DESIGN OF ELECTRICAL SYSTEM FOR OFFSHORE PLATFORM

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
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June 2007

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.

Suhaida Abd KAdir Aljailani

ABSTRACT

Design of electrical system is indeed important in many operations not to disregard the operation for offshore platform. Offshore operations acquire its own generation of power supply to support the facilities on the platform. Designing the electrical system for any operations involves three main elements which are generation, distribution and protection. Design process involves much analysis. Software simulation is conducted replacing the manual methods of calculations. This simulation process reduces error during calculations and time consume in design process. The objectives of this project are to provide design of the electrical system demand for an offshore platform and to design the most optimum system including the selection of generators for the system. Studies and research of power system has been conducted. The network has been designed and modeled. Simulation on the network performance which includes loadflow and fault analysis has been conducted. The methodology and scope of study are as follows:

i. Conceptual design

ii. Gathering of necessary power system components and data

iii. Simulating, troubleshooting and analysis the modeled power system

ACKNOWLEDGEMENTS

I would like to take this opportunity to give my warmest gratitude to everyone who has involved in making my final year project a success. First of all, I would like to thank my Project Supervisor, Mr. Ir. Perumal Nallagownden who has been willing to share and spend his tight schedule in guiding me throughout completing the project. Without his motivation and guidance I will not be able to achieve the main goal of the project.

Special thanks to Mdm Rosehayati Ahmad (training supervisor), for sharing her experienced and knowledge as well as her time to entertain my queries and doubts at the early stage of the project.

I would like to give appreciation and thank to the Final Year Project Committee. Without their management and coordination, the flow of this project might not be as expected.

Special thank to Ms Siti Hawa, Mr Yaasin and all technicians of Electrical Engineering Programme for being very helpful.

Lastly to my parents who have help me in many ways. Not to forget to all my friends and others who have help in the project directly or indirectly.

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LIST OF ABBREVIATIONS

EOR	Enhance Oil Recovery
DEG	Diesel Engine Generator
IEC	International Electrotechnical Commission
CENELEC	European Committee for Electrotechnical Standardization
IP	Ingress Protection
CCVT	Close-cycled Vapour Turbogenerator
HVDC	High Voltage Direct Current
DC	Direct Current
AC	Alternating Current
DOL	Direct On Line
UPS	Uninterruptible Power Supply
GTG	Gas Turbine Genarator
HV	High Voltage
LV	Low Voltage
PTS	PETRONAS Technical Standard

CHAPTER 1
INTRODUCTION

1.1 Background of Study

An oil platform is a large structure that caters machinery needed for drilling process and accommodation for workers on the platform. Platform may be attached to the ocean floor or floating. There are few types of structure design depends on the complexity of the offshore industry itself.

Normally, oil platform are located a few hundreds kilometers away from the shore. Lately due to reducing amount of oil, many oil companies have expand the drilling process to deepwater region. Platform usually consists of a few modules such as drilling module, power generation module, gas lift module and etc. Each module is built to support main operation on the mother platform.

Offshore installations are complex accommodation and industrial plants operating in high sulfurous and humidity environments [1]. Offshore installation demands the highest possible security of supply. Interruptions in the operation will caused production loss as well as endanger the lives of personnel. Thus, in system design and operation measurement to raise the supply security to the highest level is taken into consideration.

Power system should be ensure safe to operate and maintain, reliable which allow continuity of power supply and energy-efficient. Moreover it is necessary that power system are designed to be stable and protected under any conceivable disturbance. Design of power system involves much analysis. In the past, design processes are tedious and time consuming as calculations with mathematical modeling are required. However with the availability of computer aided tool now, the design processes are modeled differently.

The electrical system consists of three major components:

i. Generation
ii. Transmission
iii. Distribution

This project involves design of the electrical system for water injection platform. Water injection and gas injection are most widely used Enhanced Oil Recovery (EOR) methods. EOR is a method used to artificially increase reservoir pressure in order to supplement the natural oil drive mechanism.

1.2 Problem Statement

Offshore platforms have one basic objective that is safe production. Offshore structures range from simple operation to complex processing centers located in extremely tough environmental conditions with a large operation and maintenance workforce. Different operations on a platform require different design of electrical installation.

Equipment selection and location on offshore platforms is in accordance with the hazardous area classification and the need to have a safe, reliable and secure installation requiring minimum maintenance [1]. Unscheduled interruptions to production caused by equipment failure are costly and its maintenance is complex.

Designing an electrical system for platform requires information from other disciplines such as the mechanical, structural, instrument and etc. This is because the electrical system designed shall meet the requirement of equipments planned to be installed on the platform. With the data of expected load required for the process on the platform known, will then the size and type of the generator to be used can be estimated and designed.

In general, design criteria of an optimum generation system are reliability, adequacy and economically. Whereas in distribution system details of its accessibility to the load, standardize in voltage and current and the utilities to be supplied should be taken into consideration. Protection is important to prevent the system from experiencing fault such as short circuit, overload, undervoltage, lightning and etc. Fault at the network affects the operation of a platform. Shutting down the operation will halt the production and affect the cost of the project.

Modeling and simulation of the power system is conducted to determine its performances. Operating characteristics of the equipments, power system behaviour and acceptable assumptions are required to obtain an accurate implementation of simulation and interpretation of the results.

Detail studies have to be conducted and analyzed to determine the most practicable electrical system implementation. Throughout the project, selection of power generation, distribution and protection will be discussed.

1.3 Objectives and Scope of Study

1.3.1 Objectives

i. Understand the design of electrical system for offshore platform by conducting feasibility studies on the power generation, power distribution and protection.
ii. To estimate the load capacities based on the information gathered from the consultants.
iii. To design a schematic diagram of the overall electrical system using ERACS software.
iv. To conduct loadflow (power flow), fault analysis using ERACS software.

1.3.2 Scope of study

The scope of study can be summarized as literature review on fundamental of electrical system installation for offshore platform specifically to cater the demand of facilities on water injection platform module. Focus will be emphasized on the generation, distribution and protection consideration. Ultimately, the study will come out with the most suitable design as intended.

To conduct the simulation study of the network, the author has chosen ERACS software. Among the analysis conducted with the software are as discussed below:

- Load analysis to determine the capacities of the power generation and distribution of the equipment. This analysis verifies whether the steady-state voltage drops and transient voltage deviations are within the acceptable operating limits of the equipment.
- Fault analysis is carried out to find out power interrupting ratings and to ensure that the electrical equipment will withstand the short circuit current.

CHAPTER 2
LITERATURE REVIEW

2.1 System design

The purpose of an electrical supply network is to provide continuous supply of power to meet the requirement of varying load, and to do it with a high degree of reliability. To ensure that the electrical supply is economical and with a minimum risk of failure, a supply network must have:

- Adequate power to cope with the highest possible load
- Provision of surplus power and distributing equipment capacity
- Switchgear, transformers and cables are capable of continuous operation in the most rough conditions
- Switchgear, transformers and cables are rated to carry the maximum short-circuit fault currents
- A protective system capable of isolating faulty equipment with minimum of interference to the rest of the network and with minimum damage.
- Battery-supported supplies for activities that cannot be tolerate even a short power interruption
- For offshore installations some means of starting a platform from cold; which is usually known as a 'black start'

System design must be based upon the continuous maximum rating. In order for a system to be designed to carry out its functions as mentioned above, following information must be available:

- Total electrical connected load
- Nature of each item of the load
- Installation of the load
- Diversity of the connected load under various conditions
- Topography of the installation

Figure 1 below shows the power system of a large oil production platform. There are 3 by 50% rated generators with actual ratings increased to about 25MW. The feeders from the main 11 kV busbar are duplicated radial feeds via the transformers to lower voltages.

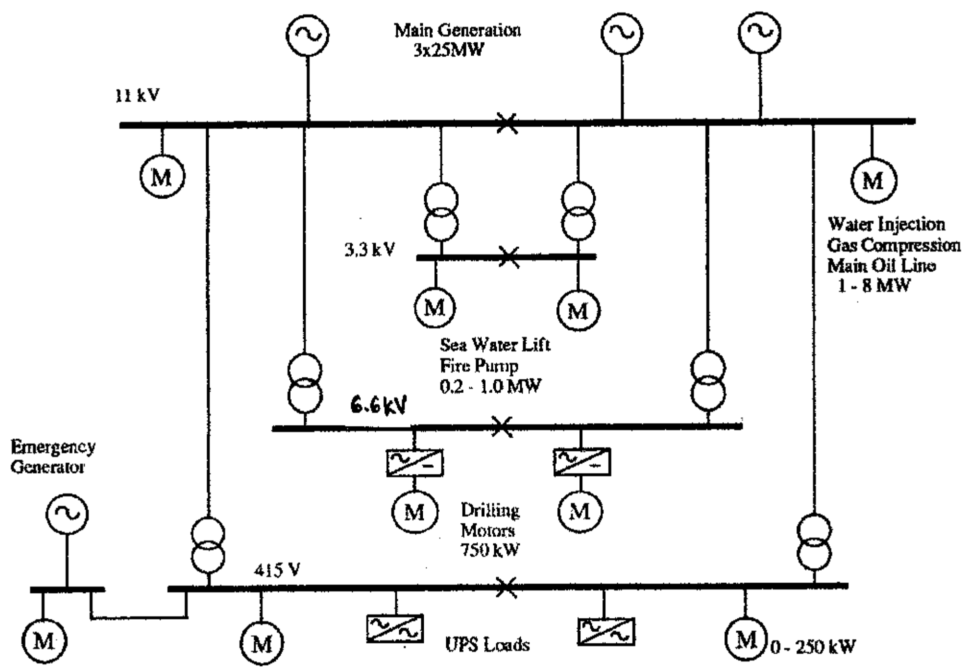

Figure 1 Typical Electrical System Design of Oil Production Platform

2.2 Power System Design and Equipment Selection

In the design of electrical installation few important aspects need to be considered to comply with good engineering practice.

2.2.1 Regulations

PETRONAS technical standard (PTS) is a guideline used in all PETRONAS offshore as well as onshore operation. One of the main PTS in electrical is the PTS 33.64.10.10. This PTS gives minimum technical requirements for the design, engineering and installation of electrical facilities. In this PTS it covers design & engineering principles, electrical system design, design & selection requirements for equipment & cables, engineering & installation requirements and design & engineering requirements for particular installations.

Standards, codes & regulations in PTS 33.64.10.10 is based on the publications of the International Electrotechnical Commission (IEC) and on the relevant documents issued by the European Committee for Electrotechnical Standardization (CENELEC). Two main considerations are:

- The design and engineering of the electrical installation shall satisfy all legal requirements of the national and/or local authorities of the country in which the electrical installation will be located.
- The electrical installation shall be suitable for the site conditions as specified by the Principal.

The design of the electrical installation shall be based on the provision of a safe and reliable supply of electricity at all times. The design of electrical systems and equipment shall ensure that all operating and maintenance activities can be performed safely and conveniently and shall permit periods of continuous operation. The insulating and dielectric materials used in all electrical equipment shall be non-toxic and shall not contain compounds that are persistent and/or hazardous environmental contaminants.

PTS 33.64.10.10 also classify protection against explosion and fire hazards:

- The electrical apparatus shall be properly select for areas where flammable gas or vapour risks may arise.
- Area classification and the selection of apparatus for use in areas where there is a flammable dust hazard shall be in accordance with IEC 61241.

In general the design of the electrical installation shall correspond to any specific design criteria, philosophy and objective that may be stated in the project definition phase. The philosophies to be employed depend on the size and complexity of the installation. The conceptual designs and philosophies relating to the electrical system shall be adequately illustrated by a system design description such as a key line diagram, basic layout drawings and functional/outline specifications. System studies and protection reports, etc., shall be provided in support of the design. The scope of the system studies shall be defined.

In this project, the author will follow PTS 33.64.10.10 as guideline to design the most optimum electrical design. Besides this PTS 33.64.10.10 there are several sub-PTS to support other specific requirements of electrical design.

