	48.387	83.261	[kA]	[kA]
		Int.Duty	0.001	0.008	36.062	-81.51	29.981	6.861	0-10 kA/Fuse		50.621/	38.565
		30-cycle	0.001	0.010	28.216	-81.56	23.459		10-20 kA/PwrBrk		42.901/	36.323
									>20 kA		38.565	
C-T11-1		Mom.Duty			0.000	0.00	0.000	0.000	48.387	83.261		
		Int.Duty			0.000	0.00	0.000	0.000	0-10 kA/Fuse		50.621/	38.565
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		42.901/	36.323
									>20 kA		38.565	

Grid: Grid	System Stage: Grid	Annex: / 15

Bus / Element	Rated Voltage [kV]	Duty	Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	Symmetrical Current (E/Z) [deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
C-T11-2		Mom.Duty			0.653	98.24	0.543	6.908	48.387	83.261		
		Int.Duty			0.653	98.24	0.543	6.908	0-10 kA/Fuse		50.621/	38.565
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		42.901/	36.323
									>20 kA		38.565	
T-11		Mom.Duty			28.947	98.58	24.066	6.624	48.387	83.261		
		Int.Duty			28.947	98.58	24.066	6.624	0-10 kA/Fuse		50.621/	38.565
		30-cycle			28.216	98.44	23.459		10-20 kA/PwrBrk		42.901/	36.323
									>20 kA		38.565	
M-T11-1		Mom.Duty			3.733	95.71	3.103	10.000	48.387	83.261		
		Int.Duty			3.733	95.71	3.103	10.000	0-10 kA/Fuse		50.621/	38.565
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		42.901/	36.323
									>20 kA		38.565	
M-T11-2		Mom.Duty			2.737	101.31	2.275	5.000	48.387	83.261		
		Int.Duty			2.737	101.31	2.275	5.000	0-10 kA/Fuse		50.621/	38.565
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		42.901/	36.323
									>20 kA		38.565	
30												
T12 SEC	0.48										MCCB	LV Fuse
		Mom.Duty	0.001	0.008	35.933	-81.67	29.874	7.136	48.599	83.538	[kA]	[kA]
		Int.Duty	0.001	0.008	35.933	-81.67	29.874	7.136	0-10 kA/Fuse		50.790/	38.693
		30-cycle	0.001	0.010	27.931	-81.65	23.221		10-20 kA/PwrBrk		43.044/	36.443
									>20 kA		38.693	
C-T12-1		Mom.Duty			0.000	0.00	0.000	0.000	0.000	0.000		
		Int.Duty			0.000	0.00	0.000	0.000	0-10 kA/Fuse		0.000/	0.000
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		0.000/	0.000
									>20 kA		0.000	
C-T12-2		Mom.Duty			1.713	95.06	1.424	11.300	48.599	83.538		
		Int.Duty			1.713	95.06	1.424	11.300	0-10 kA/Fuse		50.790/	38.693
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		43.044/	36.443
									>20 kA		38.693	
T-12		Mom.Duty			28.969	98.51	24.084	6.687	48.599	83.538		
		Int.Duty			28.969	98.51	24.084	6.687	0-10 kA/Fuse		50.790/	38.693
		30-cycle			27.931	98.35	23.221		10-20 kA/PwrBrk		43.044/	36.443
									>20 kA		38.693	
M-T12-1		Mom.Duty			2.320	94.76	1.929	12.000	48.599	83.538		
		Int.Duty			2.320	94.76	1.929	12.000	0-10 kA/Fuse		50.790/	38.693
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		43.044/	36.443
									>20 kA		38.693	
M-T12-2		Mom.Duty			2.943	101.31	2.447	5.000	48.599	83.538		
		Int.Duty			2.943	101.31	2.447	5.000	0-10 kA/Fuse		50.790/	38.693
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		43.044/	36.443
									>20 kA		38.693	

