ELECTRICAL POWER SYSTEM MODELING AND SIMULATION OF UNIVERSITI TEKNOLOGI PETRONAS GAS DISTRICT COOLING PLANT

by

Hayfa Amira Binti Ahmad Kamal

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

JUNE 2010

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CERTIFICATION OF APPROVAL

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Approved:

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
June 2010

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.

(HAYFA AMIRA BINTI AHMAD KAMAL)

ABSTRACT

This document is the final report of Final Year Project entitled "Electrical Power System Modeling and Simulation of Universiti Teknologi PETRONAS Gas District Cooling Plant". MatLab with Power System Analysis Toolbox (PSAT) is used to develop the model and to come out with load flow result. Load flow is important to analyze whether the system is reliable and effective to cater the demand from the customer. In the first chapter, an introduction of the Gas District Cooling (GDC) plant and load flow analysis is included as well as the problem statement and the objectives of this project. The second part is the literature review where the author wrote down the detailed research that has been done in order to execute the project. The information is important for the readers as well for the basic understanding of the project. The methodology which comes in the third part is the explanation of the process and activities the author done along the journey in completing the project. In the fifth part, the results are shown and discussion based on the results. The last part is conclusion and recommendations where the author wrote down the summary of the project and recommended how the project can be improve.

ACKNOWLEDGEMENT

Sir Isaac Newton once said, "If I have seen farther from other men, it is because I have stood on the shoulders of giants." I am most grateful to all the personnel whose works I have drawn from them. They are the giants on whose shoulders I stood while working for my final year project. Upon completing the two semesters of my final year project, I would like to express my deepest appreciation, first and foremost to ALLAH, The Almighty, for giving me the strength and perseverance to undertake all the tasks assigned.

Million of thanks especially to my supervisor, Associate Professor Dr Irraivan Elamvazuthi, for his support and enthusiasm throughout my final year semesters. My utmost gratitude aptly is also dedicated to my co-supervisor, Dr Nursyarizal, for assisting me in solving the problems critically. Not to forget the staffs from Universiti Teknologi PETRONAS Gas District Cooling Plant for providing me the data needed for this project.

Last but not least, I wish to pay tribute to my family, especially my parents, Haji Ahmad Kamal Ariffin and Mrs. Masharumi Md. Kassim for their encouragement and tolerance in many ways during my final year project period. And also to my friends, who shared their ideas, experiences and encouragement.

Thank you.

May ALLAH SWT bless all of you.

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INTRODUCTION

1.1 Background of Study

1.1.1 Makhostia Gas District Cooling Plant at Universiti Teknologi PETRONAS

Figure 1: Makhostia Gas District Cooling Plant at UTP

Makhostia Sdn Bhd is a Bumiputra Company established in 2003 to undertake the business of providing services for the Operation and Maintenance of utility plants [1]. They are a "partner" to PETRONAS undertaking the operation and maintenance of their utility power plant producing chilled water for air conditioning to their customers. The plants operated comprise Gas Turbines, Waste Heat Boilers, and Chillers of all types.

On 1st November 2005, Makhostia took over the Universiti Teknologi PETRONAS (UTP) Gas District Cooling (GDC) Plant in Tronoh, Perak. The plant construction began in 2001 and was commissioned in April 2003 to supply both chilled water and electricity to the Universiti Teknologi PETRONAS campus in Tronoh, Perak. The plant currently producing Chilled Water of 4000RT and Electricity generation of 8.4MW and will be further increased to 11000RT and 20MW to meet higher demand as the student population increases to 11,000. It operates on an island operation during normal mode condition and import supply from Tenaga Nasional Berhad (TNB) if any faulty at the generators or demand is above than normal.

1.1.2 Load Flow Analysis

Load flow analysis is probably the most important of all network calculations since it concerns the network performance in its normal operating conditions. It is performed to investigate the magnitude and phase angle of the voltage at each bus and the real and reactive power flows in the system components. Load flow studies are typically performed for minimum and maximum load conditions to establish the full voltage range at each point in the network and determine circuit loading. The following may be established from load flow studies:

- Voltage profile (i.e. busbar voltages).
- Optimum transformers tap settings.
- Real and reactive power flow in the branches of the network.
- System losses.
- Effect of rearranging circuits and incorporating new circuit on system loading.
- Effects of temporary loss of generation and transmission circuits on system loading.
- Improvement from change of conductor size and system voltage.
- Optimum system running conditions and load distribution.

Load flow analysis has a great importance in future expansion planning, in stability studies and in determining the best economical operation for existing systems. Also load flow results are very valuable for setting the proper protection devices to insure the security of the system. In order to perform a load flow study, full data must be provided about the studied system, such as connection diagram, parameters of transformers and lines, rated values of each equipment, and the assumed values of real and reactive power for each load. [2]

1.2 Problem Statement

Gas District Cooling Plant owned by Makhostia is responsible to supply electricity to Universiti Teknologi PETRONAS. To maintain the reliability and effectiveness, modeling and simulation is required to determine the performance of the power system in the plant. Load flow study is needed to calculate the total load in the plant and demand from Universiti Teknologi PETRONAS who is the customer. This is important as to ensure the generators available can cater all the loads even in various worst case scenarios that might happens during real situation of the operation of the plant.

1.3 Objectives and Scope of Study

The objectives of this project are:

- To select the best software to be used for the modeling and simulation,
- To understand the operation of electricity supply from GDC Plant to UTP,
- To do the modeling and simulation of the plant system using the selected software based on the scenarios,
- To analyze the plant system reliability and effectiveness using the result from load flow study and,
- To come out with network visualization of the system's line flows.

CHAPTER 2

LITERATURE REVIEW

2.1 History of Load Flow Analysis

Before 1929 all load flow calculations were made by hand. In 1929, network calculators by Westinghouse or network analyzers by General Electric were employed to perform load flow calculations. The first paper describing the first digital method to solve the load flow problem was published in 1954 [3]. However, the first really successful digital method of load flow was developed by Ward and Hale in 1956 [4]. Most of the early iterative methods were based on the *Y*-matrix of the *Gauss-Seidel* method. It requires minimum computer storage and needs only a small number of iterations for small networks. Unfortunately, as the size of the network is increased, the number of iterations required increases dramatically for large systems.

In some cases, the method does not provide a solution at all. Therefore, the slowly converging behavior of the *Gauss-Seidel* method and its frequent failure to converge in ill-conditioned situations caused the development of the *Z*-matrix methods. Even though these methods have considerable better converging characteristics, they also have the disadvantage of needing a significantly larger computer storage memory owing to the fact that the *Z*-matrix is full, contrary to the *Y*-matrix, which is sparse.

These difficulties encountered in load flow studies led to the development *of Newton- Raphson* method. This method was originally developed by Van Ness and Griffin [5] and later by others including Tinney, Hart, Britton, Dommel, Powell, Stott, Peterson and Meyer [6]. The method is based on the *Newton-*

Raphson algorithm to solve the simultaneous quadratic equations of the power network. Contrary to the *Gauss-Seidel* algorithm, it needs a larger time per iteration, but only a few of iterations, and is significantly independent of the network size. Therefore, most of the load flow problems that could not be solved by the *Gauss-Seidel* method e.g. systems with negative impedances are solved with no difficulties with this method. But it was not computationally competitive on large systems because of the rapid increase of computer time and storage requirement with problem size.

However, the development of a very efficient sparsity-programmed ordered elimination technique by Tinney and others to solve the simultaneous equations has enhanced the efficiency of the *Newton-Raphson* method, in terms of speed and storage requirements, and has made it the most widely used load flow method. The method has been further improved by the addition of automatic controls and adjustments e.g. program-controlled in phase tap changers, phase-angle regulators and area interchange control. Since system planning studies and system operations may require multiple case load flow solutions in some situations, the recent research efforts have been concentrated on the development of the decoupled *Newton-Raphson* methods where the real and reactive portions of the solution were separated during the iterations. The result was simplified load flows that solved in seconds for large networks and allowed the function of Security Analysis to be accomplished. Later additions to this grouping of functions included the Optimal Power Flow which allowed production cost to be minimized considering line losses, security constraints etc. [7].

2.2 Bus Classification

Each bus in the system has four variables: voltage magnitude, voltage angle, real power and reactive power. During the operation of the power system, each bus has two known variables and two unknowns. Generally, the bus must be classified as one of the following bus types [2]:

2.2.1 Slack or Swing Bus

This bus is considered as the reference bus. It must be connected to a generator of high rating relative to the other generators. During the operation, the voltage of this bus is always specified and remains constant in magnitude and angle. In addition to the generation assigned to it according to economic operation, this bus is responsible for supplying the losses of the system.

2.2.2 Generator or Voltage Controlled Bus

During the operation the voltage magnitude at this the bus is kept constant. Also, the active power supplied is kept constant at the value that satisfies the economic operation of the system. Most probably, this bus is connected to a generator where the voltage is controlled using the excitation and the power is controlled using the prime mover control (as you have studied in the last experiment). Sometimes, this bus is connected to a VAR device where the voltage can be controlled by varying the value of the injected VAR to the bus.

2.2.3 Load Bus

This bus is not connected to a generator so that neither its voltage nor its real power can be controlled. On the other hand, the load connected to this bus will change the active and reactive power at the bus in a random manner. To solve the load flow problem we have to assume the complex power value (real and reactive) at this bus.