2.2.2 Hazardous areas

The selection and installation of equipment in hazardous areas is generally based on national and international codes or standards, e.g. IEC 79 and BS5345 [1]. Generator packages, switchrooms and transformers are usually kept outside the hazardous areas but not for equipment directly related to the process such as motors driving pumps, fans and compressors together with process heating, light fittings and instrumentation devices. In practice most hazardous areas are of the zone 2 classification with small pockets of zone 1 around vents and larger areas around the drilling facilities [1]. Equipment located in hazardous areas will further be classified by IP model Code of Safe Practice Part 15. In addition equipment in exposed areas has higher protection (IP rating) against ingress of solid material and/or moisture [1].

2.2.3 Main Power Supply

The main power supply usually consists of generators driven by turbine gas engine prime movers. However depending on the power demand of the facilities operation, then type of power generation is selected. There are a few types of power generation. Each of this power generation has its own maximum capacity and advantage as well as disadvantages. Below are a few ways to generate power:

i. Gas turbine generator
   - Power rating: >1MW

ii. Microturbine
   - Power rating: 30kW, 80kW, 100kW

iii. CCVT (close-cycled vapour turbogenerator)
   - Power rating: 3kW to 5kW

iv. Submarine cable
   - Two main concerns:

     - High cost Installation and distance

     - Materials to be used

v. Diesel generator
   - needs to be re-fuel and produce pollutants

vi. HVDC (high voltage direct current)
   - Impractical to be used for large demand application as it will require massive converter to convert DC to AC. Most equipment requires alternating. It obliges wider area to be installed.

vii. Gas engine

viii. Tap power from grid

ix. Solar panel
   - Costly to be installed
   - Only suitable for small power distribution usage

The cable size and distribution voltage are governed by the load and distance involved. Centralized power generation and distribution *can* potentially minimize maintenance costs whilst improving the safety and the reliability of operations [1].

2.2.4 Emergency Power Sources

In most design emergency power sources consists of diesel driven generators, battery system or combination of both. The main purpose of having Emergency generators is:

- To provide power to essential load e.g. utility pumps, platform floodlights and etc
- To provide black start operation
- As back-up power supply in the event of power failure at main power generation
- As platform main power source during planned shutdown period

2.2.5 Cable Systems

In general all cables are flame retardant with higher fire resistant specifications reserved for high risk areas and critical circuits (i.e. escape route lighting, shutdown and safety systems including fire alarms, fire pumps, gas detection etc...). All cables are armoured except in a few cases (control rooms and other clean, internal, non-hazardous areas with additional mechanical limited to essential services in accommodation modules [1].

2.2.6 Motors and Transformers

Motors are generally squirrel cage induction type with DOL starting. Transformers are synthetic liquid sealed types or dry cast resin units [1].

Design of electrical system installation begins with the estimation of the electrical load capacity. The consumption of electrical loads depends on the facilities installed. Electrical single line diagram is produced to show the power distribution and the flow of the process involving electrical component. Electrical distribution system starts from the main power generator and then being step down through distribution transformers. From step down transformer, power will be flowed to the loads. In between the line, protection devices such as circuit breaker, bus tie, relays are being placed. Emergency or back up equipment for instance diesel generator and UPS system are also installed to ensure a continuous power flow.

Guidelines on the design and selection of the power distribution equipment are analyzed. Study on the protection requirement for generators, electric motors, feeders and small power, lighting and etc is considered. Literature review of the facilities on the platform such as the cabling system, electric motors, lighting and etc is prepared.

2.2.7 Power system studies

Designing power systems involves performing several studies to evaluate the efficiency of the power delivery in the network. Beside these studies are conducted to measure the suitability of equipment selected for the network.

Two main studies are conducted throughout the project:

i. Loadflow

This study analyzes system's capability to adequately supply to the connected load. Real and reactive power flow and bus voltages and currents are determined.

ii. Fault analysis

Fault analysis determines the maximum fault current obtained during system disturbance. Increasing level of available short circuit current is often due to expansion of plant and adding larger loads to the network. Dangerous situation will occurs if the short circuit capacity exceeds the capacity of protective device. In power system, protective device acts to interrupt fault currents during fault conditions. However high short circuit current may cause violent failure of the device and cause severe damage to the device and network.

2.2.8 Power system protection

Electrical system must be protected against damage which may occur during abnormal conditions. There are two types of abnormalities:

i. Chronic condition - operation outside the designed ratings due to overloading or incorrect functioning of the system

ii. Acute condition - fault conditions due usually to breakdown of some part of the system

Thus to overcome this abnormalities a protection scheme is required in electrical system design. Principles of protection system are:

i. To maintain electrical supplies to the system as possible after a fault has been isolated

ii. To protect equipments on the plant from damage due to abnormal conditions and faults

iii. To isolate faulted equipment to limit the risk

iv. To limit damage to the cable system resulting from a fault

The basic principle of protection is to disconnect and isolate the faulty part of the system. This is to ensure that the fault is not sustained and aggravated by a continuing flow of power into it and to prevent damages to the rest of the system.

No system of protection can be designed without knowing the conditions in the network which it has to protect. Therefore the level fault currents at various point of the network must be known first before selecting the best protection system

CHAPTER 3
METHODOLOGY / PROJECT WORK

3.1 Project flow

Planning is the most important aspects in conducting a project. Well planned project ensures a systematical procedure throughout the project and enable the work to be done within a specified time requirement.

As for this project, the author started off by performing literature review on electrical system design to familiarize with the system. Next all the necessary data is collected and the estimated load for the network is calculated and tabulated using EXCEL software. Then power generation analysis is performed to select the most reliable generating system for the network. Performances of the network are observed by conducting power flow and protection analysis using ERACS software. Results from the simulations are analyzed and last but not least all necessary information is being documented.

A process flow chart is outlined (refer to APPENDIX A) in order to cater the project schedule. Time management is important to ensure that the project is feasible and could be completed within the allocated time frame.

3.1.1 Simulation tool

ERACS software is a PC-based, fully integrated and user friendly. To start simulating network, data is entered and saved in a central database. This software is able to predict system behaviour under both normal and abnormal conditions depending on how the user sets the setting. ERACS helps to reduce error in calculations compares to normal hand calculations.

The procedure of the project implementation is illustrated as Figure 2 below:

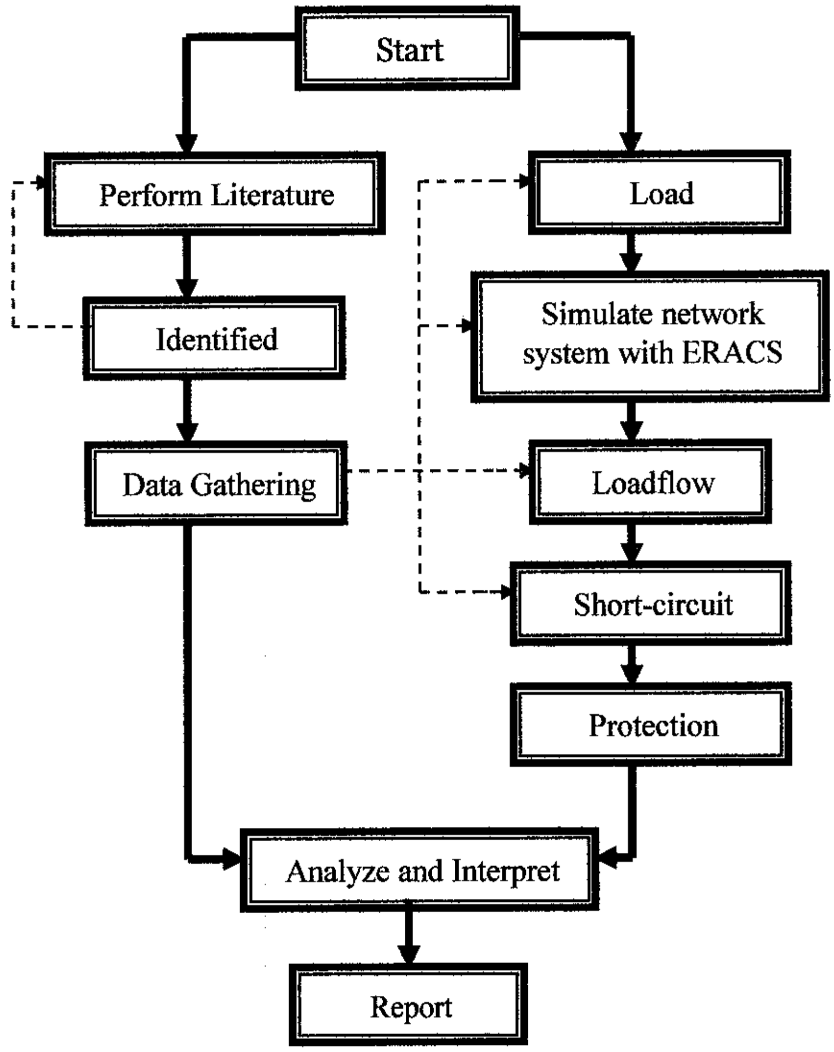

Figure 2 Project Process Workflow

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Load analysis

The load analysis is done to establish the running and peak load at the water injection platform and subsequently size the generator set rating. The analysis is done by considering the operating scenario of the pumps that required the generator running at its maximum capacity

Once the information on the load required for each of the equipment is collected, peak load or the demand for the platform facilities can be estimated. Based on the data collected from the design department, value of load required for each of the equipment is entered in a spreadsheet (refer to APPENDIX B). From the spreadsheet, estimated peak load is determined.

Based on the spreadsheet attached in Appendix B each of the equipment has been categorized to continuous, intermittent and standby as per PTS 33.64.10.10. These categories show the performing usage of the equipment. Below briefly explained the difference between all three loads:

- Continuous - All loads that are required continuously or cyclically for normal operation and which may be reasonably expected to occur simultaneously (e.g. HVAC, UPS, battery chargers etc).
- Intermittent - All process and utility loads required for normal operation but neither operating continuously nor simultaneously (e.g. Compressor Pre Lube Oil Pump Motor).

- Standby - All loads required during the maintenance or changeover from a duty to standby or during abnormal circumstances.

According to PETRONAS Technical Standard (Rev 12), electrical loads shall be classified as performing a service, which is vital, essential or non-essential.

Vital Service

- A vital service is actually a safety matter. The failure of this service during operation or when failing is called upon can causes an unsafe condition of the process or installation jeopardize life or cause damage to the installation. The energy source, lines of supply and the equipment performing a vital service shall be completely duplicated.

Essential Service

- An essential supply is related to economic matter. Therefore the economics of partial or complete duplication of the energy source of the lines of supply or of the equipment performing essential service shall be evaluated in relation to the consequences of service interruptions that will affect the quality or the quantity of the product.

Non-essential Service

- According to PTS definitions, non-essential service is defined as services, which fall under neither vital nor essential category.

Formula to calculate the peak load based on PTS is as shown below:

- Peak load (kW) = (100% of total continuous load) + (30% of total intermittent load @ the largest individual intermittent load whichever is higher) + (10% of total standby load @ the largest individual standby load whichever is higher)

In design practice estimating the demand of load shall include the possibility of future growth of the platform. Roughly the estimation of future growth of a platform is taken to be 25% of its estimated peak load.