Grid: Grid	System Stage: Grid	Annex: / 16

Bus / Element	Rated Voltage [kV]	Duty	Equivalent Impedance R[Ohm]	Equivalent Impedance X[Ohm]	Symmetrical Current (E/Z) [kA]	Symmetrical Current (E/Z) [deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
31												
FDR P	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.068	0.604	13.117	-83.59	313.518	10.130	18.897	32.153	[kA]	[kA]
		Int.Duty	0.071	0.660	12.000	-83.88	286.821	10.581		2 cycles	12.000	14.962
		30-cycle	0.091	0.907	8.737	-84.27	208.846			3 cycles	12.000	12.875
										5 cycles	12.000	12.095
										8 cycles	12.000	12.000
C-M2		Mom.Duty			12.687	96.54	303.254	8.728	18.897	32.153		
		Int.Duty			11.689	96.22	279.393	9.177		2 cycles	12.000	14.962
		30-cycle			8.737	95.73	208.846			3 cycles	12.000	12.875
										5 cycles	12.000	12.095
										8 cycles	12.000	12.000
T-13		Mom.Duty			0.430	92.68	10.287	21.352	18.897	32.153		
		Int.Duty			0.311	92.42	7.444	23.640		2 cycles	12.000	14.962
		30-cycle			0.000	0.00	0.000			3 cycles	12.000	12.875
										5 cycles	12.000	12.095
										8 cycles	12.000	12.000
32												
FDR Q	13.80										Sym.Base	Tot.Base
		Mom.Duty	0.075	0.609	12.980	-83.01	310.249	9.042	18.348	31.325	[kA]	[kA]
		Int.Duty	0.078	0.666	11.885	-83.34	284.069	9.500		2 cycles	11.885	14.584
		30-cycle	0.097	0.913	8.681	-83.90	207.493			3 cycles	11.885	12.548
										5 cycles	11.885	11.908
										8 cycles	11.885	11.885
C-M3		Mom.Duty			12.821	96.98	306.463	8.163	18.348	31.325		
		Int.Duty			11.812	96.66	282.328	8.570		2 cycles	11.885	14.584
		30-cycle			8.681	96.10	207.493			3 cycles	11.885	12.548
										5 cycles	11.885	11.908
										8 cycles	11.885	11.885
T-14		Mom.Duty			0.158	97.52	3.786	7.575	18.348	31.325		
		Int.Duty			0.073	97.10	1.741	8.026		2 cycles	11.885	14.584
		30-cycle			0.000	0.00	0.000			3 cycles	11.885	12.548
										5 cycles	11.885	11.908
										8 cycles	11.885	11.885
33												
T10 MCC	0.48										MCCB	LV Fuse
		Mom.Duty	0.002	0.008	33.299	-76.39	27.685	4.438	40.584	70.293	[kA]	[kA]
		Int.Duty	0.002	0.008	33.299	-76.39	27.685	4.438	0-10 kA/Fuse		42.737/	33.299
		30-cycle	0.002	0.010	26.050	-76.87	21.658		10-20 kA/PwrBrk		36.219/	33.299
									>20 kA		33.299	
C-T10-2		Mom.Duty			31.601	104.09	26.273	3.985	40.584	70.293		
		Int.Duty			31.601	104.09	26.273	3.985	0-10 kA/Fuse		42.737/	33.299
		30-cycle			26.050	103.13	21.658		10-20 kA/PwrBrk		36.219/	33.299
									>20 kA		33.299	

Grid: Grid | System Stage: Grid | Annex: / 17

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
M-T10-3		Mom.Duty			1.720	94.76	1.430	12.000	40.584	70.293		
		Int.Duty			1.720	94.76	1.430	12.000	0-10 kA/Fuse		42.737/	33.299
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		36.219/	33.299
									>20 kA		33.299	
34												
T11 MCC	0.48										MCCB	LV Fuse
		Mom.Duty	0.002	0.008	33.060	-76.35	27.486	4.193	39.767	68.856	[kA]	[kA]
		Int.Duty	0.002	0.008	33.060	-76.35	27.486	4.193	0-10 kA/Fuse		41.863/	33.060
		30-cycle	0.002	0.010	26.297	-77.28	21.863		10-20 kA/PwrBrk		35.479/	33.060
									>20 kA		33.060	
C-T11-2		Mom.Duty			32.410	103.76	26.945	4.082	39.767	68.856		
		Int.Duty			32.410	103.76	26.945	4.082	0-10 kA/Fuse		41.863/	33.060
		30-cycle			26.297	102.72	21.863		10-20 kA/PwrBrk		35.479/	33.060
									>20 kA		33.060	
M-T11-3		Mom.Duty			0.654	98.13	0.543	7.000	39.767	68.856		
		Int.Duty			0.654	98.13	0.543	7.000	0-10 kA/Fuse		41.863/	33.060
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		35.479/	33.060
									>20 kA		33.060	
35												
T12 MCC	0.48										MCCB	LV Fuse
		Mom.Duty	0.002	0.008	33.117	-76.85	27.533	4.608	40.715	70.520	[kA]	[kA]
		Int.Duty	0.002	0.008	33.117	-76.85	27.533	4.608	0-10 kA/Fuse		42.875/	33.117
		30-cycle	0.002	0.010	26.053	-77.41	21.660		10-20 kA/PwrBrk		36.336/	33.117
									>20 kA		33.117	
C-T12-2		Mom.Duty			31.417	103.60	26.120	4.133	40.715	70.520		
		Int.Duty			31.417	103.60	26.120	4.133	0-10 kA/Fuse		42.875/	33.117
		30-cycle			26.053	102.59	21.660		10-20 kA/PwrBrk		36.336/	33.117
									>20 kA		33.117	
M-T12-3		Mom.Duty			1.720	94.76	1.430	12.000	40.715	70.520		
		Int.Duty			1.720	94.76	1.430	12.000	0-10 kA/Fuse		42.875/	33.117
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		36.336/	33.117
									>20 kA		33.117	
36												
T13-SEC	2.40										Sym.Base	Tot.Base
		Mom.Duty	0.009	0.112	12.381	-85.25	51.468	15.929	18.973	31.886	[kA]	[kA]
		Int.Duty	0.011	0.123	11.206	-85.00	46.584	14.409		2 cycles	11.206	14.859
		30-cycle	0.016	0.159	8.657	-84.29	35.986			3 cycles	11.206	12.802
										5 cycles	11.206	11.693
										8 cycles	11.463	11.343
T-13		Mom.Duty			9.148	95.81	38.027	9.821	18.973	31.886		
		Int.Duty			9.051	95.78	37.624	9.881		2 cycles	11.206	14.859
		30-cycle			8.657	95.71	35.986			3 cycles	11.206	12.802
										5 cycles	11.206	11.693
										8 cycles	11.463	11.343