2.3 Synchronous Generator

Synchronous generator is basically a synchronous machine that used to convert mechanical power to electrical power. DC power supply is used on the rotor winding that will induce a magnetic field in rotor. The rotor itself will turn by a prime mover that will also produce a rotating magnetic field that will produce 3 phase voltage. There are 2 winding which is field winding (rotor) and armature (stator) winding. Below is basically the equivalent circuit of synchronous generator:

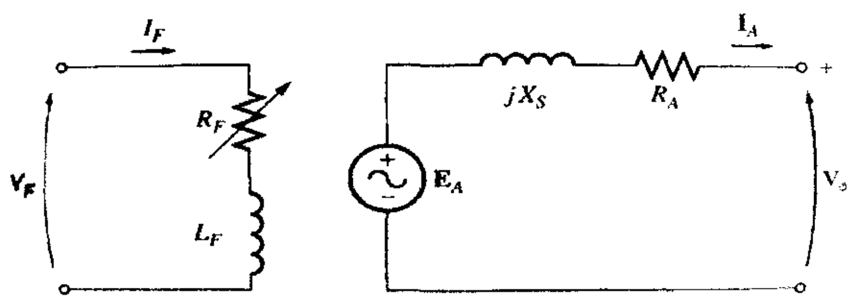

Figure 2: Equivalent Circuit of Synchronous Generator

The rotation of the magnetic field in this machine is related to the stator electrical frequency which is:

$$fe = \frac{n_m P}{120}$$

The frequency that is used in Malaysia is about 50 Hz, therefore the generator will turn at fix speed depending on the number of poles. The magnitude of the voltage induced in stator is:

$E_A = K\O\omega$; where K is constant

The armature induced voltage phase is given by

$$V_\varnothing = E_A - jXI_A$$

The final equation is

$$V_\varnothing = E_A - jXI_A - R_AI_A$$

There are four types of generator, which are:

- Slack: The voltage magnitude is specified and the voltage angle is set at zero. The real and reactive powers are calculated by the load flow. A slack generator provides the balancing for the initially unknown power losses in the system.
- PV: The real power and voltage magnitude are specified, the reactive power and voltage angle are calculated by load flow.
- PQ: The real and reactive power are specified, the voltage, magnitude and angle are calculated by load flow.
- VA: The voltage magnitude and angle are specified, the real and reactive powers are calculated by load flow.

2.4 Transformer

A transformer is a device that changes electric power at one voltage level to another voltage level through the action of a magnetic field. It consists of two or more coils of wire wrapped around a common ferromagnetic core. These coils are not directly connected. The only one connection between the coils is the common magnetic flux present within the core [9].

2.4.1 *Transformer Configuration*

Power transformer has one or two types of cores. One type of cores consists of very simple rectangular laminated steel with transformer winding wrapped around two sides of rectangle. The primary and secondary winding is wrapped one on top of the other because of below reasons:

- Simplified problem insulating HV winding from core
- Less leakage

Power transformer has a variety of names that used in power system nowadays depending on the voltage itself. A unit transformer is a transformer that attached to a generator and was used to step-up the voltage transmission level (110kV above). At the end of the transmission line, the voltage is then step-down and this transformer are called *substation transformer* (132kV to 11kV). The last transformer that takes the lower voltage or LV (415V and 240V) are called distribution transformer.

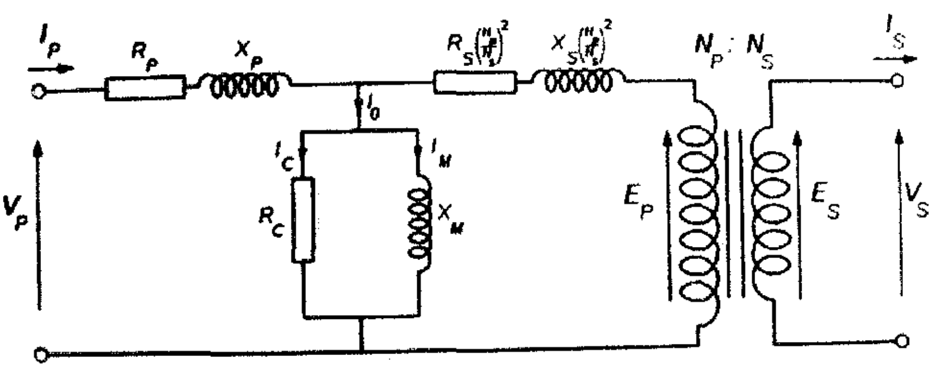

Figure 3: Equivalent Circuit of Transformer

2.4.2 *Ideal Transformer*

Consider the transformer was an ideal transformer, which means the transformer having a lossless device at input winding and output winding. The relationship between input and output voltage, current input and output are shown below:

$$\frac{Vp(t)}{Vs(t)} = \frac{Np}{Ns} = \frac{is(t)}{ip(t)} = a$$; which a is defines as turn ratio

Vp(t) = Voltage at primary side
Vs(t) = Voltage at secondary side
Np = turns of wire at primary side
Ns = turns of wire at secondary side

2.5 Per Unit Method

The per-unit method of calculation in its basic concept is to develop counterpart impedance or reactance network diagram of the power system involved and resolve these impedances down to a single impedance value through delta, wye, series, parallel conversion equations. While it is possible to do the calculation with the actual system ohmic values, it becomes very complex when several voltages levels are involve since ohmic values at different voltages are not directly compatible. With the aid of the per-unit mathematical technique, it has facilitated this difficulty. While the equivalent diagram and the per-unit mathematics are two separate fields, they usually are used together and referred to as the per-unit method of determining short circuit values.

For Medium voltage power system usually benefit the application of the per-unit method because the analysis normally undertaken involves a relatively few specific points in an existing system. Also in this system, reactance usually far exceeds resistance high X/R ratio, permitting resistance to be ignored, which greatly simplifies the mathematics.

The primary advantages of the per-unit system are as follow:

a. The per-unit values for transformer impedance, voltage and current are identical when referred to the primary and secondary line (no need to reflect impedances from one side of the transformer to the other, the transformer is a single impedance).

b. The per-unit values for various components lie within a narrow range regardless of the equivalent rating.

c. The per-unit values clearly represent the relative values of the circuit quantities. Many of the ubiquitous scaling constants are eliminated.

d. Ideal for computer simulations.

Per-unit system is based on the formula shown below:

$$\text{Per unit} = \frac{\textit{actual quantity}}{\textit{base quantity}}$$

Using this method, all quantities are expressed as ratios of some base value or values. In many respects the method is similar to the use of percentage values. When analyzing a real system, all parameters such as voltage, current, power, and impedance can be converted to per unit. If the bases are chosen wisely, the entire system may then be analyzed and the local results calculated.

2.5.1 Choosing Base Value

It is wise to choose one base power for the entire system. Choice also depends on rating of generators or transformers. If network contains multiple voltages, select base power based on section of most interest. Example for commercial building of mainly 415V can choose 100kVA. Distribution utility with 11kV can use 10MVA. Transmission utility can choose 100MVA or 1000MVA.

2.6 Load Flow Calculations

2.6.1 Gauss Seidel

Gauss–Seidel method, also known as the Liebmann method or the method of successive displacement, is an iterative method used to solve a linear system of equations. It is named after the German mathematicians Carl Friedrich Gauss and Philipp Ludwig von Seidel, Though it can be applied to any matrix with non-zero elements on the diagonals, convergence is only guaranteed if the matrix is either diagonally dominant, or symmetric and positive definite [10]. Gauss-Seidel method is simple to understand and to write computer programs. Time taken for each iteration will be small. However, number of iterations will be generally large. Particularly when the system size is large convergence rate will be very poor. Hence, Gauss-Seidel method is not recommended for large scale power systems [11]. An example of Gauss Seidel calculation can be found in Appendix 2.

2.6.2 Newton-Raphson

In numerical analysis, Newton's method (also known as the Newton–Raphson method), named after Isaac Newton and Joseph Raphson, is perhaps the best known method for finding successively better approximations to the zeroes (or roots) of a real-valued function. Newton's method can often converge remarkably quickly; especially if the iteration begins "sufficiently near" the desired root. Just how near "sufficiently near" needs to be, and just how quickly "remarkably quickly" can be, depends on the problem. Unfortunately, when iteration begins far from the desired root, Newton's method can easily lead an unwary user astray with little warning. Thus, good implementations of the method embed it in a routine that also detects and perhaps overcomes possible convergence failures [12]. An example of calculation using Newton-Raphson can be found in Appendix 3.

2.6.3 Fast Decoupled

Fast Decoupled Power Flow method makes use of constant matrices. Therefore, it is enough to do factorization only once. In every iteration mismatch powers are calculated and changes in bus voltages are recalculated easily. The iterations are continued until the mismatch powers become less than the specified tolerance. Fast Decoupled Power Flow method is well suited for practical large scale power systems [9]. An example of calculation using Fast Decoupled can be found in Appendix 4.