Below is the estimation of the overall load required for the platform including future growth:

- From the load list, the peak load = 1345.42 kW
- Total estimated load = total peak load x 25% growth
  = 1345.42 x 125%
  = 1681.78 kW
  = 1.7 MW

4.2 Power generation analysis

Based on the load list in APPENDIX B, the most suitable main generator option is the gas turbine generator. Gas turbine generator has a rotary engine that extracts energy from a flow of combustion gas. The upstream compressor is coupled to a downstream turbine, and a combustion chamber in-between. Gas turbine mechanism can be explained as follow:

- Energy is released when air is mixed with fuel and ignited in the combustor
- Combustion increases the temperature, which in turn increases the pressure resulting in an increase in the velocity and volume of the gas flow
- The gas is directed through a nozzle over the turbine's blades, spinning the turbine and powering the compressor

There are a few conditions that lead to the selection of the generating system:

- Load demand - Cover all the required load for the process to be carried out on the platform
- Space
- Weight
- Reliability - Performance of the generator should be taken into consideration. The most reliable generator shall be the one that can withstand up to the expected year of process, robust and less maintenance

Based on the load analysis, two gas turbines each rated at 1.175MW are chosen. Both turbines will be running to cater the platform demand. Each turbine is equally loaded. Power supply is secured as long as turbines are healthy. With two GTG, platform loads will have more flexibility to cater for bigger motor load, this can eliminate future unforeseen problems should there be changes in the equipment ratings.

Diesel engine generator is available as back-up power supply, incase of platform shutdown due to process upset.

4.3 Modeling and simulation

4.3.1 Single line diagram

Based on the information of the equipment planned to be installed on the platform, single line diagram is drawn. The single line diagram shows the AC electrical generation and distribution system of the plant including all HV feeds, main LV feeds and sub-distribution boards and etc.

The design and model of power system network for the water injection platform is as shown in Figure 3. Referring to Figure 3, the network consists of 2 main busbars and

2 sub-busbars. Busbar 1 is rated at 6.6kV known as HV (high voltage) busbar whereas Busbar 2 known as LV (low voltage) busbar, Busbar 3 and Busbar 4 are both rated at 0.4kV. The network consists of two main GTG each rated at 1.1785MW and a standby DEG rated at 0.8MW. DEG is connected at Busbar 3. An auto-recloser is added in between busbar 2 and busbar 3. The auto-recloser is placed on the connector that connects the two busbar. In normal condition the auto-recloser switch will be in open position. Once the sensor in the auto-recloser detects voltage level changes from the utility line, its switch will be closed to allow the standby generator to supply power to the essential loads. Two transformers are connected in between HV busbar and LV busbar. These transformer forms a step-down process from 6.6kV of HV busbar to 0.4kV of LV busbar. Motors placed at these busbars indicate the machinery as listed in the load list (APPENDIX B).

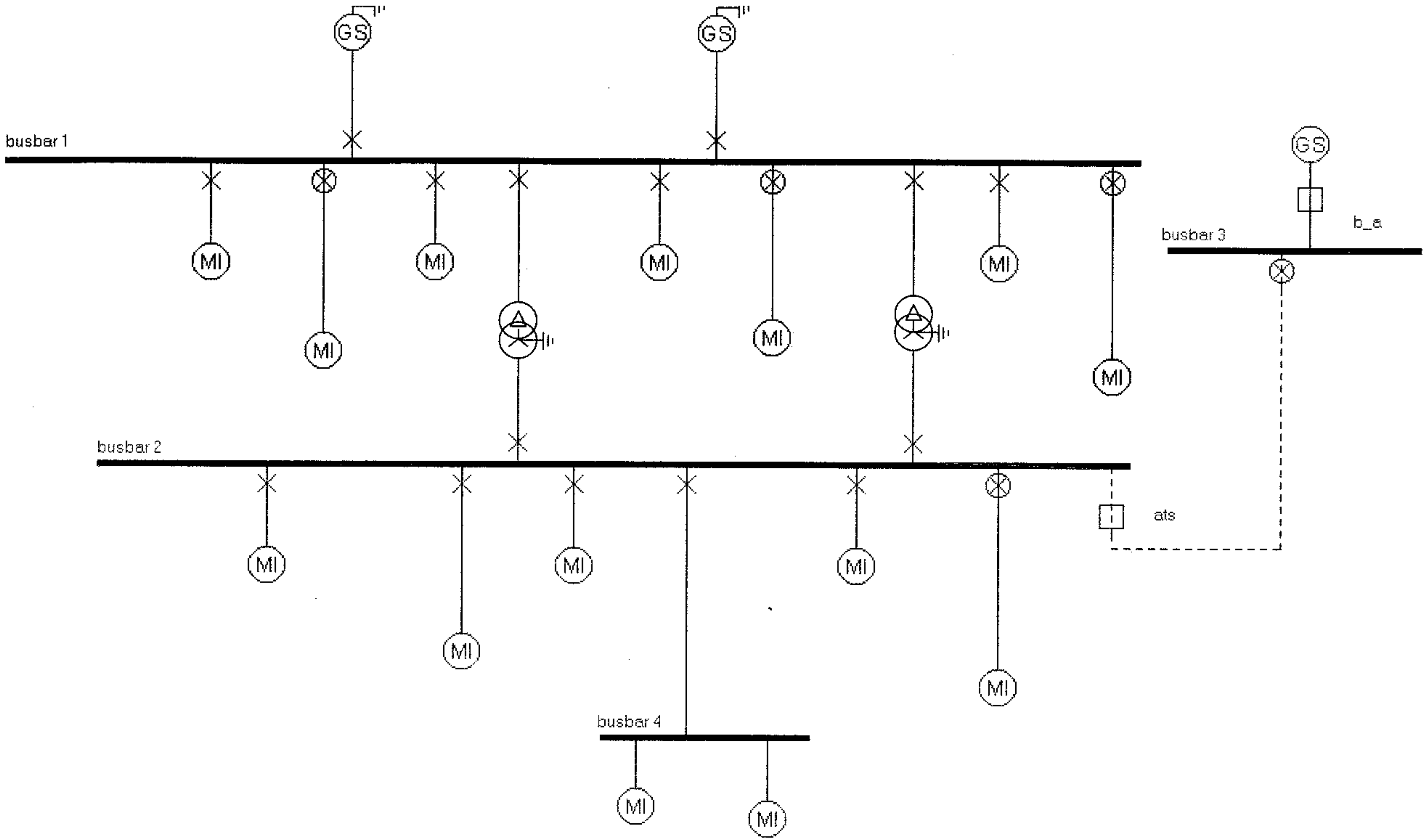

Figure 3 Single Line Diagram

4.3.2 Loadflow

Loadflow is a study performing the analysis and calculates the steady state conditions of the power system network. Loadflow calculation can be done manually however it will be time consuming and impractical to do for a big system. Thus with the help of ERACS software the tedious calculation can be simplified. ERACS will determine the network voltage profile, current and real and reactive power flows. Three scenarios are created to examine the loadflow analysis.

4.3.2.1 Scenario1: normal condition

During normal operation of the platform two turbine generators shall be running in parallel. The turbine generators are connected to HV busbar. Motors rated 200kW and above are connected to this busbar.

For the low voltage busbar, two power transformers are connected. Motors rated below 200kW are connected to the LV busbar. For emergency and black start purpose, one emergency diesel generator is installed. The emergency diesel generator is connected to an auto-recloser. During normal operation of the platform the emergency generator shall not be running and auto-recloser between Busbar 2 and Busbar 3 will be in OPEN position. On detection of dead bus, Diesel Generator set will get started automatically and supplies to Busbar 2 and Busbar 4. The network is as shown if Figure 4 below. The simulation result is as shown in APPENDIX C.

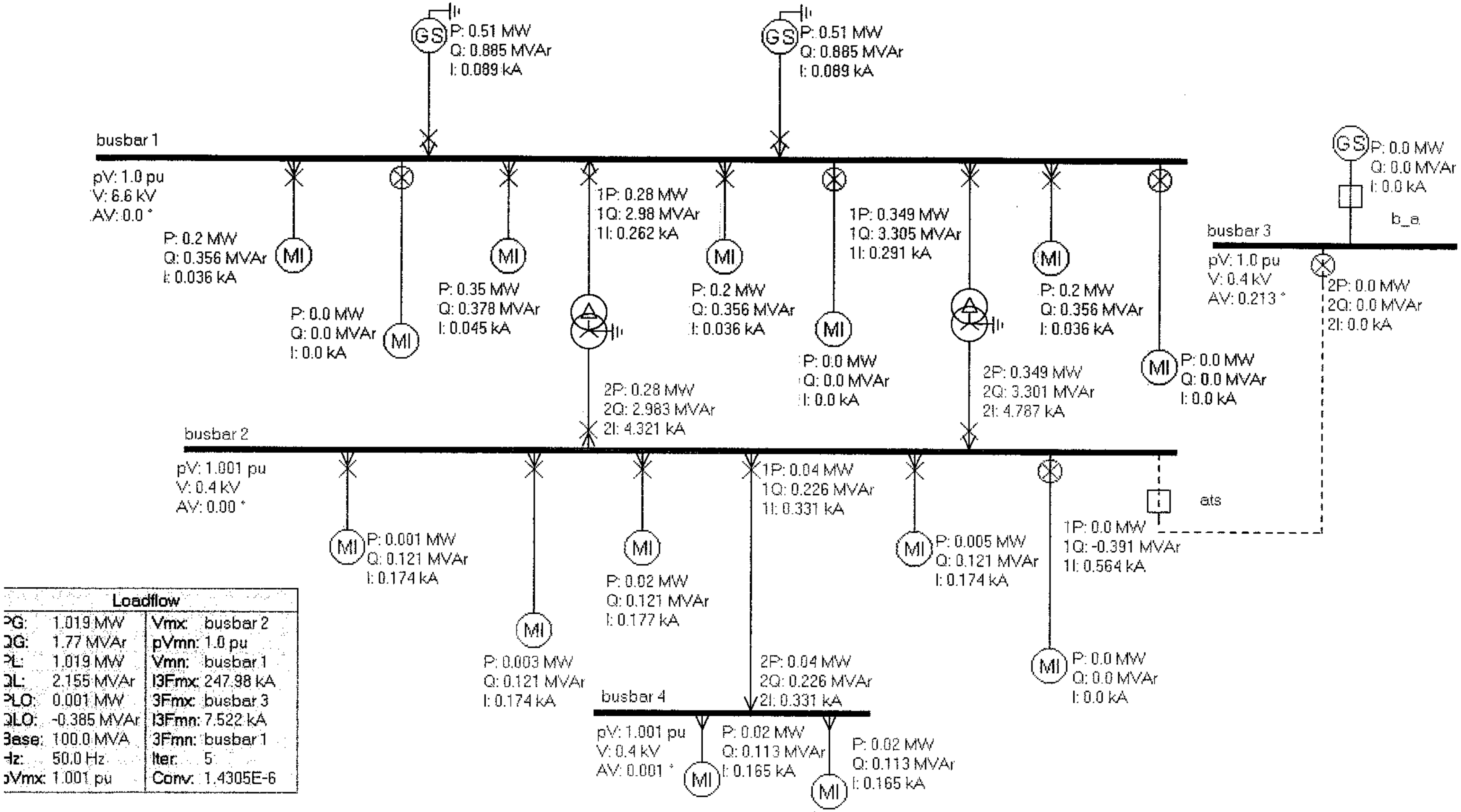

Figure 4 Scenario 1

4.3.2.2 Scenario2: one generator set is turn off

During this operation of the platform only one turbine will be running. Since the total load of the network is still within the capacity of the generator set therefore not much different is observed in the real and reactive power rated at each of the motor. The only difference observes during this scenario is the amount of power generated at the turbine.

During this operation of the platform the emergency generator shall not be running and auto-recloser between Busbar 2 and Busbar 3 will be in OPEN position. On detection of dead bus, Diesel Generator set will get started automatically and supplies to Busbar 2 and Busbar 4. The network is as shown if Figure 5 below. The simulation result is as shown in APPENDIX D.