Grid: Grid | System Stage: Grid | Annex: / 18

	Rated Voltage [kV]		Equivalent Impedance R[Ohm]	X[Ohm]	Symmetrical Current (E/Z) [kA]	[deg]	Apparent Power [MVA]	X/R ratio	Asym.RMS X/R based [kA]	Asym.Peak X/R based [kA]		
M-T13-1		Mom.Duty			3.240	91.74	13.467	32.850	18.973	31.886		
		Int.Duty			2.160	91.74	8.978	32.850		2 cycles	11.206	14.859
		30-cycle			0.000	0.00	0.000			3 cycles	11.206	12.802
										5 cycles	11.206	11.693
										8 cycles	11.463	11.343
37												
T14-SEC	0.48										MCCB	LV Fuse
		Mom.Duty	0.002	0.011	25.607	-80.64	21.289	6.577	34.061	58.674	[kA]	[kA]
		Int.Duty	0.002	0.011	25.607	-80.64	21.289	6.577	0-10 kA/Fuse		35.673/	27.177
		30-cycle	0.002	0.014	19.304	-80.02	16.049		10-20 kA/PwrBrk		30.232/	25.607
									>20 kA		27.177	
T-14		Mom.Duty			19.797	100.13	16.459	5.599	34.061	58.674		
		Int.Duty			19.797	100.13	16.459	5.599	0-10 kA/Fuse		35.673/	27.177
		30-cycle			19.304	99.98	16.049		10-20 kA/PwrBrk		30.232/	25.607
									>20 kA		27.177	
M-T14-1		Mom.Duty			4.060	94.76	3.376	12.000	34.061	58.674		
		Int.Duty			4.060	94.76	3.376	12.000	0-10 kA/Fuse		35.673/	27.177
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		30.232/	25.607
									>20 kA		27.177	
M-T14-2		Mom.Duty			1.766	101.31	1.468	5.000	34.061	58.674		
		Int.Duty			1.766	101.31	1.468	5.000	0-10 kA/Fuse		35.673/	27.177
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		30.232/	25.607
									>20 kA		27.177	
38												
480 TIE	0.48										MCCB	LV Fuse
		Mom.Duty	0.004	0.009	27.136	-66.74	22.561	2.341	28.930	48.404	[kA]	[kA]
		Int.Duty	0.004	0.009	27.136	-66.74	22.561	2.341	0-10 kA/Fuse		29.429/	27.136
		30-cycle	0.004	0.011	22.551	-69.32	18.749		10-20 kA/PwrBrk		27.136/	27.136
									>20 kA		27.136	
C-T10-1		Mom.Duty			0.000	0.00	0.000	0.000	0.000	0.000		
		Int.Duty			0.000	0.00	0.000	0.000	0-10 kA/Fuse		0.000/	0.000
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		0.000/	0.000
									>20 kA		0.000	
C-T11-1		Mom.Duty			27.136	113.26	22.561	2.326	28.930	48.404		
		Int.Duty			27.136	113.26	22.561	2.326	0-10 kA/Fuse		29.429/	27.136
		30-cycle			22.551	110.68	18.749		10-20 kA/PwrBrk		27.136/	27.136
									>20 kA		27.136	
C-T12-1		Mom.Duty			0.000	0.00	0.000	0.000	0.000	0.000		
		Int.Duty			0.000	0.00	0.000	0.000	0-10 kA/Fuse		0.000/	0.000
		30-cycle			0.000	0.00	0.000		10-20 kA/PwrBrk		0.000/	0.000
									>20 kA		0.000	