CHAPTER 3

METHODOLOGY

3.1 Project Work Procedure

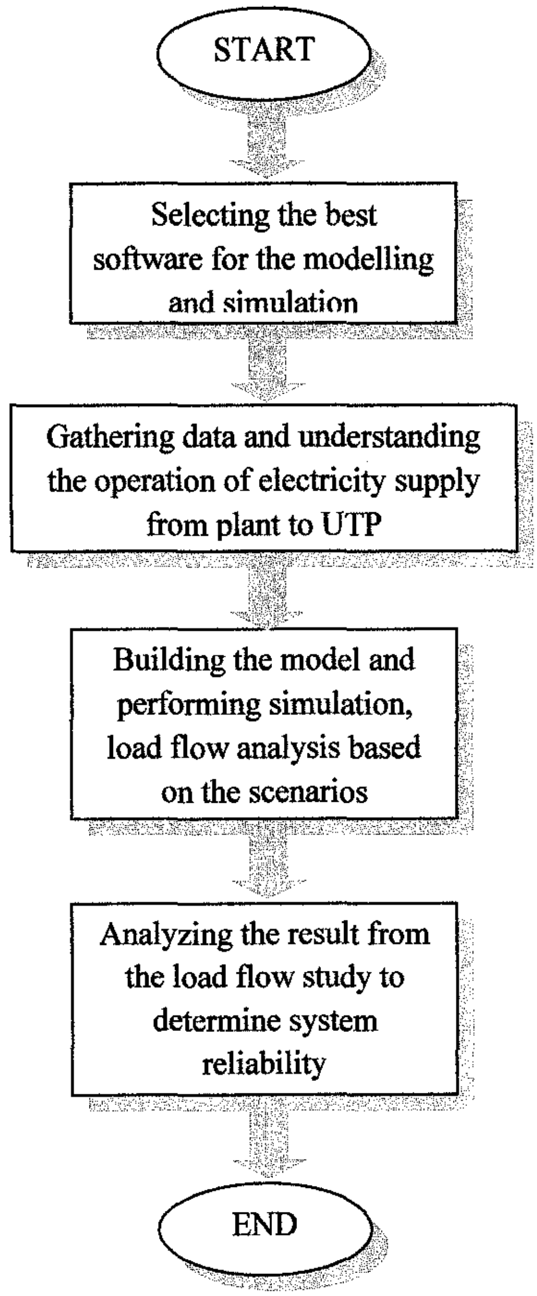

Figure 4: Project Work Procedure Flow Chart

3.2 Load Flow Analysis Method

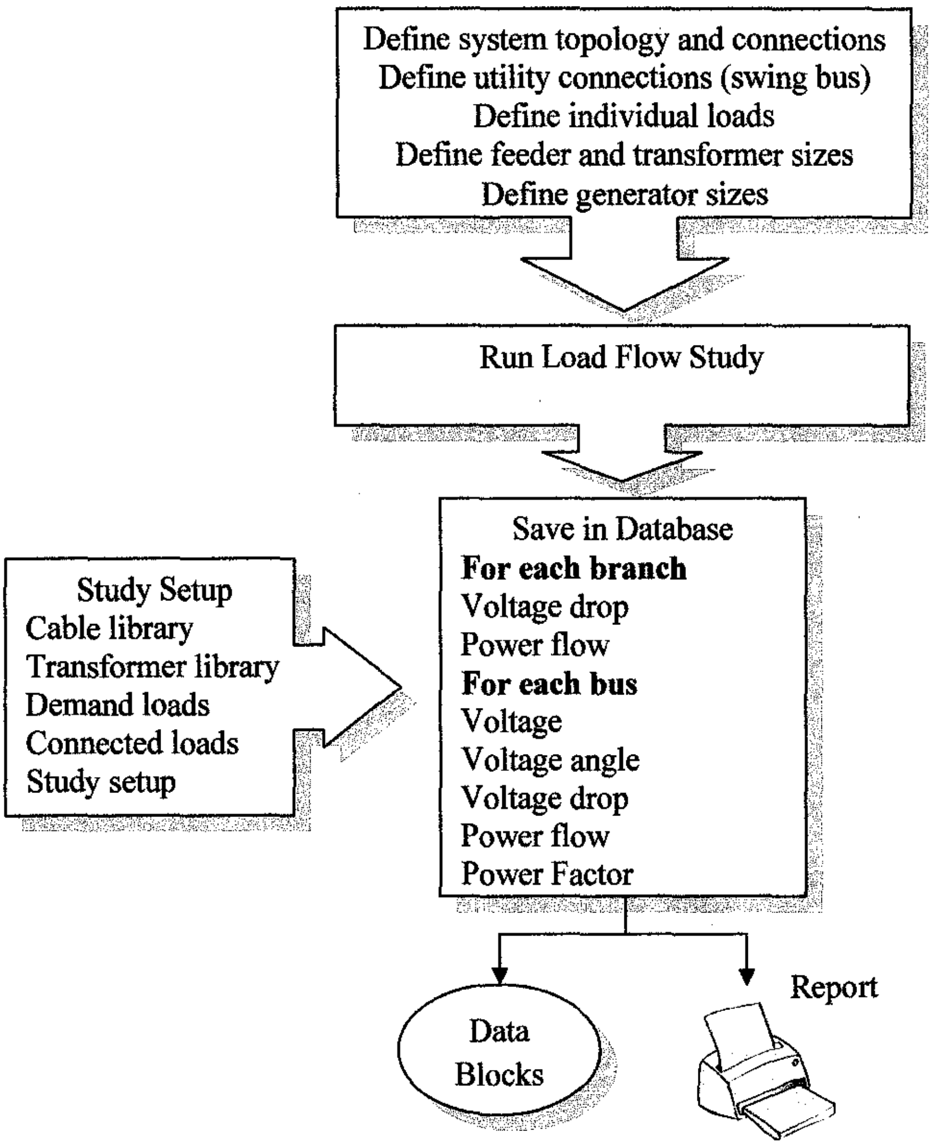

Figure 5: Load Flow Analysis Flow Chart

3.3 Selecting the Most Suitable Software for the Modeling and Simulation

In the earlier stage of this project, ERACS has been selected as the software to do the modeling and simulation. After 70% of the modeling is done on the software, it is found that ERACS has poor library content and this has become a challenge to the author to continue the project using ERACS. After a detailed research, MatLab with Power System Analysis Toolbox (PSAT) is selected to replace ERACS. PSAT is a Matlab toolbox for electric power system analysis and simulation. The command line version of PSAT is also GNU Octave compatible. All operations can be assessed by means of graphical user interfaces (GUIs) and a Simulink-based library provides a user-friendly tool for network design.

The main features of PSAT are: Power Flow; Continuation Power Flow; Optimal Power Flow; Small Signal Stability Analysis; Time Domain Simulation; Phasor Measurement Unit (PMU) Placement; Complete Graphical User Interface; User Defined Models; FACTS Models; Wind Turbine Models; Conversion of Data Files from several Formats; Export results to EPS, plain text, MS Excel and LaTeX files; Interfaces to GAMS and UWPFLOW Programs; Command Line Usage; and GNU Octave Compatibility. [13]

3.4 Modeling in Matlab using PSAT

In developing model for analysis in MatLab PSAT, design specifications and descriptions of all major equipments need to be verified first as depicted below:

3.4.1 TNB Supply

TNB 11kV supply is sourced from the Sri Iskandar main station that has an installed capacity of 2 x 30 mVA 132/11kV transformers. Two (2) nos. 11kV supply feeders using 3/c 240 mm^2 XLPE/SWA/PVA aluminum type connects the Sri Iskandar station to the UTP main intake supply (MIS) station.

3.4.2 UTP Main Intake Supply (MIS) 11kV Station

The MIS station is the point of common coupling between the TNB network and the GDC network. Also connected to the MIS station bus are UTP loads and two (2) 11kV supply feeders from the GDC plant. Parallel connection with TNB 11kV electrical network will be done for greater security of supply in the event of a shutdown in one of the gas turbine generators for maintenance or due to a fault incidence. TNB shall be providing a standby power of 4MW for each incoming feeder.

3.4.3 11kV Plant Switchgears in Electrical Room at GDC Plant (MIS Feeder)

The MIS Feeder serves as the main interface substation between GTG output and power supply or intake to or from MIS. MIS Feeder can receive power supply from both GTG output and TNB. MIS Feeder is also the main electricity power supply intake substation for the internal used at GDC Plant.

3.4.4 Gas Turbine Generators GTG-A & GTG-B

GTG-A and GTG-B are of similar ratings with respective power output of 4.2 MW at 0.8 power factor 11kV 50Hz. The GTG's are intended to meet the full UTP load requirement under normal operation. Energy import from TNB is required when one of the GTG's is undergoing maintenance outage or is faulty.

To cater for the GTG auxiliary loads (at 415V), 2 units of 315kVA 11/0.433kV 50Hz transformers Tx-GTG-A and Tx-GTG-B are installed and connected to the GTG switchgear bus. For this study, a constant load has been connected at this bus representing the addition of all the loads. Total power for each bus is 88.836kW and 56.910kVAr at maximum load.

To meet the reactive power requirement of the GDC plant and to ensure that the overall system power factor is at 0.9 or better to satisfy TNB requirement it is intended to operate the GTG's to supply the VAr requirement by controlling the field excitation. Each GTG is capable of producing 4200 tan ($\cos^{-1} 0.8$) = 3150 kVAr.

3.4.5 415V System for Internal Utility Used at GDC Plant

Two (2) sets of 2500kVA 11/0.433kV transformers are installed from 11kV MIS Feeder to two (2) sets of 415V Motor Control Centre (MCC) and some low voltage distribution board for GDC Plant used.

The 415V MCCs are mainly distributed the power supply to the mechanical equipment such as pump, fan, motor, chiller and boiler. Furthermore, the MCC also have two (2) switchboards named Main Distribution (MDB) and Essential Main Switch Board (EMSB) respectively. For this study, all the loads have been added and represented with one constant power load. For MCC1, the rated power is 1541.720kW and 1148.910kVAr. For MCC2, the rated power is 1552.54kW and 723.980kVAr. For MDB and EMSB, the loads have been added into both MCCs.

The MDB are distributed mainly to 240V single-phase equipment used such as street lighting, lighting and small socket outlet, exhaust fan and those miscellaneous appliances.

The EMSB are distributed mainly to 240V single-phase essential load such as 110V DC Battery Charger power intake, Uninterrupted Power Supply (UPS) and the auxiliary supply for switchgears.

3.5 Scenarios of Power Supply to UTP

There are four (4) scenarios of ways to supply power to the GDC plant loads and UTP loads. The first (1^{st}) one is using both the plant's generators. The second (2^{nd}) scenario using one of the generators and backed up by TNB supply. The third (3^{rd}) scenario is totally using the local emergency generator in the plant and the last scenario is from both TNB feeders. Table 1 below shows the four scenarios of power supply to UTP:

Table 1: Four Scenarios for Power Supply to UTP

Scenario	TNB Output	GTG Output from GDC Plant	Internal Consumption at GDC Plant	UTP (Customer)
1	No Supply	Have Supply	From GTG Output	From GTG Output
2	Have Supply	Have Supply	From GTG Output	From GTG Output, Top Up by TNB
3	No Supply	No Supply	No Supply, Using local emergency generator	No Supply, Using local emergency generator
4	Have Supply	No Supply	From TNB	From TNB

For this study, the third (3^{rd}) scenario will not be analyzed. There will only be three (3) scenarios to be analyzed that are when supply is coming from TNB only, supply is coming from GTG output of GDC plant only and supply is coming from both TNB and GTG output.