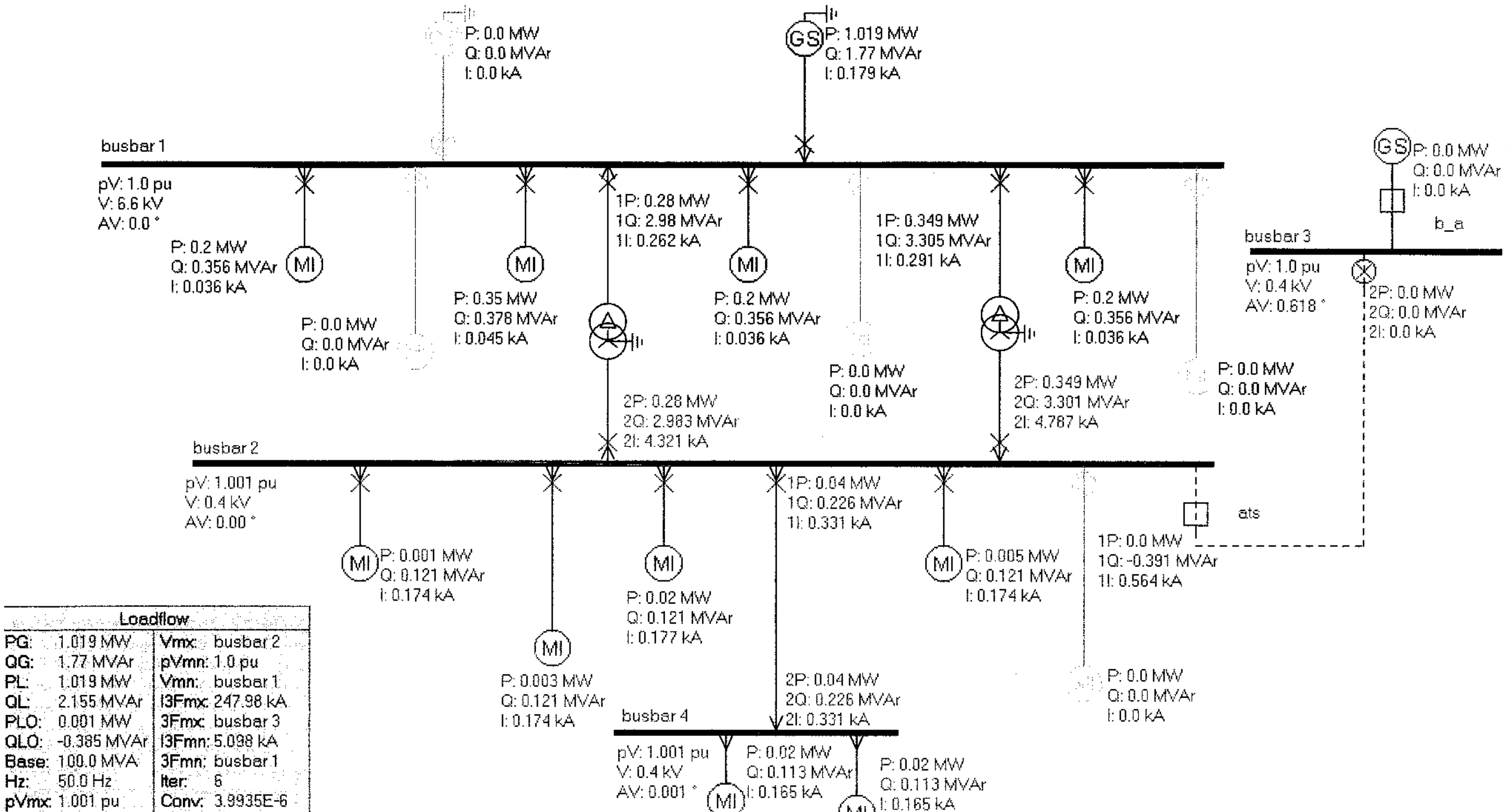

Figure 5 Scenario 2

4.3.2.3 Scenario3: emergency condition

During this operation of the platform the emergency generator shall be running and auto-recloser between Busbar 2 and Busbar 3 will be in CLOSE position. On detection of dead bus, Diesel Generator set will get started automatically and supplies to Busbar 2 and Busbar 4. The network is as shown if Figure 6 below. The simulation result is as shown in APPENDIX E.

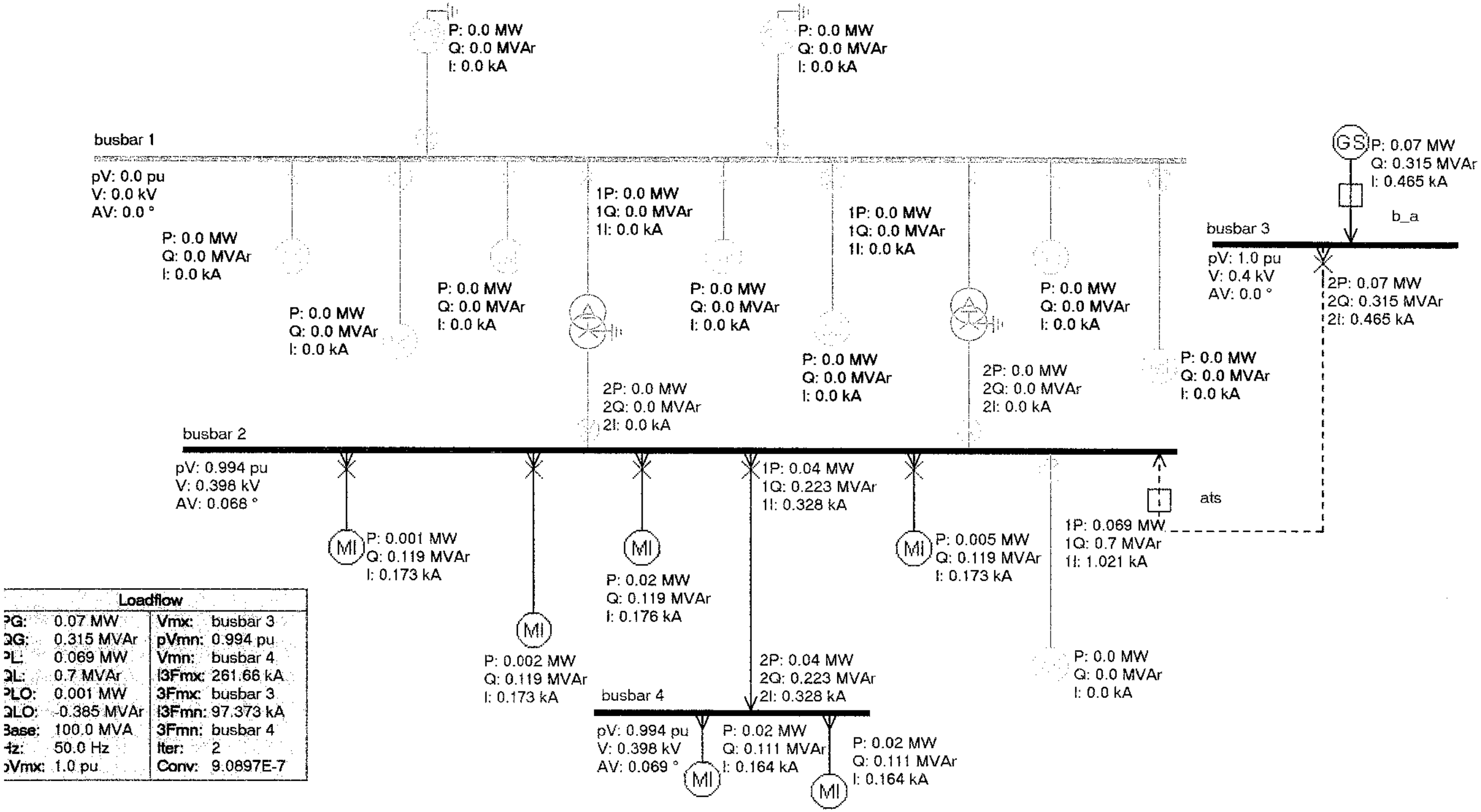

Figure 6 Scenario 3

4.3.2.4 Summary of loadflow results

Table 1 Description of each scenario

Scenario	Description
1	Two turbine generators are running, all transformers are in operation, all tie-breakers are closed, auto-recloser is opened.
2	Only one turbine generator is running, all transformers are in operation, all tie-breakers are closed, auto-recloser is opened.
3	Auto-recloser is closed, only DEG operates, all transformer are not operating, all tie-breakers to the HV side are opened

Table 2 Summary of rated MW values of generator set at different scenario

Scenario	GEN 1	GEN 2	STANDBY GEN
1	0.501 MW	0.501 MW	0 MW
2	0 MW	1.001 MW	0 MW
3	0 MW	0 MW	0.052 MW

4.3.3 Fault analysis

The fault analysis is done to calculate the perspective fault current at main switchboard and subsequently size the busbar rating. The network is as shown if Figure 7 below. The simulation result is as shown in APPENDIX F.

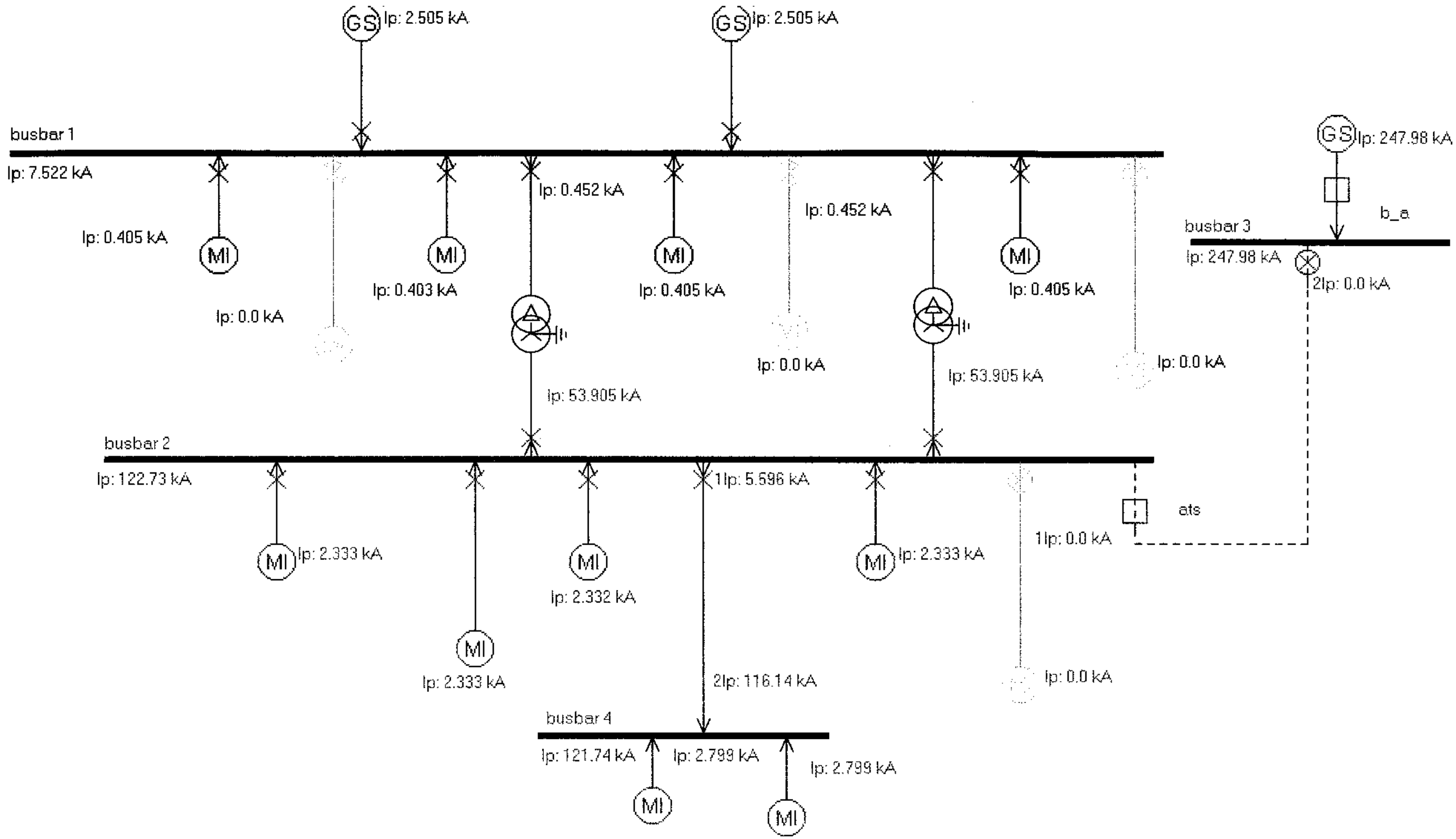

Figure 7 Three Phase Fault Analysis

4.3.4 Protection

As the operation of the electrical system involves not only machineries but human life, safety is certainly an important issue. Any unsafe act is a treat to human, network and system performance. Therefore protection system is designed to provide a safe workspace for personnel and minimize damage to the overall system as well as isolating faulty devices from the system.