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| Grid: Grid                                    System Stage: Grid                         | Annex:               / 19     |
-----------------------------------------------------------------------------------------------------------------------------
|                    Rated       Equivalent          Symmetrical       Apparent   X/R     Asym.RMS   Asym.Peak               |
|                    Voltage      Impedance          Current  (E/Z)    Power      ratio   X/R based  X/R based               |
|                    [kV]       R[Ohm]  X[Ohm]       [kA]     [deg]    [MVA]              [kA]       [kA]                    |
-----------------------------------------------------------------------------------------------------------------------------
|39                                                                                                                          |
| T3 SEC             4.16                                                                                Sym.Base   Tot.Base |
|           Mom.Duty           0.047   0.475        5.033  -84.41    36.262   14.070     7.599      12.810       [kA]       [kA] |
|           Int.Duty           0.055   0.524        4.558  -84.06    32.841   12.536              2 cycles     4.558      5.891 |
|           30-cycle           0.081   0.670        3.558  -83.14    25.638                       3 cycles     4.558      5.067 |
|                                                                                                5 cycles     4.558      4.683 |
|                                                                                                8 cycles     4.605      4.561 |
|   T-3                           Mom.Duty          3.656   96.98    26.340    8.173     7.599      12.810                       |
|                                 Int.Duty          3.640   96.95    26.228    8.202              2 cycles     4.558      5.891 |
|                                 30-cycle          3.558   96.86    25.638                       3 cycles     4.558      5.067 |
|                                                                                                5 cycles     4.558      4.683 |
|                                                                                                8 cycles     4.605      4.561 |
|   M-T3-1                        Mom.Duty          1.381   91.93     9.949   29.740     7.599      12.810                       |
|                                 Int.Duty          0.921   91.93     6.633   29.740              2 cycles     4.558      5.891 |
|                                 30-cycle          0.000    0.00     0.000                       3 cycles     4.558      5.067 |
|                                                                                                5 cycles     4.558      4.683 |
|                                                                                                8 cycles     4.605      4.561 |
|41                                                                                                                          |
| LGTS               0.48                                                                                MCCB       LV Fuse  |
|           Mom.Duty           0.002   0.008       33.361  -76.27    27.736    4.180    40.100      69.429       [kA]       [kA] |
|           Int.Duty           0.002   0.008       33.361  -76.27    27.736    4.180     0-10 kA/Fuse          42.212/    33.361 |
|           30-cycle           0.002   0.010       26.250  -77.21    21.824             10-20 kA/PwrBrk        35.774/    33.361 |
|                                                                                        >20 kA              33.361             |
|   SQD-I-Li busway               Mom.Duty         33.361  103.73    27.736    4.093    40.100      69.429                      |
|                                 Int.Duty         33.361  103.73    27.736    4.093     0-10 kA/Fuse          42.212/    33.361 |
|                                 30-cycle         26.250  102.79    21.824             10-20 kA/PwrBrk        35.774/    33.361 |
|                                                                                        >20 kA              33.361             |
|49                                                                                                                          |
| RECT               0.48                                                                                MCCB       LV Fuse  |
|           Mom.Duty           0.001   0.008       35.274  -81.31    29.326    6.715    47.123      81.130       [kA]       [kA] |
|           Int.Duty           0.001   0.008       35.274  -81.31    29.326    6.715     0-10 kA/Fuse          49.326/    37.578 |
|           30-cycle           0.001   0.009       29.912  -81.04    24.868             10-20 kA/PwrBrk        41.803/    35.393 |
|                                                                                        >20 kA              37.578             |
|   T-17                          Mom.Duty         30.747   99.13    25.563    6.222    47.123      81.130                      |
|                                 Int.Duty         30.747   99.13    25.563    6.222     0-10 kA/Fuse          49.326/    37.578 |
|                                 30-cycle         29.912   98.96    24.868             10-20 kA/PwrBrk        41.803/    35.393 |
|                                                                                        >20 kA              37.578             |
|   M-T17-1                       Mom.Duty          4.533   95.71     3.769   10.000    47.123      81.130                      |
|                                 Int.Duty          4.533   95.71     3.769   10.000     0-10 kA/Fuse          49.326/    37.578 |
|                                 30-cycle          0.000    0.00     0.000             10-20 kA/PwrBrk        41.803/    35.393 |