CHAPTER 4

RESULT AND DISCUSSION

4.1 First Scenario; Power Supply from GDC Plant GTGs Only

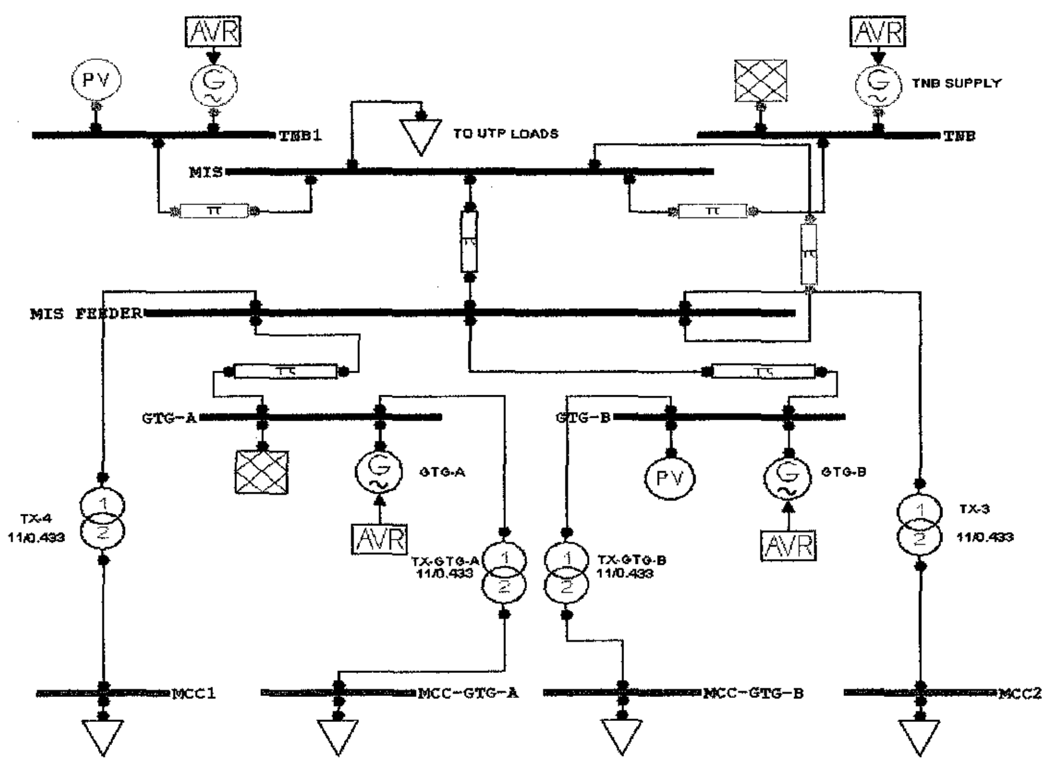

Figure 6: System Modeling for First Scenario; Power Supply from GDC Plant GTGs Only

Figure 6 shows the modeling of GDC plant electrical system when supply is coming from both of the generators only. This is the normal scenario. Model colored in yellow/orange color indicated they are not connected. Power supplies from the generators are used to cater the demand of internal GDC plant loads and demand from customer's loads.

4.1.1 Load Flow Static Report

Table 2 below shows the load flow report when the plant is operating in normal condition which is the supplies is from the two generators. It shows that the two generators are reliable to cater all the internal loads of the plant as well as the customer's loads. But further increment in customer's loads will require the plant to expand their system. Negative active power indicates power consumption while positive means power generated.

Table 2: Load Flow Static Report for First Scenario; Power Supply from GDC GTGs Only

Bus	Voltage (kV)	Active Power (MW)
GTG-A	10.8660	2.8992
GTG-B	10.8660	4.2000
MCC-GTG-A	0.4020	0.1500
MCC-GTG-B	0.4020	0.1500
MCC1	0.4020	-0.4990
MCC2	0.4020	-0.3990
MIS	10.8660	-5.9000
MIS FEEDER	10.8660	0.0000
TNB	0.0000	0.0000
TNB-1	0.0000	0.0000

4.1.2 *Network Visualization of Line Flows*

Figure 7 below shows the network visualization of the line flows. For this scenario, it can be seen that Generator B is producing more than Generator A just enough for the loads. Most of the power is supplied to UTP loads.

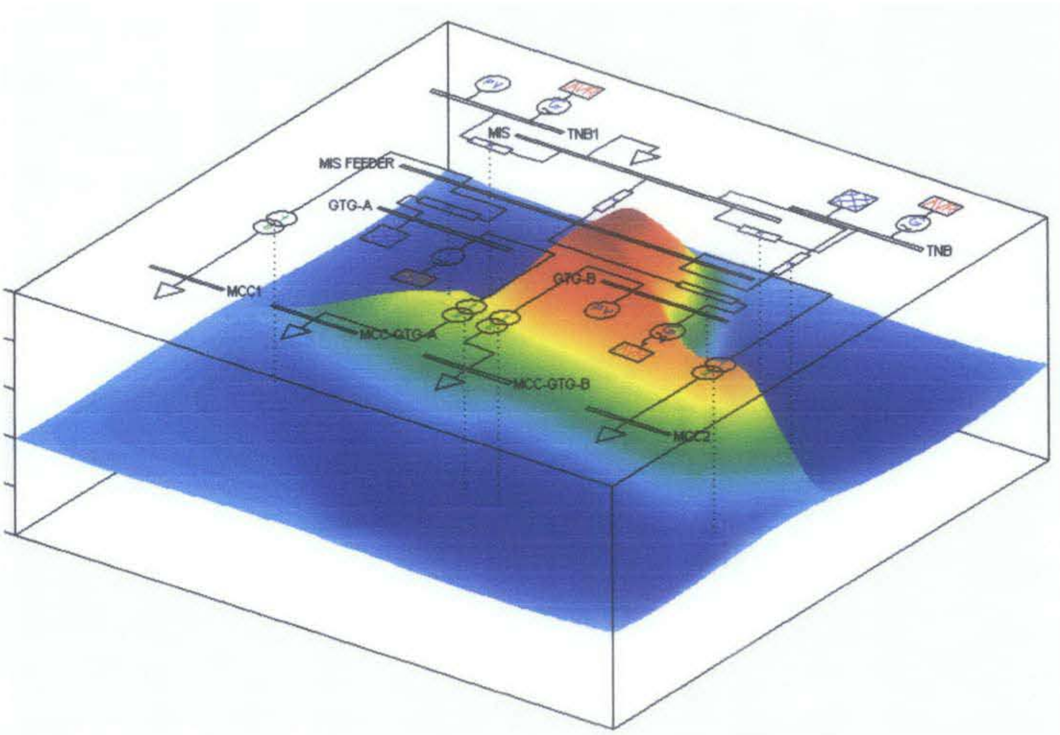

Figure 7: Network Visualization of Line Flows for First Scenario; Supply from Both GDC Plant GTGs

4.2 Second Scenario; Power Supply from GDC Plant GTG and Top up by TNB

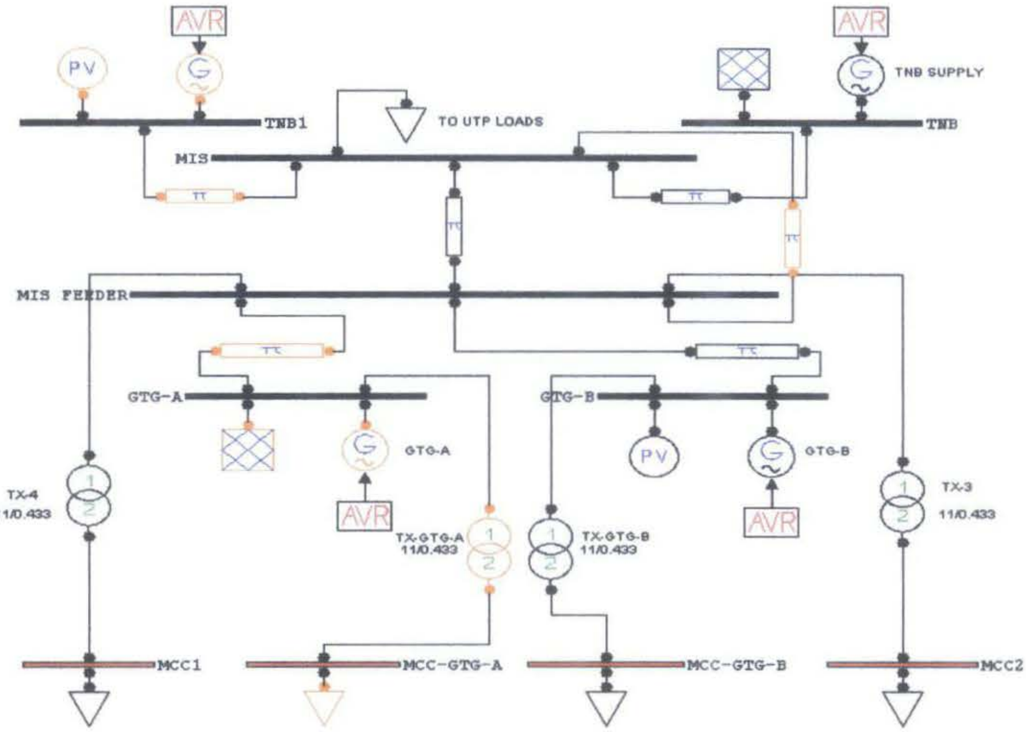

Figure 8: System Modeling for Second Scenario; Power Supply from GDC Plant GTG and Top up by TNB

Figure 8 shows the modeling of GDC plant electrical system when supply is coming from one of the plant GTG and top up by TNB supply. Model colored in yellow/orange color indicated they are not connected. This situation normally happens when one of the plant's generators is on maintenance or is at fault.

4.2.1 Load Flow Static Report

Table 3 below shows that if one of the plant's generators is not working, one of the TNB supply can be imported to cater for the customer's demand. Therefore, it is wise to always put TNB supply to be on standby mode in case one of the generators is at fault or on maintenance. Negative active power indicates power consumption while positive means power generated.

Table 3: Load Flow Static Report for Second Scenario; Power Supply from GDC GTG and TNB

Bus	Voltage (kV)	Active Power (MW)
GTG-A	0.0000	0.0000
GTG-B	10.8660	4.2000
MCC-GTG-A	0.0000	-0.1500
MCC-GTG-B	0.4020	-0.1500
MCC1	0.4020	-0.4990
MCC2	0.4020	-0.3990
MIS	10.8660	-5.9000
MIS FEEDER	10.8660	0.0000
TNB	10.8660	2.7492
TNB-1	0.0000	0.0000

4.2.2 Network Visualization of Line Flows

Figure 9 below shows the network visualization of the line flows. For this scenario, it can be seen that Generator B is producing at its maximum to cater for the internal loads and UTP loads. And TNB is used to cater the rest of UTP loads.