Protection of a system has the main function to ensure automatic disconnection in occurrence of short circuit. Some of the protection attributes to select appropriate protection system of a network are as listed below:

- Selectivity
- Security
- Sensitivity
- Dependability
- Speed

CHAPTER 5
CONCLUSION

5.1 Summary

As mention previously, design of electrical power systems involves much analysis. It is essential to perform these analyses in order to design the most optimum power systems.

A schematic diagram (refer to figure 1) was drawn based on information obtained from the load list (refer to APPENDIX B). Once the schematic diagram is obtained, performance analysis is conducted. First, the loadflow analysis is conducted. Three scenarios are created and the results are obtained as shown in FIGURE 4, 5 and 6. A detail result of each scenario is as attached in APPENDIX C, D and E. From the loadflow analysis conducted the total load of the whole network is 1.019 MW. Power supplied by the main generators is equally shared depending on the total network load. Difference of each scenario is as shown in Table 1 and 2. Fault analysis result is as obtained in figure 7 and detail result of the analysis as attached in APPENDIX F.

By conducting the loadflow analysis, it enables sizing of the generator as well as designing the overall distribution of the network. The fault analysis on the other hand enables the most appropriate protection scheme for the network. Both analyses are indeed required in order to have the most optimum design of an electrical system.

It can be concluded that the simulation studies are crucial in design of power system. Simulation improves the routine design and allows easier performance assessment of the power system. In order to perform the simulation with ERACS software, it is important to put the right rating and assumption in order to obtain correct simulation of the networks.

5.2 Recommendation

5.2.1 Perform other analysis

ERACS software provides other program modules. Thus the analysis of the network can be extend by conducting other modules such as harmonic impedance, transient stability and others in order to have better understanding of the performance of the electrical design.

5.2.2 Comparison result with other software

There is other software which is also able to perform power performance analysis. Results of simulation from other software can be compared. This can broaden the scope of simulation.

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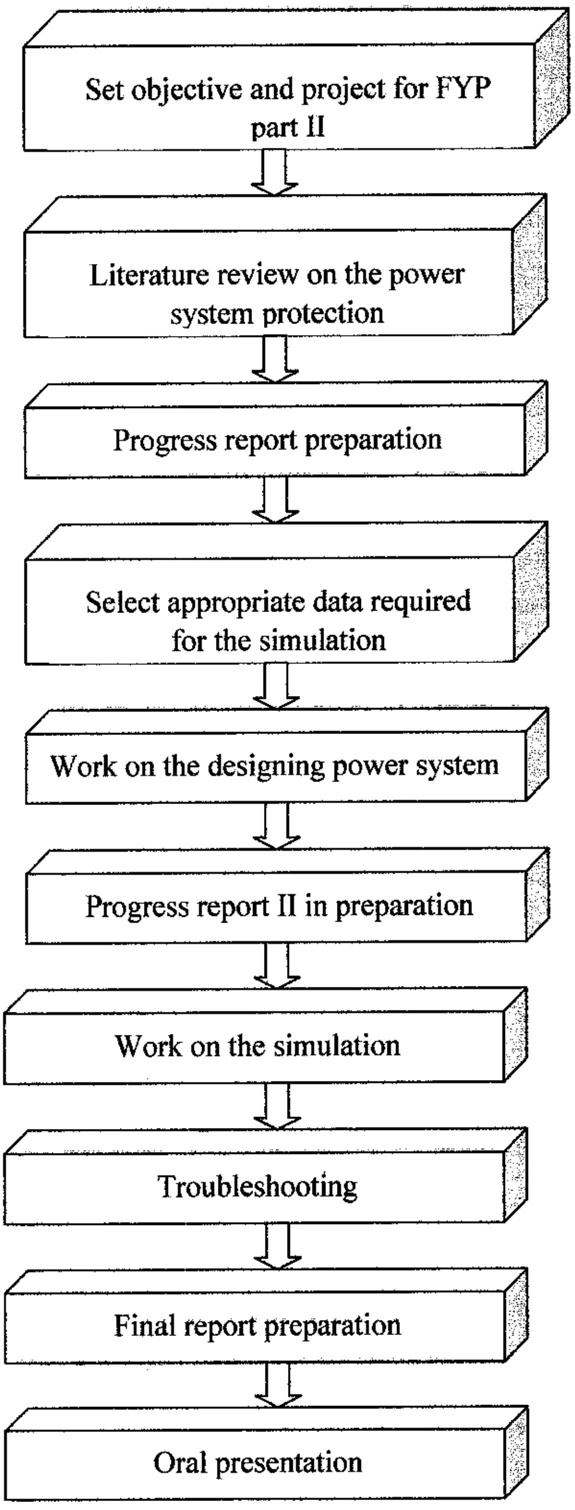
APPENDICES

APPENDIX A
PROCESS FLOW CHART



Process Flow Chart

APPENDIX B

LOADLIST

EQUIP. NO.	DESCRIPTION	Load Type	Essential	Non-Essen	Busbar Statu	LOAD	RATING	FACTOR A/B	at load factor C	FACTOR at load factor C	Continuous		Intermittent		Stand-by	
						A	B	C	D			E		F		G
						kW	kW	in decimals	in decimals	cos φ	kW	kVAr	kW	kVAr	kW	kVAr
	Wellhead															
1	Multiphase Flow					1.02	1.20	0.85	0.95	0.88	1.07	0.58				
2	Wellhead control panel					2.13	2.50	0.85	0.95	0.88	2.24	1.21				
	Sea Water Treatment															
1	Sea water lift pump					170.00	200.00	0.85	0.95	0.88	178.95	96.59				
2	Sea water lift pump					170.00	200.00	0.85	0.95	0.88	178.95	96.59				
3	Sea water lift pump					170.00	200.00	0.85	0.95	0.88					178.95	96.59
4	Sea water injection pump					297.50	350.00	0.85	0.95	0.88	313.16	169.02				
5	Sea water injection pump					297.50	350.00	0.85	0.95	0.88					313.16	169.02
7	Other equipment					17.00	20.00	0.85	0.95	0.88			17.89	9.66		
8	Chemical injection pump					42.50	50.00	0.85	0.95	0.88	44.74	24.15				
9	Chemical injection pump					42.50	50.00	0.85	0.95	0.88					44.74	24.15
	Utilities															
1	Air compressor					170.00	200.00	0.85	0.95	0.88	178.95	96.59				
2	Air compressor					170.00	200.00	0.85	0.95	0.88						
3	Ligthings					34.00	40.00	0.85	0.95	0.88	35.79	19.32				
4	UPS					17.00	20.00	0.85	0.95	0.88	17.89	9.66				
5	UPS					17.00	20.00	0.85	0.95	0.88	17.89	9.66				
	Others															
1	MOV					42.50	50.00	0.85	0.95	0.88	44.74	24.15				
								TOTAL			1014.36	547.50	17.89	9.66	536.84	289.76
								Apparent Power			1152.69		20.33		610.05	
								Power Factor			0.88		0.88		0.88	
								Peak Load			1345.42 kW					

Formula :

Connected Load = Summation of motors / load ratings

Peak Load = Total Continuous Load
+ 0.3 x Total Intermittent Load
+ 0.1 x Total Standby Load

Definitions:

a) **Absorbed loads**
- for pumps, shaft load on duty point;
- for instrumentation, computers, communication, air conditioning, the required load during full operation of plant
- for lighting during dark hours
- for workshop, the average total load in normal full operation

b) **Consumed loads**
E - "Continuous"; all loads that may continuously be required for normal operation, including lighting.
F - "Intermittent and spares"; the loads required for intermediate pumping, storage, loading,etc. and all electrical spares of electrically driven units
G - "Stand-by"; loads required in emergencies only or those of normally not running electrically driven units, stand-by for normally running steam-driven ones (e.g. pumps)

Notes:

1 Navigational aid system is solar powered.

APPENDIX C

LOAD FLOW ANALYSIS : SCENARIO 1

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

SYSTEM STATISTICS

Study Base MVA	=	100.000
Study Base Frequency (Hz)	=	50.000
Number of Busbars	=	4
Number of Shunts	=	0
Number of Lines	=	1
Number of Cables	=	1
Number of Transformers	=	2
Number of Tap Changers	=	0
Number of Synchronous Machines	=	3
Number of Induction Machines	=	14
Number of Wind Turbine Generators	=	0
Number of Bus Sections	=	0
Number of Series Elements	=	0

STUDY PARAMETERS

Load Power Multiplier	=	1.000000
Load Reactive Multiplier	=	1.000000
Convergence Tolerance	=	0.000005
Convergence Control	=	Method 2
Maximum Iterations	=	25
Overload Flag Level	=	100.0% Of Rating
Automatic Tap Changers		OFF

BUSBAR DATA

Busbar Identifier	Nominal kV	Three Phase Fault MVA	Three Phase Fault kA	Single Phase Fault MVA	Single Phase Fault kA	Transf. Shift Angle (deg.)	Nominal Bus Freq. (Hz)
busbar 1	6.600	150.0	13.122	200.0	17.495	0.0	50.0
busbar 2	0.400	31.0	44.745	45.0	64.952	30.0	50.0
busbar 3	0.400	31.0	44.745	45.0	64.952	0.0	50.0
busbar 4	0.400	31.0	44.745	45.0	64.952	30.0	50.0

LINE DATA

First Busbar	Second Busbar	Line Identifier	No.Of Ccts	Line Length	Library Key	Rating (kA)	Positive Sequence R(pu)	Positive Sequence X(pu))	Positive Sequence B(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Zero Sequence B(pu)	Equivalent Pi Model
busbar 2	busbar 4	1_2	1	1.00	1_1	1.000	0.01000	0.01000	0.00000	0.01000	0.01000	0.00000	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

CABLE DATA

First Busbar	Second Busbar	Cable Identifier	No.Of Ccts	Cable Length	Library Key	Rating (kA)	Positive Sequence R(pu)	Positive Sequence X(pu)	Positive Sequence B(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Zero Sequence B(pu)	Equivalent Pi Model
busbar 2	busbar 3	connector 1	1	1.00	cable1	2.500	0.3821	1.0990	0.0039	0.5382	1.0990	0.0042	CABLE OPEN AT SECOND

TRANSFORMER DATA

System Busbar	Winding No.	Rating (MVA)	Winding Type	Angle (deg.)	Pos/Neg. Sequence R(pu)	Pos/Neg. Sequence X(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Neutral Earth R(pu)	Neutral Earth X(pu)	Voltage Ratio	Off-Nom Tap (%)
DATA for Transformer with ID. trans_a				No. of units	1 using library key trans_a							
busbar 1	1	150.000	D	30.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20
busbar 2	2	150.000	YN	0.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20
DATA for Transformer with ID. trans_b				No. of units	1 using library key trans_a							
busbar 1	1	150.000	D	30.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.00
busbar 2	2	150.000	YN	0.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20