|                                                                                        >20 kA              37.578             |
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| Grid: Grid                                    System Stage: Grid                         | Annex:               / 20     |
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|                    Rated       Equivalent          Symmetrical       Apparent   X/R     Asym.RMS   Asym.Peak               |
|                    Voltage      Impedance          Current  (E/Z)    Power      ratio   X/R based  X/R based               |
|                    [kV]       R[Ohm]  X[Ohm]       [kA]     [deg]    [MVA]              [kA]       [kA]                    |
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|50                                                                                                                          |
| GEN-1             13.80                                                                                Sym.Base   Tot.Base |
|           Mom.Duty           0.046   0.594       13.385  -85.59   319.925   21.236    21.111      35.255       [kA]       [kA] |
|           Int.Duty           0.045   0.624       12.741  -85.87   304.530   22.059              2 cycles    12.892     18.113 |
|           30-cycle           0.060   0.813        9.777  -85.79   233.697                       3 cycles    13.234     15.679 |
|                                                                                                5 cycles    13.120     14.077 |
|                                                                                                8 cycles    13.358     13.240 |
|   C1A                           Mom.Duty          7.424   96.63   177.443    8.599    21.111      35.255                       |
|                                 Int.Duty          6.857   96.32   163.891    9.027              2 cycles    12.892     18.113 |
|                                 30-cycle          5.895   95.97   140.893                       3 cycles    13.234     15.679 |
|                                                                                                5 cycles    13.120     14.077 |
|                                                                                                8 cycles    13.358     13.240 |
|   T-18                          Mom.Duty          0.139   96.14     3.334    9.296    21.111      35.255                       |
|                                 Int.Duty          0.060   95.85     1.444    9.755              2 cycles    12.892     18.113 |
|                                 30-cycle          0.000    0.00     0.000                       3 cycles    13.234     15.679 |
|                                                                                                5 cycles    13.120     14.077 |
|                                                                                                8 cycles    13.358     13.240 |
|   GEN1                          Mom.Duty          5.835  -88.47   139.459   37.400    21.111      35.255                       |
|                                 Int.Duty          5.835  -88.47   139.459   37.400              2 cycles    12.892     18.113 |
|                                 30-cycle          3.890  -88.47    92.973                       3 cycles    13.234     15.679 |
|                                                                                                5 cycles    13.120     14.077 |
|                                                                                                8 cycles    13.358     13.240 |
|51                                                                                                                          |
| AUX                0.48                                                                                MCCB       LV Fuse  |
|           Mom.Duty           0.001   0.008       33.595  -81.28    27.931    6.863    45.081      77.571       [kA]       [kA] |
|           Int.Duty           0.001   0.008       33.595  -81.28    27.931    6.863     0-10 kA/Fuse          47.162/    35.930 |
|           30-cycle           0.002   0.010       28.238  -80.94    23.477             10-20 kA/PwrBrk        39.970/    33.841 |
|                                                                                        >20 kA              35.930             |
|   T-18                          Mom.Duty         29.007   99.20    24.116    6.171    45.081      77.571                      |
|                                 Int.Duty         29.007   99.20    24.116    6.171     0-10 kA/Fuse          47.162/    35.930 |
|                                 30-cycle         28.238   99.06    23.477             10-20 kA/PwrBrk        39.970/    33.841 |
|                                                                                        >20 kA              35.930             |
|   M-30                          Mom.Duty          1.188   98.13     0.988    7.000    45.081      77.571                      |
|                                 Int.Duty          1.188   98.13     0.988    7.000     0-10 kA/Fuse          47.162/    35.930 |
|                                 30-cycle          0.000    0.00     0.000             10-20 kA/PwrBrk        39.970/    33.841 |
|                                                                                        >20 kA              35.930             |
|   M-31                          Mom.Duty          3.409   94.76     2.834   12.000    45.081      77.571                      |
|                                 Int.Duty          3.409   94.76     2.834   12.000     0-10 kA/Fuse          47.162/    35.930 |
|                                 30-cycle          0.000    0.00     0.000             10-20 kA/PwrBrk        39.970/    33.841 |
|                                                                                        >20 kA              35.930             |
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