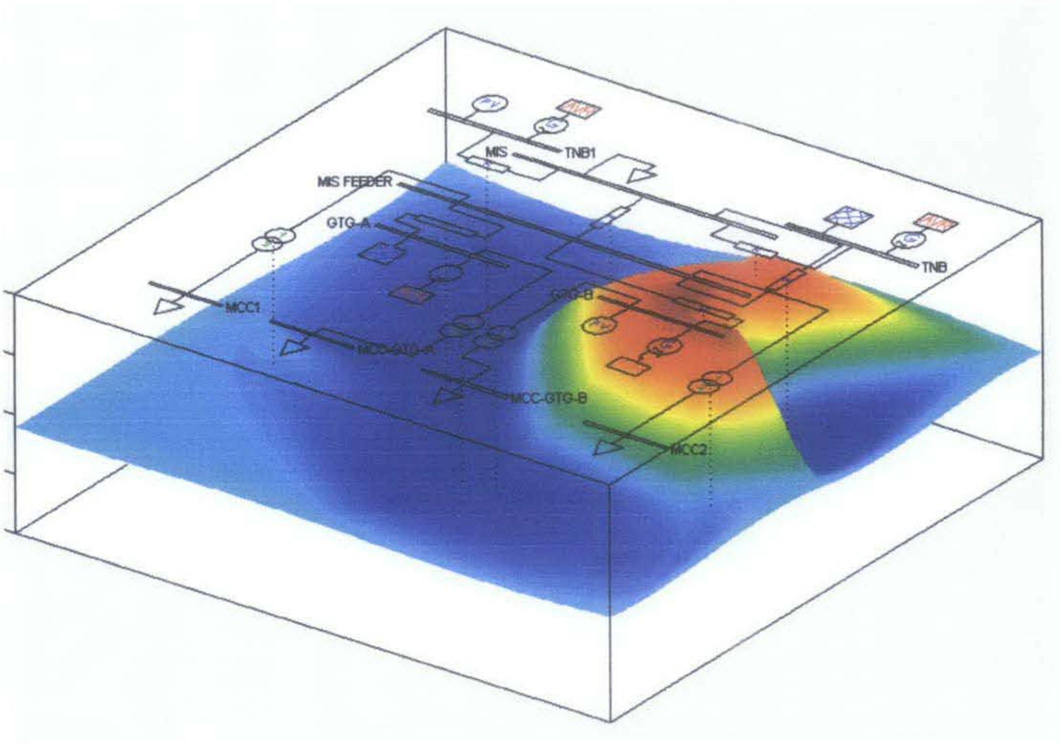

Figure 9: Network Visualization of Line Flows for Second Scenario; Supply from One GDC GTG and One TNB

4.3 Third Scenario; Power Supply from TNB Only

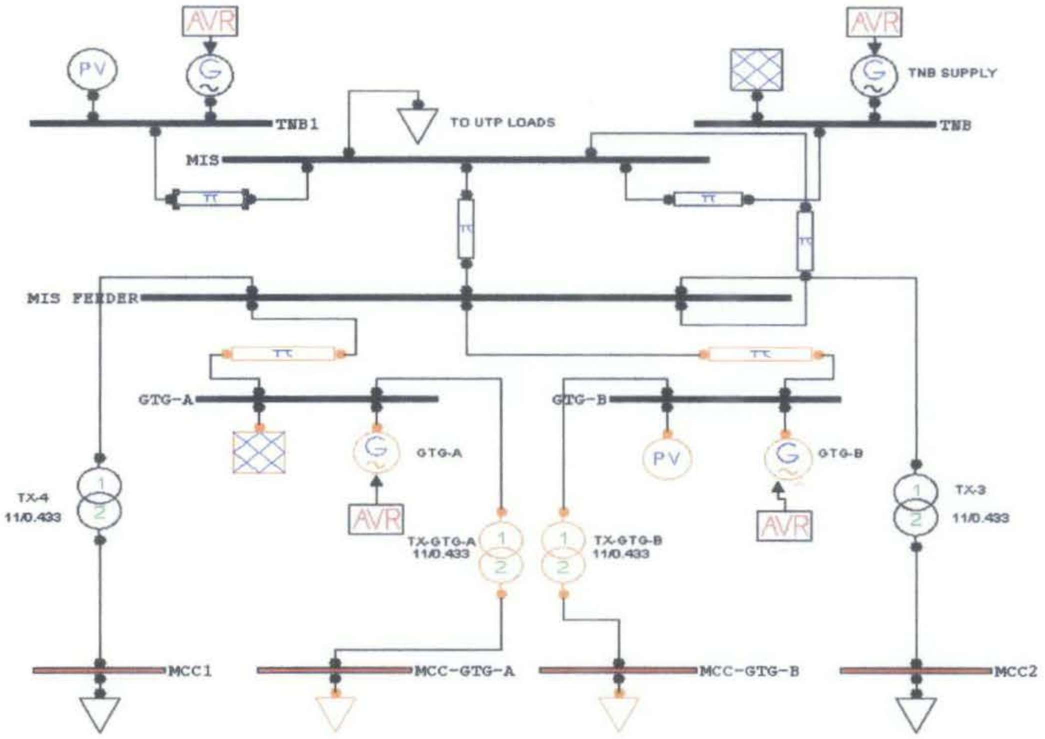

Figure 10: System Modeling for Third Scenario; Power Supply from TNB Only

Figure 10 shows the modeling of GDC plant electrical system when supply is coming from TNB only. Model colored in yellow/orange color indicated they are not connected. Power supply from TNB is used to cater the demand of internal GDC plant loads and demand from customer's loads.

4.2.1 Load Flow Static Report

Table 4 below shows that if both of the plant's generators are not working, both of the TNB supply can be imported to cater for the customer's demand. Negative active power indicates power consumption while positive means power generated.

Table 4: Load Flow Static Report for Third Scenario; Power Supply from TNB Only

Bus	Voltage (kV)	Active Power (MW)
GTG-A	0.0000	0.0000
GTG-B	0.0000	0.0000
MCC-GTG-A	0.0000	0.0000
MCC-GTG-B	0.0000	0.0000
MCC1	0.4020	-0.4990
MCC2	0.4020	-0.3990
MIS	10.8660	-5.9000
MIS FEEDER	10.8660	0.0000
TNB	10.8660	2.3482
TNB-1	10.8660	4.4510

4.2.2 Network Visualization of Line Flows

Figure 11 below shows the network visualization of the line flows. For this scenario, it can be seen that both of plant's generators are not producing any power. Supplies from TNB are used to cater the internal loads and UTP loads as well.

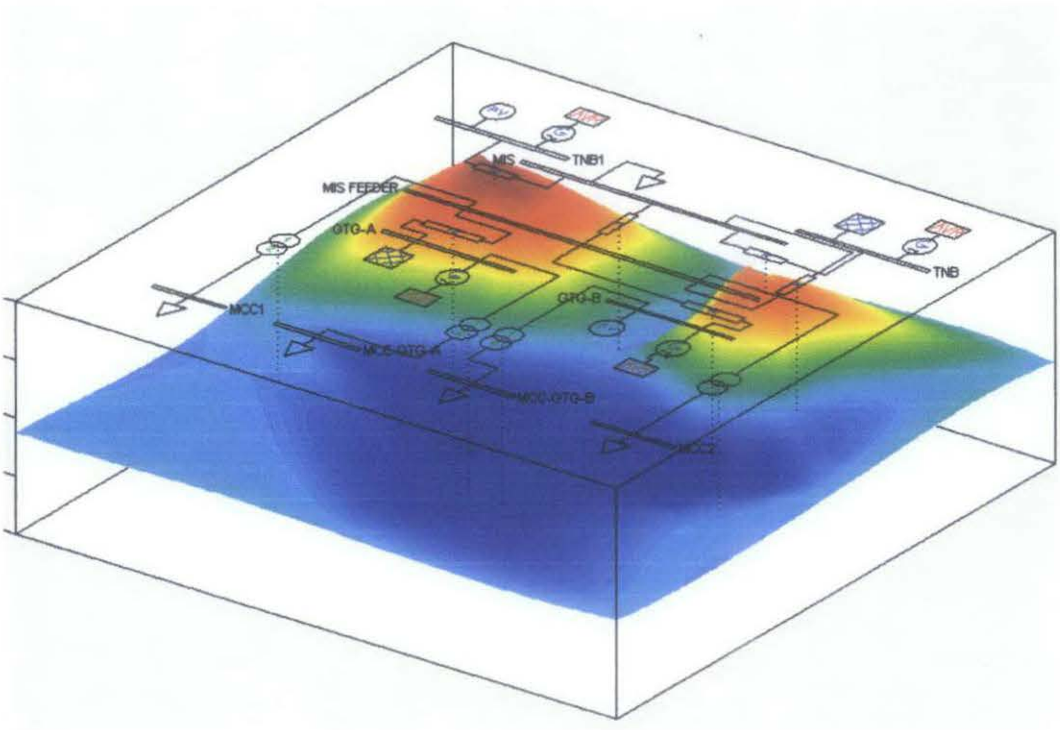

Figure 11: Network Visualization of Line Flows for Third Scenario; Supply from TNB Only

4.4 Discussion on Overall System

Voltage drops of all the buses are well within the limit of 5% to 10%. For busbar rated 11kV, it is measured at 10.866kV which is 1.21% of voltage drop. For busbar of rated 415V, it is measured 402V which is 3.17% of voltage drop. The line losses are considered small which is 0.4kW for each line and the no loss at the transformers. Lastly the power generated is enough to cater all the loads for all scenarios.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Referring to the objective, the project has been completed in the time frame given. Modeling and simulation of the electrical power system of Universiti Teknologi PETRONAS Gas District Cooling Plant has been done using the suitable software. The system has been proven to be reliable and efficient using the result of the load flow study. The generators are able to cater all the loads, internal as well as customer's loads. Voltage drops over the transformers and lines are found to be insignificant and well within the limit of 5% and -10%. The selected software which is MatLab with Power System Analysis Toolbox has been utilized to get not only the static report but also to come out with the 3D network visualization of the line flows. This visualization is important as well as it can illustrate the distribution of the supply throughout the network.

5.2 Recommendation

There are many rooms for improvement in this project. Different software may be used to do the modeling and simulation such as:

- ERACS 3.5.0,
- SKM Power Tools,
- Power System Simulator/ Advance Distribution Engineering Productivity Tool (PSS/ADEPT),

- Electrical Power System Design and Simulation (EDSA) and etc.

When other software is being used, different kind of studies can also be done after load flow study. Studies that can be done are:

- Protection Coordination Study,
- Arc Flash and Fault Analysis,
- Transient Stability Study,
- Harmonic Study and many more

Other ways to improve this project is also by expanding the model to study the system when the electricity generation is added to 20MW to cater the increasing demand from UTP.