INDUCTION MACHINE DATA

Busbar Identifier	Motor Identifier	No.Of Units	Library Key	Motor Ratings MVA	Motor Ratings MW	Motor Ratings kV	Input MW	Slip (%)	Stator R(pu)	Stator X(pu)	Magnet. X(pu)	Standstill R(pu)	Standstill X(pu)	Rotor Running R(pu)	Rotor Running X(pu)	
busbar 1	M1	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	
busbar 1	M2	1	motor_1	1.080	0.200	6.600	0.200	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M3	1	motor_3	1.080	0.350	6.600	0.350	0.4861	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	
busbar 1	M5	1	motor_3	1.080	0.350	6.600	0.350	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M6	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	
busbar 1	M4	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	
busbar 2	M8	1	motor7	0.405	0.001	0.415	0.001	0.0048	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	M9	1	motor8	0.405	0.002	0.415	0.002	0.0100	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	motor_7	1	motor10	0.405	0.005	0.415	0.005	0.0199	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	motor_7	1	motor10	0.405	0.005	0.415	0.005	100.0000	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	NOT IN SERVICE
busbar 2	M10	1	motor9	0.405	0.020	0.415	0.020	0.0797	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 1	M7	1	motor_1	1.080	0.200	6.600	0.200	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 4	m2	1	motor22	0.405	0.020	0.400	0.020	0.0741	0.0100	0.1000	3.5000	0.0200	0.1000	0.0150	0.1500	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

INDUCTION MACHINE DATA

Busbar Identifier	Motor Identifier	No.Of Units	Library Key	Motor Ratings MVA	MW	kV	Input MW	Slip (%)	Stator R(pu)	X(pu)	Magnet. X(pu)	Standstill R(pu)	X(pu)	Rotor Running R(pu)	X(pu)
busbar 4	m3	1	motor22	0.405	0.020	0.400	0.020	0.0741	0.0100	0.1000	3.5000	0.0200	0.1000	0.0150	0.1500

SYNCHRONOUS MACHINE DATA

Busbar Identifier	Machine Identifier	Type	No.Of Units	Library Key	Generator Ratings MVA BASE	MW	kV	V(pu)	Assigned MW	MVAR	Pos. Sequence R(pu)	X(pu)	Neg. Sequence R(pu)	X(pu)	Zero Sequence R(pu)	X(pu)
busbar 1	Gen a	SLACK	2	Gen a	5.000	2.350	6.600	1.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	0.0125	0.0550
					Neutral earthing						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
busbar 1	Gen b	SLACK	2	Gen a	5.000	2.350	6.600	1.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	0.0125	0.0550
					Neutral earthing						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
busbar 3		SLACK	1	Gen b	31.000	0.800	0.400	1.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	NEUTRAL O/C	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

AT STUDY END - No of iterations = 5 Convergence = 0.1431E-05
Voltage Range from 1.000pu at busbar 1 to 1.001pu at busbar 2

AC BUSBAR VALUES

Busbar Identifier	Merge	Busbar Type	PU	Voltage kV	ANG-DEG	Synch. Machines MW	Synch. Machines MVAr	Ind Motor Load MW	Ind Motor Load MVAr	Shunt MW	Loads MVAr	3 Phase Fault kA	3 Phase Fault X/R	Ph - E Fault kA	Ph - E Fault X/R
busbar 1	.	SLACK	1.000	6.600	0.000	1.019	1.770	0.950	1.446	0.000	0.000	7.52	18.384	8.39	8.413
busbar 3	.	SLACK	1.000	0.400	0.213	0.000	0.000	0.000	0.000	0.000	0.000	247.98	14.400		
busbar 2	.	LOAD	1.001	0.400	0.000	0.000	0.000	0.029	0.484	0.000	0.000	122.73	18.253	165.95	10.483
busbar 4	.	LOAD	1.001	0.400	0.001	0.000	0.000	0.040	0.226	0.000	0.000	121.74	16.132	164.03	9.529
				BUSBAR TOTALS		1.019	1.770	1.019	2.155	0.000	0.000				
				TOTAL BUS LOAD		1.019	2.155								
				SYSTEM LOSSES		0.001	-0.385								

LINE VALUES

First Busbar	Second Busbar	Branch Identifier	No.Of Ccts	Rating kA	First MW	End MVAr	Flow kA	Second MW	End MVAr	Flow kA	Loading (%)	O/L FLAG
busbar 2	busbar 4	1_2	1	1.000	0.040	0.226	0.331	-0.040	-0.226	0.331	33.1	

CABLE VALUES

First Busbar	Second Busbar	Branch Identifier	No.Of Ccts	Rating kA	First MW	End MVAr	Flow kA	Second MW	End MVAr	Flow kA	Loading (%)	O/L FLAG
busbar 2	busbar 3	connector 1	1	2.500	0.000	-0.391	0.564	0.000	0.000	0.000	22.5	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

TRANSFORMER VALUES

Transformer Identifier	No.Of Units	Winding No.	Connected Busbar	Winding kV	Voltage Ratio	Off Nominal Tap %	Rating MVA	Flow From Busbar MW	Flow From Busbar MVAr	Current kA	Percent Loading	O/L Flag
trans_a	1	1	busbar 1	6.600	1.0000	0.200	150.000	-0.280	-2.980	0.262	2.0	
		2	busbar 2	0.400	1.0000	0.200	150.000	0.280	2.983	4.321	2.0	
trans_b	1	1	busbar 1	6.600	1.0000	0.000	150.000	0.349	3.305	0.291	2.2	
		2	busbar 2	0.400	1.0000	0.200	150.000	-0.349	-3.301	4.787	2.2	

BRANCH LOSS SUMMARY

	(MW)	(MVAr)
SERIES LOSSES	0.001	0.006
SHUNT LOSSES	0.000	-0.391
TOTAL LOSSES	0.001	-0.385

INDUCTION MACHINE VALUES

Busbar Identifier	Machine Identifier	No.Of Units	Slip %	Terminal Voltage kV	Machine MW	Input MVAr	Current kA	O/L Flag
busbar 1	M1	1	0.30	6.600	0.200	0.356	0.036	
busbar 1	M2	1	MACHINE DISCONNECTED					
busbar 1	M3	1	0.53	6.600	0.350	0.378	0.045	
busbar 1	M5	1	MACHINE DISCONNECTED					
busbar 1	M6	1	0.30	6.600	0.200	0.356	0.036	
busbar 1	M4	1	0.30	6.600	0.200	0.356	0.036	
busbar 2	M8	1	0.00	0.400	0.001	0.121	0.174	
busbar 2	M9	1	0.01	0.400	0.003	0.121	0.174	
busbar 2	motor_7	1	0.02	0.400	0.005	0.121	0.174	
busbar 2	motor_7	1	MACHINE DISCONNECTED					
busbar 2	M10	1	0.09	0.400	0.020	0.121	0.177	
busbar 1	M7	1	MACHINE DISCONNECTED					
busbar 4	m2	1	0.08	0.400	0.020	0.113	0.165	
busbar 4	m3	1	0.08	0.400	0.020	0.113	0.165	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

SYNCHRONOUS MACHINE VALUES

Busbar Identifier	Machine Identifier	No.Of Units	Terminal Voltage kV	Power MW	Output MVAr	Current kA	O/L Flag
busbar 1	Gen a	2	6.600	0.510	0.885	0.089	
busbar 1	Gen b	2	6.600	0.510	0.885	0.089	
busbar 3		1	0.400	0.000	0.000	0.000	

APPENDIX D

LOAD FLOW ANALYSIS : SCENARIO 2

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

SYSTEM STATISTICS

Study Base MVA	=	100.000
Study Base Frequency (Hz)	=	50.000
Number of Busbars	=	4
Number of Shunts	=	0
Number of Lines	=	1
Number of Cables	=	1
Number of Transformers	=	2
Number of Tap Changers	=	0
Number of Synchronous Machines	=	3
Number of Induction Machines	=	14
Number of Wind Turbine Generators	=	0
Number of Bus Sections	=	0
Number of Series Elements	=	0

STUDY PARAMETERS

Load Power Multiplier	=	1.000000
Load Reactive Multiplier	=	1.000000
Convergence Tolerance	=	0.000005
Convergence Control	=	Method 2
Maximum Iterations	=	25
Overload Flag Level	=	100.0% Of Rating
Automatic Tap Changers		OFF

BUSBAR DATA

Busbar Identifier	Nominal kV	Three Phase Fault MVA	Three Phase Fault kA	Single Phase Fault MVA	Single Phase Fault kA	Transf. Shift Angle (deg.)	Nominal Bus Freq. (Hz)
busbar 1	6.600	150.0	13.122	200.0	17.495	0.0	50.0
busbar 2	0.400	31.0	44.745	45.0	64.952	30.0	50.0
busbar 3	0.400	31.0	44.745	45.0	64.952	0.0	50.0
busbar 4	0.400	31.0	44.745	45.0	64.952	30.0	50.0

LINE DATA

First Busbar	Second Busbar	Line Identifier	No.Of Ccts	Line Length	Library Key	Rating (kA)	Positive Sequence R(pu)	Positive Sequence X(pu)	Positive Sequence B(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Zero Sequence B(pu)	Equivalent Pi Model
busbar 2	busbar 4	1_2	1	1.00	1_1	1.000	0.01000	0.01000	0.00000	0.01000	0.01000	0.00000	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

CABLE DATA

First Busbar	Second Busbar	Cable Identifier	No.Of Ccts	Cable Length	Library Key	Rating (kA)	Positive Sequence R(pu)	Positive Sequence X(pu)	Positive Sequence B(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Zero Sequence B(pu)	Equivalent Pi Model
busbar 2	busbar 3	connector 1	1	1.00	cable1	2.500	0.3821	1.0990	0.0039	0.5382	1.0990	0.0042	CABLE OPEN AT SECOND

TRANSFORMER DATA

System Busbar	Winding No.	Rating (MVA)	Winding Type	Angle (deg.)	Pos/Neg. Sequence R(pu)	Pos/Neg. Sequence X(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Neutral Earth R(pu)	Neutral Earth X(pu)	Voltage Ratio	Off-Nom Tap (%)
DATA for Transformer with ID. trans_a				No. of units	1 using library key trans_a							
busbar 1	1	150.000	D	30.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20
busbar 2	2	150.000	YN	0.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20
DATA for Transformer with ID. trans_b				No. of units	1 using library key trans_a							
busbar 1	1	150.000	D	30.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.00
busbar 2	2	150.000	YN	0.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20

INDUCTION MACHINE DATA

Busbar Identifier	Motor Identifier	No.Of Units	Library Key	Motor Ratings MVA	MW	kV	Input MW	Slip (%)	Stator R(pu)	Stator X(pu)	Magnet. X(pu)	Standstill R(pu)	Standstill X(pu)	Rotor R(pu)	Running X(pu)	
busbar 1	M1	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	
busbar 1	M2	1	motor_1	1.080	0.200	6.600	0.200	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M3	1	motor_3	1.080	0.350	6.600	0.350	0.4861	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	
busbar 1	M5	1	motor_3	1.080	0.350	6.600	0.350	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M6	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	
busbar 1	M4	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	
busbar 2	M8	1	motor7	0.405	0.001	0.415	0.001	0.0048	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	M9	1	motor8	0.405	0.002	0.415	0.002	0.0100	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	motor_7	1	motor10	0.405	0.005	0.415	0.005	0.0199	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	motor_7	1	motor10	0.405	0.005	0.415	0.005	100.0000	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	NOT IN SERVICE
busbar 2	M10	1	motor9	0.405	0.020	0.415	0.020	0.0797	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 1	M7	1	motor_1	1.080	0.200	6.600	0.200	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 4		1	motor22	0.405	0.020	0.400	0.020	0.0741	0.0100	0.1000	3.5000	0.0200	0.1000	0.0150	0.1500	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

INDUCTION MACHINE DATA

Busbar Identifier	Motor Identifier	No.Of Units	Library Key	Motor Ratings MVA	MW	kV	Input MW	Slip (%)	Stator R(pu)	X(pu)	Magnet. X(pu)	Standstill R(pu)	X(pu)	Rotor Running R(pu)	X(pu)
busbar 4		1	motor22	0.405	0.020	0.400	0.020	0.0741	0.0100	0.1000	3.5000	0.0200	0.1000	0.0150	0.1500

SYNCHRONOUS MACHINE DATA

Busbar Identifier	Machine Identifier	Type	No.Of Units	Library Key	Generator Ratings MVA BASE	MW	kV	V(pu)	Assigned MW	MVAR	Pos. Sequence R(pu)	X(pu)	Neg. Sequence R(pu)	X(pu)	Zero Sequence R(pu)	X(pu)
busbar 1	Gen a	SLACK	2	Gen a	5.000	NOT IN SERVICE		1.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	0.0125	0.0550
					Neutral earthing						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
busbar 1	Gen b	SLACK	2	Gen a	5.000	2.350	6.600	1.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	0.0125	0.0550
					Neutral earthing						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
busbar 3		SLACK	1	Gen b	31.000	0.800	0.400	1.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	NEUTRAL O/C	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

AT STUDY END - No of iterations = 6 Convergence = 0.3994E-05
Voltage Range from 1.000pu at busbar 1 to 1.001pu at busbar 2

AC BUSBAR VALUES

Busbar Identifier	Merge	Busbar Type	PU	Voltage kV	Voltage ANG-DEG	Synch. Machines MW	Synch. Machines MVAr	Ind Motor Load MW	Ind Motor Load MVAr	Shunt MW	Loads MVAr	3 Phase Fault kA	3 Phase Fault X/R	Ph - E Fault kA	Ph - E Fault X/R
busbar 1	.	SLACK	1.000	6.600	0.000	1.019	1.770	0.950	1.446	0.000	0.000	5.10	21.165	5.46	9.101
busbar 3	.	SLACK	1.000	0.400	0.618	0.000	0.000	0.000	0.000	0.000	0.000	247.98	14.400		
busbar 2	.	LOAD	1.001	0.400	0.000	0.000	0.000	0.029	0.484	0.000	0.000	83.54	21.048	116.32	13.365
busbar 4	.	LOAD	1.001	0.400	0.001	0.000	0.000	0.040	0.226	0.000	0.000	83.11	19.151	115.41	12.276
				BUSBAR TOTALS		1.019	1.770	1.019	2.155	0.000	0.000				
				TOTAL BUS LOAD		1.019	2.155								
				SYSTEM LOSSES		0.001	-0.385								

LINE VALUES

First Busbar	Second Busbar	Branch Identifier	No.Of Ccts	Rating kA	First MW	End MVAr	Flow kA	Second MW	End MVAr	Flow kA	Loading (%)	O/L FLAG
busbar 2	busbar 4	1_2	1	1.000	0.040	0.226	0.331	-0.040	-0.226	0.331	33.1	

CABLE VALUES

First Busbar	Second Busbar	Branch Identifier	No.Of Ccts	Rating kA	First MW	End MVAr	Flow kA	Second MW	End MVAr	Flow kA	Loading (%)	O/L FLAG
busbar 2	busbar 3	connector 1	1	2.500	0.000	-0.391	0.564	0.000	0.000	0.000	22.5	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

TRANSFORMER VALUES

Transformer Identifier	No.Of Units	Winding No.	Connected Busbar	Winding kV	Voltage Ratio	Off Nominal Tap %	Rating MVA	Flow From Busbar MW	Flow From Busbar MVAr	Current kA	Percent Loading	O/L Flag
trans_a	1	1	busbar 1	6.600	1.0000	0.200	150.000	-0.280	-2.980	0.262	2.0	
		2	busbar 2	0.400	1.0000	0.200	150.000	0.280	2.983	4.321	2.0	
trans_b	1	1	busbar 1	6.600	1.0000	0.000	150.000	0.349	3.305	0.291	2.2	
		2	busbar 2	0.400	1.0000	0.200	150.000	-0.349	-3.301	4.787	2.2	

BRANCH LOSS SUMMARY

	(MW)	(MVAr)
SERIES LOSSES	0.001	0.006
SHUNT LOSSES	0.000	-0.391
TOTAL LOSSES	0.001	-0.385

INDUCTION MACHINE VALUES

Busbar Identifier	Machine Identifier	No.Of Units	Slip %	Terminal Voltage kV	Machine MW	Input MVAr	Current kA	O/L Flag
busbar 1	M1	1	0.30	6.600	0.200	0.356	0.036	
busbar 1	M2	1	MACHINE DISCONNECTED					
busbar 1	M3	1	0.53	6.600	0.350	0.378	0.045	
busbar 1	M5	1	MACHINE DISCONNECTED					
busbar 1	M6	1	0.30	6.600	0.200	0.356	0.036	
busbar 1	M4	1	0.30	6.600	0.200	0.356	0.036	
busbar 2	M8	1	0.00	0.400	0.001	0.121	0.174	
busbar 2	M9	1	0.01	0.400	0.003	0.121	0.174	
busbar 2	motor_7	1	0.02	0.400	0.005	0.121	0.174	
busbar 2	motor_7	1	MACHINE DISCONNECTED					
busbar 2	M10	1	0.09	0.400	0.020	0.121	0.177	
busbar 1	M7	1	MACHINE DISCONNECTED					
busbar 4		1	0.08	0.400	0.020	0.113	0.165	
busbar 4		1	0.08	0.400	0.020	0.113	0.165	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

SYNCHRONOUS MACHINE VALUES

Busbar Identifier	Machine Identifier	No.Of Units	Terminal Voltage kV	Power MW	Output MVAr	Current kA	O/L Flag
busbar 1	Gen a	2	MACHINE DISCONNECTED				
busbar 1	Gen b	2	6.600	1.019	1.770	0.179	
busbar 3		1	0.400	0.000	0.000	0.000	

APPENDIX E

LOAD FLOW ANALYSIS : SCENARIO 3

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

SYSTEM STATISTICS

Study Base MVA	=	100.000
Study Base Frequency (Hz)	=	50.000
Number of Busbars	=	4
Number of Shunts	=	0
Number of Lines	=	1
Number of Cables	=	1
Number of Transformers	=	2
Number of Tap Changers	=	0
Number of Synchronous Machines	=	3
Number of Induction Machines	=	14
Number of Wind Turbine Generators	=	0
Number of Bus Sections	=	0
Number of Series Elements	=	0

STUDY PARAMETERS

Load Power Multiplier	=	1.000000
Load Reactive Multiplier	=	1.000000
Convergence Tolerance	=	0.000005
Convergence Control	=	Method 2
Maximum Iterations	=	25
Overload Flag Level	=	100.0% Of Rating
Automatic Tap Changers		OFF

BUSBAR DATA

Busbar Identifier	Nominal kV	Three Phase Fault MVA	Three Phase Fault kA	Single Phase Fault MVA	Single Phase Fault kA	Transf. Shift Angle (deg.)	Nominal Bus Freq. (Hz)
busbar 1	6.600	150.0	13.122	200.0	17.495	0.0	50.0NOT IN USE
busbar 2	0.400	31.0	44.745	45.0	64.952	0.0	50.0
busbar 3	0.400	31.0	44.745	45.0	64.952	0.0	50.0
busbar 4	0.400	31.0	44.745	45.0	64.952	0.0	50.0

LINE DATA

First Busbar	Second Busbar	Line Identifier	No.Of Ccts	Line Length	Library Key	Rating (kA)	Positive Sequence R(pu)	Positive Sequence X(pu))	Positive Sequence B(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Zero Sequence B(pu)	Equivalent Pi Model
busbar 2	busbar 4	1_2	1	1.00	1_1	1.000	0.01000	0.01000	0.00000	0.01000	0.01000	0.00000	

Run on 13-Jun-2007 by supervisor from data set up on 13-Jun-2007 by supervisor

Network Name : prac_1
Data State Name : 17/4

CABLE DATA

First Busbar	Second Busbar	Cable Identifier	No.Of Ccts	Cable Length	Library Key	Rating (kA)	Positive Sequence R(pu)	Positive Sequence X(pu)	Positive Sequence B(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Zero Sequence B(pu)	Equivalent Pi Model
busbar 2	busbar 3	connector 1	1	1.00	cable1	2.500	0.3821	1.0990	0.0039	0.5382	1.0990	0.0042	

TRANSFORMER DATA

System Busbar	Winding No.	Rating (MVA)	Winding Type	Angle (deg.)	Pos/Neg. Sequence R(pu)	Pos/Neg. Sequence X(pu)	Zero Sequence R(pu)	Zero Sequence X(pu)	Neutral Earth R(pu)	Neutral Earth X(pu)	Voltage Ratio	Off-Nom Tap (%)	
DATA for Transformer with ID. trans_a				No. of units		1 using library key trans_a							
busbar 1	1	150.000	D	30.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20	
busbar 2	2	150.000	YN	0.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20	OPEN AT SYSTEM BUS
DATA for Transformer with ID. trans_b				No. of units		1 using library key trans_a							
busbar 1	1	150.000	D	30.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.00	
busbar 2	2	150.000	YN	0.00	0.0016	0.0158	0.0016	0.0158	0.0000	0.0000	1.0000	0.20	OPEN AT SYSTEM BUS

INDUCTION MACHINE DATA

Busbar Identifier	Motor Identifier	No.Of Units	Library Key	Motor Ratings MVA	MW	kV	Input MW	Slip (%)	Stator R(pu)	Stator X(pu)	Magnet. X(pu)	Standstill R(pu)	Standstill X(pu)	Rotor Running R(pu)	Rotor Running X(pu)	
busbar 1	M1	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M2	1	motor_1	1.080	0.200	6.600	0.200	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M3	1	motor_3	1.080	0.350	6.600	0.350	0.4861	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M5	1	motor_3	1.080	0.350	6.600	0.350	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M6	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 1	M4	1	motor_1	1.080	0.200	6.600	0.200	0.2778	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 2	M8	1	motor7	0.405	0.001	0.415	0.001	0.0048	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	M9	1	motor8	0.405	0.002	0.415	0.002	0.0100	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	motor_7	1	motor10	0.405	0.005	0.415	0.005	0.0199	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 2	motor_7	1	motor10	0.405	0.005	0.415	0.005	100.0000	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	NOT IN SERVICE
busbar 2	M10	1	motor9	0.405	0.020	0.415	0.020	0.0797	0.0054	0.1292	3.2292	0.0269	0.1076	0.0161	0.1615	
busbar 1	M7	1	motor_1	1.080	0.200	6.600	0.200	100.0000	0.0050	0.1200	3.0000	0.0250	0.1000	0.0150	0.1500	NOT IN SERVICE
busbar 4		1	motor22	0.405	0.020	0.400	0.020	0.0741	0.0100	0.1000	3.5000	0.0200	0.1000	0.0150	0.1500	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

INDUCTION MACHINE DATA

Busbar Identifier	Motor Identifier	No.Of Units	Library Key	Motor Ratings MVA	MW	kV	Input MW	Slip (%)	Stator R(pu)	X(pu)	Magnet. X(pu)	Standstill R(pu)	X(pu)	Rotor Running R(pu)	X(pu)
busbar 4		1	motor22	0.405	0.020	0.400	0.020	0.0741	0.0100	0.1000	3.5000	0.0200	0.1000	0.0150	0.1500

SYNCHRONOUS MACHINE DATA

Busbar Identifier	Machine Identifier	Type	No.Of Units	Library Key	Generator Ratings MVA BASE	MW	kV	V(pu)	Assigned MW	MVAR	Pos. Sequence R(pu)	X(pu)	Neg. Sequence R(pu)	X(pu)	Zero Sequence R(pu)	X(pu)
busbar 1	Gen a	SLACK	2	Gen a	5.000	NOT IN SERVICE		0.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	0.0125	0.0550
					Neutral earthing						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
busbar 1	Gen b	SLACK	2	Gen a	5.000	NOT IN SERVICE		0.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	0.0125	0.0550
					Neutral earthing						0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
busbar 3		SLACK	1	Gen b	31.000	0.800	0.400	1.000	0.000	0.000	0.0125	0.1800	0.0500	0.2400	NEUTRAL O/C	

:S Loadflow module by ... from data set up on 13-Jun-2007 by Supervisor
on 13-Jun-2007 by Supervisor

work Name : prac_1
a State Name : 17/4

STUDY END - No of iterations = 2 Convergence = 0.9090E-06
Voltage Range from 0.994pu at busbar 4 to 1.000pu at busbar 3