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APPENDICES

Appendix 1: Gantt Chart of FYP 1

		No. of weeks																
No.	Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17-26
1	Preliminary Research Work: GE Fanuc Seminar										MID SEMESTER BREAK							
2	Plant Visit: Gas District Cooling, UTP																	
3	Submission of preliminary report																	
4	Study of FIX software manual																	
5	Submission of progress report																	
6	Install iPower Option for iFIX 5.0																	
7	Study and explore iPower Option for iFIX 5.0																	
8	Mid-term Seminar																	
9	Research on alternative for Load Flow Analysis																	
10	Submission of interim draft report																	
11	Research on ERACS																	
12	Submission of interim report																	
13	Oral presentations																	
14	Modelling and Simulation on ERACS - existing system																	
15	Modelling and Simulation on ERACS - future expansion																	
16	Analyzing load flow study																	

Key Milestone

Activities Completed

FYP 2 Activities

Appendix 2: Gantt Chart of FYP2

No.	Activities	No. of weeks															
		20-26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
1	Modeling of the existing GDC electrical system	■															
2	Analyzing system in both operating conditions	■	■	■	■												
3	Submission of Progress Report 1					●											
4	Searching for alternative software to be used					■	■										
5	Modeling of the GDC electrical system based on 3 scenarios.						■	■	■	MID SEMESTER BREAK	■	■	■	■			
6	Submission of Progress Report 2										●						
7	Analyze result based on load flow study										■	■	■	■	■		
8	Poster Exhibition												●				
9	Submission of Dissertation (soft bound)														●		
10	Oral Presentation															●	
11	Submission of Dissertation (hard bound)																●

● Key Milestone

■ Activities Schedule

Appendix 3: Sample of Gauss Seidel Calculations

A linear system shown as $Ax = b$ is given by

$$A = \begin{bmatrix} 2 & 3 \\ 5 & 7 \end{bmatrix}, \quad b = \begin{bmatrix} 11 \\ 13 \end{bmatrix} \text{ and } \quad x^{(0)} = \begin{bmatrix} 1.1 \\ 2.3 \end{bmatrix}$$

We want to use the equation $x^{(k)} = Tx^{(k-1)} + C$. Now we must find D^{-1} the inverse of the diagonal values of the matrix only and the LU decomposition of the matrix A.

We will use $A = D - L - U$ to help solve this system.

$$D = \begin{bmatrix} 2 & 0 \\ 0 & 7 \end{bmatrix}, \quad L = \begin{bmatrix} 0 & 0 \\ -5 & 0 \end{bmatrix} \text{ and } \quad U = \begin{bmatrix} 0 & -3 \\ 0 & 0 \end{bmatrix}$$

To find T we use the equation $T = (D - L)^{-1}U$.

$$T = \left(\begin{bmatrix} 2 & 0 \\ 0 & 7 \end{bmatrix} - \begin{bmatrix} 0 & 0 \\ -5 & 0 \end{bmatrix} \right)^{-1} \times \begin{bmatrix} 0 & -3 \\ 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & -1.5 \\ 0 & 1.071 \end{bmatrix}.$$

Now we have found T and we need to find C using the equation $C = (D - L)^{-1}b$.

$$C = \left(\begin{bmatrix} 2 & 0 \\ 0 & 7 \end{bmatrix} - \begin{bmatrix} 0 & 0 \\ -5 & 0 \end{bmatrix} \right)^{-1} \times \begin{bmatrix} 11 \\ 13 \end{bmatrix} = \begin{bmatrix} 5.5 \\ -2.07 \end{bmatrix}$$

Now we have T and C and we can use them iteratively X matrices. So, now you will have $x^{(1)} = Tx^{(0)} + C$.

$$x^{(1)} = \begin{bmatrix} 0 & -1.5 \\ 0 & 1.071 \end{bmatrix} \times \begin{bmatrix} 1.1 \\ 2.3 \end{bmatrix} + \begin{bmatrix} 5.5 \\ -2.07 \end{bmatrix} = \begin{bmatrix} 2.05 \\ 0.392 \end{bmatrix}$$

And now we can find $x^{(2)}$.

$$x^{(2)} = \begin{bmatrix} 0 & -1.5 \\ 0 & 1.071 \end{bmatrix} \times \begin{bmatrix} 2.05 \\ 0.392 \end{bmatrix} + \begin{bmatrix} 5.5 \\ -2.07 \end{bmatrix} = \begin{bmatrix} 4.91 \\ -1.65 \end{bmatrix}.$$

Now you can test for convergence to see if you have found a set of possible solutions.

Appendix 4: Sample of Newton Raphson Calculations

The bus admittance matrix can be obtained as:

$$Y = \begin{array}{c} 1 \\ 2 \\ 3 \end{array}\overset{\begin{array}{ccc} 1 & 2 & 3 \end{array}}{\begin{bmatrix} -j15 & j10 & j5 \\ j10 & -j15 & j5 \\ j5 & j5 & -j10 \end{bmatrix}} = j \begin{array}{c} 1 \\ 2 \\ 3 \end{array}\overset{\begin{array}{ccc} 1 & 2 & 3 \end{array}}{\begin{bmatrix} -15 & 10 & 5 \\ 10 & -15 & 5 \\ 5 & 5 & -10 \end{bmatrix}}$$

$$|Y| = \begin{array}{c} 1 \\ 2 \\ 3 \end{array}\overset{\begin{array}{ccc} 1 & 2 & 3 \end{array}}{\begin{bmatrix} 15 & 10 & 5 \\ 10 & 15 & 5 \\ 5 & 5 & 10 \end{bmatrix}} \quad \text{and} \quad \theta = \begin{array}{c} 1 \\ 2 \\ 3 \end{array}\overset{\begin{array}{ccc} 1 & 2 & 3 \end{array}}{\begin{bmatrix} -90^0 & 90^0 & 90^0 \\ 90^0 & -90^0 & 90^0 \\ 90^0 & 90^0 & -90^0 \end{bmatrix}}$$

This gives,

In this problem,

$$PI_2 = 1.8184$$
$$PI_3 = -1.2517$$
$$QI_3 = -1.2574$$

And unknown quantities = $\begin{bmatrix} \delta_2 \\ \delta_3 \\ |V_3| \end{bmatrix}$

With flat start, $\begin{array}{l} V_1 = 1.0\angle 0^0 \\ V_2 = 1.1\angle 0^0 \\ V_3 = 1.0\angle 0^0 \end{array}$

We know that,

$$P_i = |V_i|^2 G_{ii} + \sum_{\substack{n=1 \\ n \neq i}}^{N} |V_i||V_n||Y_{in}| \cos(\theta_{in} + \delta_n - \delta_i)$$

$$Q_i = -|V_i|^2 B_{ii} - \sum_{\substack{n=1 \\ n \neq i}}^{N} |V_i||V_n||Y_{in}| \sin(\theta_{in} + \delta_n - \delta_i)$$

Substituting the values of bus admittance parameters, expression for P_2, P_3 and Q_3 are obtained as below;

$$P_2 = |V_2|^2 G_{22} + |V_2||V_1||Y_{21}| \cos(\theta_{21} + \delta_1 - \delta_2) + |V_2||V_3||Y_{23}| \cos(\theta_{23} + \delta_3 - \delta_2)$$

$$= 0 + 10|V_2||V_1| \cos(90 + \delta_1 - \delta_2) + 5|V_2||V_3| \cos(90 + \delta_3 - \delta_2)$$

$$= -10|V_2||V_1| \sin(\delta_1 - \delta_2) - 5|V_2||V_3| \sin(\delta_3 - \delta_2)$$

Similarly,

$$P_3 = -5\ |V_3||V_1| \sin(\delta_1 - \delta_3) - 5\ |V_3||V_2| \sin(\delta_2 - \delta_3)$$

Likewise,

$$Q_3 = -|V_3|^2 B_{33} - |V_3||V_1||Y_{31}| \sin(90 + \delta_1 - \delta_3) - |V_3||V_2||Y_{32}| \sin(90 + \delta_2 - \delta_3)$$

$$= 10|V_3|^2 - 5|V_3||V_1| \cos(\delta_1 - \delta_3) - 5|V_3||V_2| \cos(\delta_2 - \delta_3)$$

To check whether bus 2 will remain as P-V bus, Q_2 need to be calculated,

$$Q_2 = 15|V_2|^2 - 10\ |V_2||V_1| \cos(\delta_1 - \delta_2) - 5\ |V_2||V_3| \cos(\delta_3 - \delta_2)$$

$$= (15 \times 1.1 \times 1.1) - (10 \times 1.1 \times 1 \times 1) - (5 \times 1.1 \times 1 \times 1) = 1.65$$

This lies within Q limits. Thus bus 2 remains as P-V bus. Since $\delta_1 = \delta_2 = \delta_3 = 0$

We get $P_2, P_3 = 0$

$$Q_3 = (10 \times 1 \times 1) - (5 \times 1 \times 1) - (5 \times 1 \times 1.1) = -0.5$$

$$\Delta P_2 = PI_2 - P_2 = 1.8184 - 0 = 1.8184$$
$$\Delta P_3 = PI_3 - P_3 = -1.2517 - 0 = -1.2517$$
$$\Delta Q_3 = QI_3 - Q_3 = -1.2574 + 0.5 = -0.7274$$

$$\begin{array}{c} \\ P_2 \\ P_3 \\ Q_3 \end{array} \begin{array}{c} \begin{array}{ccc} \delta_2 & \delta_3 & |V_3| \end{array} \\ \left[\begin{array}{cc|c} H_{22} & H_{23} & N_{23} \\ H_{32} & H_{33} & N_{33} \\ \hline M_{32} & M_{33} & L_{33} \end{array} \right] \end{array} \left[\begin{array}{c} \Delta\delta_2 \\ \Delta\delta_3 \\ \dfrac{\Delta|V_3|}{|V_3|} \end{array} \right] = \left[\begin{array}{c} \Delta P_2 \\ \Delta P_3 \\ \Delta Q_3 \end{array} \right]$$

$H_{ii} = -Q_i - |V_i|^2 B_{ii}$ $\qquad H_{ij} = -|V_i||V_j||Y_{ij}| \cos(\delta_j - \delta_i)$

$N_{ii} = P_i;\ \ M_{ii} = P_i$ $\qquad N_{ij} = |V_i||V_j||Y_{ij}| \sin(\delta_j - \delta_i)$

$L_{ii} = Q_i - |V_i|^2 B_{ii}$ $\qquad M_{ij} = |V_i||V_j||Y_{ij}| \sin(\delta_j - \delta_i)$

$H_{22} = -Q_2 - |V_2|^2 B_{22} = -1.65 + (1.1 \times 1.1 \times 15) = 16.5$

$H_{33} = Q_3 \quad V_3|^2 B_{33} = 0.5 + 10 = 10.5$

$N_{33} = P_3 = 0; \qquad M_{33} = P_3 = 0$

$L_{33} - Q_3 - |V_3|^2 B_{33} - -0.5 + 10 - 9.5$

$H_{23} = - |V_2||V_3| \, |Y_{23}| \cos(\delta_3 - \delta_2) - -1.1x1x5x1 = -5.5$ and $H_{32} - -5.5$

$N_{23} = - |V_2||V_3| \, |Y_{23}| \sin(\delta_3 - \delta_2) = 0$

$M_{23} = |V_3||V_2| \, |Y_{32}| \sin(\delta_2 - \delta_3) = 0$

Thus $\begin{bmatrix} 16.5 & -5.5 & 0 \\ -5.5 & 10.5 & 0 \\ 0 & 0 & 9.5 \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \dfrac{\Delta|V_3|}{|V_3|} \end{bmatrix} = \begin{bmatrix} 1.8184 \\ -1.2517 \\ -0.7274 \end{bmatrix}$

Solving the above $\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \dfrac{\Delta|V_3|}{|V_3|} \end{bmatrix} = \begin{bmatrix} 0.08538 \\ -0.07449 \\ -0.07657 \end{bmatrix}$

Therefore

$$\delta_2^{(1)} = 0 + 0.08538 = 0.08538 \text{ rad.} = 4.89^0$$
$$\delta_3^{(1)} = 0 - 0.07449 = -0.07449 \text{ rad.} = -4.27^0$$
$$V_3^{(1)} = 1.0 - 0.07657 = 0.9234$$

Thus
$$V_1 = 1.0\angle 0^0$$
$$V_2 = 1.1\angle 4.89^0$$
$$V_3 = 0.9234 \angle -4.27^0$$

This completes the first iteration.