BUSBAR VALUES

Busbar Identifier	Merge	Busbar Type	Voltage PU	Voltage kV	Voltage ANG-DEG	Synch. Machines MW	Synch. Machines MVAr	Ind Motor Load MW	Ind Motor Load MVAr	Shunt Loads MW	Shunt Loads MVAr	3 Phase Fault kA	3 Phase Fault X/R	Ph - E Fault kA	Ph - E Fault X/R
usbar 1			BUS DISCONNECTED												
usbar 3	.	SLACK	1.000	0.400	0.000	0.070	0.315	0.000	0.000	0.000	0.000	261.66	14.406	1.83-747.767	
usbar 2	.	LOAD	0.994	0.398	0.068	0.000	0.000	0.029	0.477	0.000	0.000	98.08	4.625	1.83-283.784	
usbar 4	.	LOAD	0.994	0.398	0.069	0.000	0.000	0.040	0.223	0.000	0.000	97.37	4.528	1.83-274.766	
				BUSBAR TOTALS		0.070	0.315	0.069	0.700	0.000	0.000				
				TOTAL BUS LOAD		0.069	0.700								
				SYSTEM LOSSES		0.001	-0.385								

LINE VALUES

First Busbar	Second Busbar	Branch Identifier	No.Of Ccts	Rating kA	First MW	End MVAr	Flow kA	Second MW	End MVAr	Flow kA	Loading (%)	O/L FLAG
busbar 2	busbar 4	1_2	1	1.000	0.040	0.223	0.328	-0.040	-0.223	0.328	32.8	

CABLE VALUES

First Busbar	Second Busbar	Branch Identifier	No.Of Ccts	Rating kA	First MW	End MVAr	Flow kA	Second MW	End MVAr	Flow kA	Loading (%)	O/L FLAG
busbar 2	busbar 3	connector 1	1	2.500	-0.069	-0.700	1.021	0.070	0.315	0.465	40.8	

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor

Network Name : prac_1
Data State Name : 17/4

SYNCHRONOUS MACHINE VALUES

Busbar Identifier	Machine Identifier	No.Of Units	Terminal Voltage kV	Power MW	Output MVAr	Current kA	O/L Flag
busbar 1	Gen a	2	MACHINE DISCONNECTED				
busbar 1	Gen b	2	MACHINE DISCONNECTED				
busbar 3		1	0.400	0.070	0.315	0.465	

APPENDIX F

FAULT STUDY AND ANALYSIS

ERACS Fault module By ERA Technology Ltd. ERACS Version: 3.5.0. Fault Version: 3.5.0
Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor
Network Name : prac_1
Data State Name : 17/4
Study Name : sc

FAULT IMPEDANCE VALUES

Rph(pu)	Rph(ohm)	Xph(pu)	Xph(ohm)	Rgnd(pu)	Rgnd(ohm)	Xgnd(pu)	Xgnd(ohm)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

REACTANCE SELECTION: Synchronous machine Positive Sequence reactance is employed and asynchronous machines are included in the system model.

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor
Network Name : prac_1
Data State Name : 17/4
Study Name : Three phase fault at busbar busbar 1

FAULT CURRENTS

Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	MVA	
busbar 1	7.522	0.000	0.000	7.522	7.522	7.522	0.000	85.986	Magnitude
	18.384	0.000	0.000	18.384	18.383	18.386	0.000		X/R Ratio
	-86.9	0.0	0.0	-86.9	153.1	33.1	0.0		Angle (deg)

BUSBAR VOLTAGES

Bus ID	Vp(kV)	Vn(kV)	Vz(kV)	Vr(kV)	Vy(kV)	Vb(kV)	Vres(kV)	
busbar 1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Magnitude
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Angle (deg)

TRANSFORMER CURRENTS

Tx ID	Bus No	Wnd No	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
trans_a	busbar 1	1	0.452	0.000	0.000	0.452	0.452	0.452	0.000	Magnitude
			91.7	0.0	0.0	91.7	-28.3	-148.3	0.0	Angle (deg)
trans_b	busbar 1	1	0.452	0.000	0.000	0.452	0.452	0.452	0.000	Magnitude
			91.7	0.0	0.0	91.7	-28.3	-148.3	0.0	Angle (deg)

INDUCTION MACHINE CURRENTS

IM ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
M1	busbar 1	0.405	0.000	0.000	0.405	0.405	0.405	0.000	Magnitude
		-91.1	0.0	0.0	-91.1	148.9	28.9	0.0	Angle (deg)
M2	busbar 1	Machine disconnected.							
M3	busbar 1	0.403	0.000	0.000	0.403	0.403	0.403	0.000	Magnitude
		-92.9	0.0	0.0	-92.9	147.1	27.1	0.0	Angle (deg)

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor
Network Name : prac_1
Data State Name : 17/4
Study Name : Three phase fault at busbar busbar 1

INDUCTION MACHINE CURRENTS

IM ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
M5	busbar 1	Machine disconnected.							
M6	busbar 1	0.405	0.000	0.000	0.405	0.405	0.405	0.000	Magnitude
		-91.1	0.0	0.0	-91.1	148.9	28.9	0.0	Angle (deg)
M4	busbar 1	0.405	0.000	0.000	0.405	0.405	0.405	0.000	Magnitude
		-91.1	0.0	0.0	-91.1	148.9	28.9	0.0	Angle (deg)
M7	busbar 1	Machine disconnected.							

SYNCHRONOUS MACHINE CURRENTS

SM ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
Gen a	busbar 1	2.505	0.000	0.000	2.505	2.505	2.505	0.000	Magnitude
		-85.1	0.0	0.0	-85.1	154.9	34.9	0.0	Angle (deg)
Gen b	busbar 1	2.505	0.000	0.000	2.505	2.505	2.505	0.000	Magnitude
		-85.1	0.0	0.0	-85.1	154.9	34.9	0.0	Angle (deg)

NEUTRAL EARTHING VOLTAGES & CURRENTS

Parent ID	Vres(kV)	Ires(kA)	
Synchronous Machine with ID Gen a	0.000	0.000	Magnitude
	0.0	0.0	Angle (deg)
Synchronous Machine with ID Gen b	0.000	0.000	Magnitude
	0.0	0.0	Angle (deg)

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor
Network Name : prac_1
Data State Name : 17/4
Study Name : Three phase fault at busbar busbar 2

FAULT CURRENTS

Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	MVA	
busbar 2	122.728	0.000	0.000	122.728	122.728	122.728	0.000	85.029	Magnitude
	18.253	0.000	0.000	18.253	18.251	18.254	0.000		X/R Ratio
	-86.9	0.0	0.0	-86.9	153.1	33.1	0.0		Angle (deg)

BUSBAR VOLTAGES

Bus ID	Vp(kV)	Vn(kV)	Vz(kV)	Vr(kV)	Vy(kV)	Vb(kV)	Vres(kV)	
busbar 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Magnitude
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Angle (deg)

LINE CURRENTS

Line ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
1_2	busbar 2	5.596	0.000	0.000	5.596	5.596	5.596	0.000	Magnitude
		92.5	0.0	0.0	92.5	-27.5	-147.5	0.0	Angle (deg)

CABLE CURRENTS

Cable ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
connector 1	busbar 2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Magnitude
		0.0	0.0	0.0	0.0	0.0	0.0	0.0	Angle (deg)

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor
Network Name : prac_1
Data State Name : 17/4
Study Name : Three phase fault at busbar busbar 2

TRANSFORMER CURRENTS

Tx ID	Bus No	Wnd No	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
trans_a	busbar 2	2	53.905	0.000	0.000	53.905	53.905	53.905	0.000	Magnitude
			93.3	0.0	0.0	93.3	-26.7	-146.7	0.0	Angle (deg)
trans_b	busbar 2	2	53.905	0.000	0.000	53.905	53.905	53.905	0.000	Magnitude
			93.3	0.0	0.0	93.3	-26.7	-146.7	0.0	Angle (deg)

INDUCTION MACHINE CURRENTS

IM ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
M8	busbar 2	2.333	0.000	0.000	2.333	2.333	2.333	0.000	Magnitude
		-88.6	0.0	0.0	-88.6	151.4	31.4	0.0	Angle (deg)
M9	busbar 2	2.333	0.000	0.000	2.333	2.333	2.333	0.000	Magnitude
		-88.7	0.0	0.0	-88.7	151.3	31.3	0.0	Angle (deg)
motor_7	busbar 2	2.333	0.000	0.000	2.333	2.333	2.333	0.000	Magnitude
		-88.8	0.0	0.0	-88.8	151.2	31.2	0.0	Angle (deg)
motor_7	busbar 2	Machine disconnected.							
M10	busbar 2	2.332	0.000	0.000	2.332	2.332	2.332	0.000	Magnitude
		-89.3	0.0	0.0	-89.3	150.7	30.7	0.0	Angle (deg)

NEUTRAL EARTHING VOLTAGES & CURRENTS

Parent ID	Vres(kV)	Ires(kA)	
Winding 2 of Transformer with ID trans_a	0.000	0.000	Magnitude
	0.0	0.0	Angle (deg)
Winding 2 of Transformer with ID trans_b	0.000	0.000	Magnitude
	0.0	0.0	Angle (deg)

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor
Network Name : prac_1
Data State Name : 17/4
Study Name : Three phase fault at busbar busbar 3

FAULT CURRENTS

Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	MVA	
busbar 3	247.984	0.000	0.000	247.984	247.984	247.984	0.000	171.808	Magnitude
	14.400	0.000	0.000	14.400	14.399	14.401	0.000		X/R Ratio
	-85.8	0.0	0.0	-85.8	154.2	34.2	0.0		Angle (deg)

BUSBAR VOLTAGES

Bus ID	Vp(kV)	Vn(kV)	Vz(kV)	Vr(kV)	Vy(kV)	Vb(kV)	Vres(kV)	
busbar 3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Magnitude
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Angle (deg)

CABLE CURRENTS

Cable ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)
connector 1	On busbar busbar 3 is disconnected.							

SYNCHRONOUS MACHINE CURRENTS

SM ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
	busbar 3	247.984	0.000	0.000	247.984	247.984	247.984	0.000	Magnitude
		-85.8	0.0	0.0	-85.8	154.2	34.2	0.0	Angle (deg)

Run on 13-Jun-2007 by Supervisor from data set up on 13-Jun-2007 by Supervisor
Network Name : prac_1
Data State Name : 17/4
Study Name : Three phase fault at busbar busbar 4

FAULT CURRENTS

Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	MVA	
busbar 4	121.738	0.000	0.000	121.738	121.738	121.738	0.000	84.342	Magnitude
	16.132	0.000	0.000	16.132	16.131	16.134	0.000		X/R Ratio
	-86.5	0.0	0.0	-86.5	153.5	33.5	0.0		Angle (deg)

BUSBAR VOLTAGES

Bus ID	Vp(kV)	Vn(kV)	Vz(kV)	Vr(kV)	Vy(kV)	Vb(kV)	Vres(kV)	
busbar 4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Magnitude
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Angle (deg)

LINE CURRENTS

Line ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
1_2	busbar 4	116.141	0.000	0.000	116.141	116.141	116.141	0.000	Magnitude
		93.6	0.0	0.0	93.6	-26.4	-146.4	0.0	Angle (deg)

INDUCTION MACHINE CURRENTS

IM ID	Bus ID	Ip(kA)	In(kA)	Iz(kA)	Ir(kA)	Iy(kA)	Ib(kA)	Ires(kA)	
	busbar 4	2.799	0.000	0.000	2.799	2.799	2.799	0.000	Magnitude
		-87.5	0.0	0.0	-87.5	152.5	32.5	0.0	Angle (deg)
	busbar 4	2.799	0.000	0.000	2.799	2.799	2.799	0.000	Magnitude
		-87.5	0.0	0.0	-87.5	152.5	32.5	0.0	Angle (deg)