Second iteration:

$Q_2 - (15 \times 1.1 \times 1.1) - (10 \times 1.1 \times 1.0 \cos 4.89^0) - (5 \times 1.1 \times 0.9234 \cos 9.16^0)$
$= 2.1761$

This is within the limits. Bus 2 remains as P-V bus.

$P_2 = (10 \times 1.1 \times 1.0 \sin 4.89^0) + (5 \times 1.1 \times 0.9234 \sin 9.16^0) = 1.7462$

$P_3 = -(5 \times 0.9234 \times 1.0 \sin 4.27^0) - (5 \times 0.9234 \times 1.1 \sin 9.16^0) = -1.1523$

$Q_3 = 10 \times 0.9234 \times 0.9234 - (5 \times 0.9234 \times 1.0 \cos 4.27^0) - (5 \times 0.9234 \times 1.1 \cos 9.16^0)$

$= -1.0914$

$\Delta P_2 = 1.8184 - 1.7462 = 0.0722$

$\Delta P_3 = -1.2517 + 1.1523 = -0.0994$

$\Delta Q_3 = -1.2574 + 1.0914 = -0.1660$

$H_{22} = -2.1761 + (1.1 \times 1.1 \times 15) = 15.9739$

$H_{33} = 1.0914 + (0.9234 \times 0.9234 \times 10) = 9.6181$

$N_{33} = -1.1523; \quad M_{33} = -1.1523$

$L_{33} = -1.0914 + (0.9234^2 \times 10) = 7.4353$

$H_{23} = -1.1 \times 0.9234 \times 5 \cos 9.16^0 = -5.0139$

$H_{32} = -5.0139$

$N_{23} = 1.1 \times 0.9234 \times 5 \sin 9.16^0 = 0.8085$

$M_{32} = 0.8085$

The linear equations are

$$\begin{bmatrix} 15.9739 & -5.0139 & 0.8085 \\ -5.0139 & 9.6181 & -1.1523 \\ 0.8085 & -1.1523 & 7.4353 \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \dfrac{\Delta|V_3|}{|V_3|} \end{bmatrix} = \begin{bmatrix} 0.0722 \\ -0.0994 \\ -0.1660 \end{bmatrix}$$

Its solution is

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \dfrac{\Delta|V_3|}{|V_3|} \end{bmatrix} = \frac{1}{937.2772} \begin{bmatrix} 70.1857 & 36.3482 & -1.9987 \\ 36.3482 & 118.1171 & 14.3530 \\ -1.9987 & 14.3530 & 128.4994 \end{bmatrix} \begin{bmatrix} 0.0722 \\ -0.0994 \\ -0.1660 \end{bmatrix}$$

$$= \begin{bmatrix} 0.001906 \\ -0.01227 \\ -0.02443 \end{bmatrix}$$

$\Delta|V_3| = -0.9234 \times 0.02443 = -0.02256$

$\delta_2^{(2)} = 0.08538 + 0.001906 = 0.08727 \text{ rad.} = 5.00^0$

$\delta_3^{(2)} = -0.07449 - 0.01227 = -0.08676 \text{ rad.} = -4.97^0$

$|V_3|^{(2)} = 0.9232 - 0.02256 = 0.9006$

Thus at the end of second iteration

$$V_1 = 1.0\angle 0^0$$
$$V_2 = 1.1\angle 5.00^0$$
$$V_3 = 0.9006\angle -4.97^0$$

Continuing in this manner the final solution can be obtained as

$$V_1 = 1.0\angle 0^0$$
$$V_2 = 1.1\angle 5^0$$
$$V_3 = 0.9\angle -5^0$$

Once we know the final bus voltages, if necessary, line flows, transmission loss and the slack bus power can be calculated following similar procedure adopted in the case of Gauss – Seidel method.

Appendix 5: Sample of Fast Decoupled Calculations

Given,

$$\begin{bmatrix} 16.5 & -5.5 \\ -5.5 & 10.5 \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \end{bmatrix} = \begin{bmatrix} 1.8184 \\ -1.2517 \end{bmatrix}$$

Solving this $\Delta\delta_2 = 0.08538$

$\Delta\delta_3 = -0.07449$

Therefore $\delta_2^{(1)} = 0 + 0.08538 = 0.08538 \text{ rad.} = 4.89^0$

$\delta_3^{(1)} = 0 - 0.07449 = -0.07449 \text{ rad.} = -4.27^0$

Thus the bus voltages are

$V_1 = 1.0 \angle 0^0$

$V_2 = 1.1 \angle 4.89^0$

$V_3 = 1.0 \angle -4.27^0$

Reactive power at bus 3 is calculated from

$$Q_3 = 10|V_3|^2 - 5\,|V_3||V_1|\cos(\delta_1 - \delta_3) - 5\,|V_3||V_2|\cos(\delta_2 - \delta_3)$$
$$= 10 \times 1.0^2 - 5 \times 1.0 \times 1.0 \times \cos(0 + 4.27) - 5 \times 1.0 \times 1.1 \times \cos(4.89 + 4.27)$$
$$= -0.4160$$

$$\Delta Q_3 = QI_3 - Q_3 = -1.2574 + 0.4160 = -0.8414$$

$$L_{33} = Q_3 - |V_3|^2 B_{33} = -0.4160 + (1.0^2 \times 10) = 9.584$$

Decoupled equation with change in voltage magnitude as variable is

$$9.584 \frac{\Delta|V_3|}{|V_3|} = -0.8414$$

i.e. $\Delta|V_3| = -0.8414 \times 1.0 / 9.584 = -0.08779$

Therefore $|V_3|^{(1)} = 1.0 - 0.08779 = 0.9122$

At the end of first iteration, bus voltages are

$V_1 = 1.0 \angle 0^0$

$V_2 = 1.1 \angle 4.89^0$

$V_3 = 0.9122 \angle -4.27^0$

Second iteration:

$$Q_2 = 15|V_2|^2 - 10\ |V_2||V_1|\ \cos(\delta_1 - \delta_2) - 5\ |V_2||V_3|\cos(\delta_3 - \delta_2)$$
$$= 15 \text{ x } 1.1^2\ -\ 10 \text{ x } 1.1 \text{ x } \cos(-4.89)\ -\ 5 \text{ x } 1.1 \text{ x } 0.9122 \text{ x } \sin(-4.27 - 4.89)$$
$$= 2.2369$$

This is within the limits. Bus 2 remains as P-V bus.

$$P_2 = -10|V_2||V_1|\ \sin(\delta_1 - \delta_2) - 5|V_2||V_3|\ \sin(\delta_3 - \delta_2)$$
$$= -10 \text{ x } 1.1 \text{ x } 1.0 \text{ x } \sin(-4.89)\ -\ 5 \text{ x } 1.1 \text{ x } 0.9122 \text{ x } \sin(-4.27 - 4.89) = 1.7364$$

$$P_3 = -5\ |V_3||V_1|\sin(\delta_1 - \delta_3) - 5\ |V_3||V_2|\ \sin(\delta_2 - \delta_3)$$
$$= -5 \text{ x } 0.9122 \text{ x } 1.0 \text{ x } \sin(4.27)\ -\ 5 \text{ x } 0.9122 \text{ x } 1.1 \text{ x } \sin(4.89 + 4.27) = -1.1383$$

$$\Delta P_2 = 1.8184 - 1.7364 = 0.082$$
$$\Delta P_3 = -1.2517 + 1.1383 = -0.1134$$

Diagonal elements of H matrix requires corresponding reactive powers.

$$Q_3 = 10|V_3|^2 - 5\ |V_3||V_1|\cos(\delta_1 - \delta_3) - 5\ |V_3||V_2|\cos(\delta_2 - \delta_3)$$
$$= 10 \text{ x } 0.9122^2\ -\ 5 \text{ x } 0.9122 \text{ x } 1 \text{ x } \cos(4.27)\ -\ 5 \text{ x } 0.9122 \text{ x } 1.1 \text{ x } \cos(9.16)$$
$$= -1.1804$$

$$H_{22} = -Q_2 - |V_2|^2 B_{22} = -2.2369\ -\ 1.1^2(-15) = 15.9131$$
$$H_{33} = -Q_3 - |V_3|^2 B_{33} = 1.1804\ -\ 0.9122^2\ (-10) = 9.5015$$
$$H_{23} = -\ |V_2||V_3|\ |Y_{23}|\cos(\delta_3 - \delta_2) = -1.1 \text{ x } 0.9122 \text{ x } 5 \text{ x } \cos(-9.16) = -4.9531$$
$$H_{32} = H_{23} = -4.9531$$

Decoupled equations with change in phase angles as variables are

$$\begin{vmatrix} 15.9131 & -4.9531 \\ -4.9531 & 9.5015 \end{vmatrix} \begin{vmatrix} \Delta\delta_2 \\ \Delta\delta_3 \end{vmatrix} = \begin{vmatrix} 0.082 \\ -0.1134 \end{vmatrix}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \end{bmatrix} = \frac{1}{126.6651} \begin{bmatrix} 9.5015 & 4.9531 \\ 4.9531 & 15.9131 \end{bmatrix} \begin{bmatrix} 0.082 \\ -0.1134 \end{bmatrix} = \begin{bmatrix} 0.001717 \\ -0.01104 \end{bmatrix}$$

$$\delta_2^{(2)} = 0.08538 + 0.001717 = 0.08710 \text{ rad.} = 4.99^0$$
$$\delta_3^{(2)} = -0.07449 - 0.01104 = -0.08553 \text{ rad.} = -4.90^0$$

Therefore

$$V_1 = 1.0\angle 0^0$$
$$V_2 = 1.1\angle 4.99^0$$
$$V_3 = 0.9122\angle -4.90^0$$

Reactive power at bus 3 is calculated as

$$\begin{aligned} Q_3 &= 10|V_3|^2 - 5\,|V_3|\,|V_1|\cos(\delta_1 - \delta_3) - 5\,|V_3|\,|V_2|\cos(\delta_2 - \delta_3) \\ &= 10 \times 0.9122^2 - 5 \times 0.9122 \times 1.0 \times \cos(4.9) - 5 \times 0.9122 \times 1.1 \times \cos(9.89) \\ &= -1.1658 \end{aligned}$$

$$\Delta Q_3 = -1.2574 + 1.1658 = -0.0916$$

$$L_{33} = Q_3 - |V_3|^2 B_{33} = -1.1658 - 0.9122^2\,(-10) = 7.1553$$

Decoupled equation with change in voltage magnitude as variable is

$$7.1553\ \frac{\Delta|V_3|}{|V_3|} = -0.0916$$

$$\frac{\Delta|V_3|}{|V_3|} = -\frac{0.0916}{7.1553} = -0.01280$$

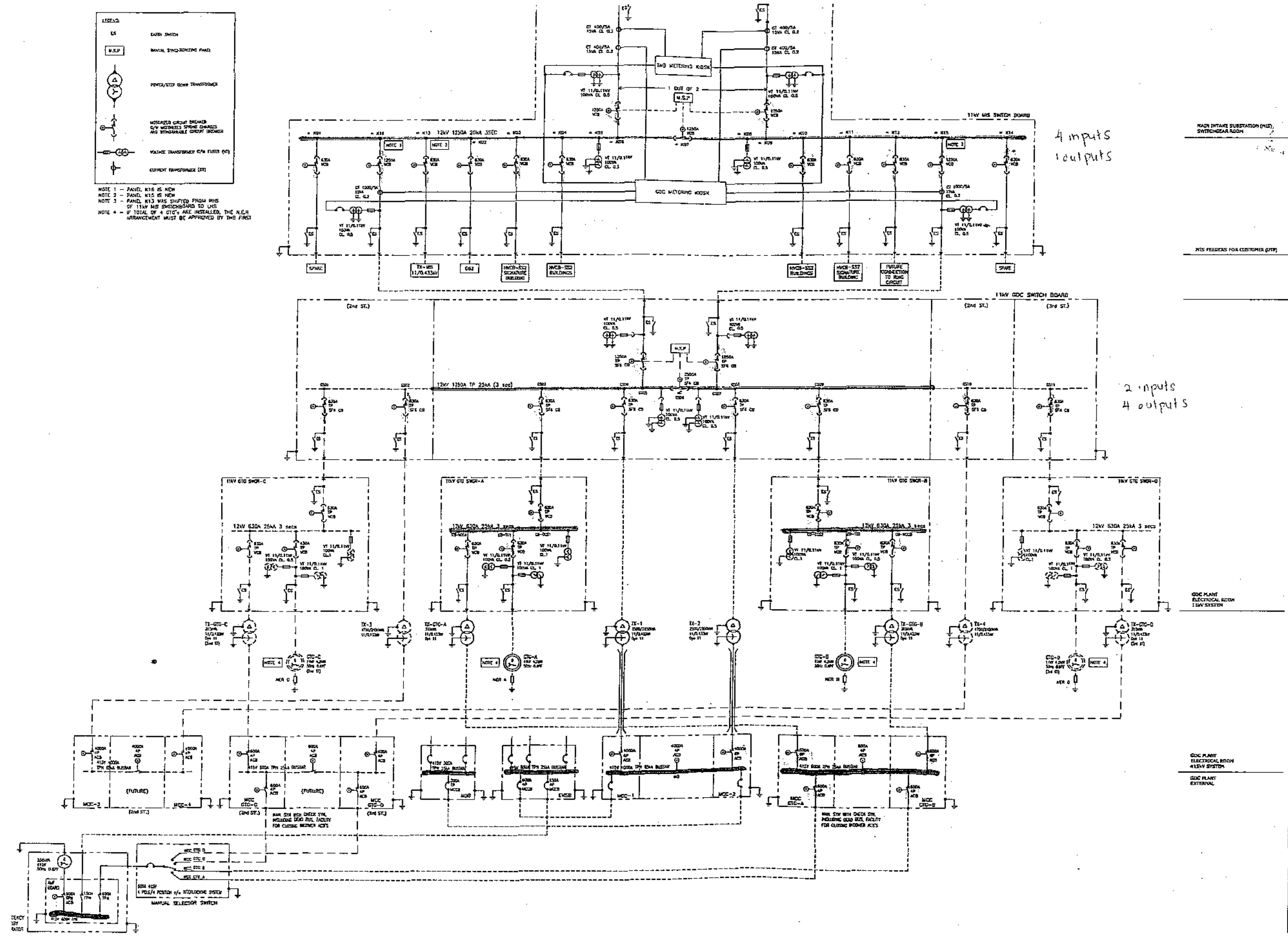
$$\Delta|V_3| = -\ 0.01280 \times 0.9122 = -0.01167$$

$$|V_3|^{(2)} = 0.9122 - 0.01167 = 0.9005$$

Thus at the end of second iteration, bus voltages are

$$V_1 = 1.0\angle 0^0$$
$$V_2 = 1.1\angle 4.99^0$$
$$V_3 = 0.9005\angle -4.90^0$$

Appendix 6: Overall Single Line Diagram of Gas District Cooling Plant, UTP



UNIVERSITI TEKNOLOGI PETRONAS

CADANGAN MEMBINA SEBUAH LOJI PENJANAAN DAN SISTEM PENDINGINAN UNGKUNGAN UNTUK UNIVERSITI TEKNOLOGI PETRONAS DIATAS LOT-LOT 13157 MUKIM BOTA DAN TANAH KERAJAAN PLOT 1 MUKIM BOTA SERTA PLOT 2 MUKIM LAYANG - LAYANG DAERAH PERAK TENGAH DI BANDAR SRI ISKANDAR PERAK DARUL RIDZUAN

Building Owner :

GAS DISTRICT COOLING (M) SDN. BHD.
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EPCC Contractor :

SHINRYO (MALAYSIA) SDN. BHD.
(95463-A)
Menara TA One (Letterbox 22-77)
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22, Jalan P. Ramlee
50250 Kuala Lumpur
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Fax : 03-2166 2214

REFERENCE DRAWING NO.

Rev.	Description	Drawn	Date
A	AS BUILT (REDRAWN)	AZIZI	11.06.03
3	REVISED AS PER COMMENTS	KAN	05.10.01
2	REVISED AS PER COMMENTS	KAN	02.10.01
1	ISSUED FOR APPROVAL	KAN	25.09.01
0	ISSUED FOR APPROVAL	KAN	31.07.01

[A] APPROVED
[B] APPROVED WITH COMMENTS
[C] REVIEWED
[D] REJECTED, REVISED AND RESUBMIT

APPROVAL OF THIS DOC. AND/OR DATA IS ONLY CONFORMANCE WITH DESIGN INTENT AND WITH THE INFORMATION CALLED FOR BY THE CONTRACT DOC. THIS APPROVAL SHALL NOT RELIEVE THE CONTRACTOR OF HIS CONTRACTUAL OBLIGATION AND SHALL NOT CONSTITUTE A BASIS FOR CHANGE ORDER

APPROVAL		Signature	Date
PMC	C & S		
	Mech		
	E & I		
GDC	C & S		
	Mech		
	E & I	[signature]	
PMC Project Manager			
GDC Project Manager		[signature]	

Project Title :

COGENERATION / DISTRICT COOLING PLANT PROJECT
UNIVERSITY TECHNOLOGY PETRONAS, TRONOH PERAK DARUL RIDZUAN
CIVIL / BUILDING WORKS, CHILLER PLANT AND COGENERATION PLANT

Drawing Title :

OVERALL SINGLE LINE DIAGRAM

AS BUILT

Scale : N.T.S		CodFile : ASMUTPEO20RA	
Drawn By : AZIZI		Approved By:	
Designed By : HAMZAH		Date : 11.06.03	
Drawing Number :		Revision	

Appendix 7: List of Loads in Gas District Cooling Plant, UTP

P-0131 A/B - CHILLED WATER PUMP (SAC)

ITEM	DESCRIPTION
KW	132KW
Pole	4
Volt.	415V
Amp	225.5A
Hz	50
Rpm	1485
Rating	S1
P.F.	0.86

P-0111 A/B - CHILLED WATER PUMP (TES TANK)

ITEM	DESCRIPTION
KW	75KW
Pole	4
Volt.	415V
Amp	126.3A
Hz	50
Rpm	1483
Rating	S1
P.F.	0.89

P-0112 A/B - CHILLED WATER PUMP (TES TANK)

ITEM	DESCRIPTION
KW	90KW
Pole	4
Volt.	415V
Amp	149
Hz	50
Rpm	1484
Rating	S1
P.F.	0.89

CHILLED WATER PUMP MOTOR FOR EC

P-0121A/B/C/D

ITEM	DESCRIPTION
KW	15KW
Pole	4
Volt.	415V
Amp	28.7
Hz	50
Rpm	1457
Rating	S1
P.F.	0.83

ELECTRIC CHILLER FAN 1 TO 4

EC 0121A/B/C/D

ITEM	DESCRIPTION
HP	3
Volts	415
Ph	3
Hz	50
Amp	6.1A

ELECTRIC CHILLER FAN 5 TO 16

EC 0121A/B/C/D

ITEM	DESCRIPTION
KW	4
Pole	415
Volt.	3
Amp	50
Hz	6.6A

P-0231A/B-COOLING WATER PUMP C/TOWER

ITEM	DESCRIPTION
KW	90KW
Pole	4
Volt.	400
Amp	158.5
Hz	50
Rpm	1484
Rating	S1
P.F.	0.89

CT 0231 A/B-F1/F2/F3/F4-C/TOWER FAN MOTOR

ITEM	DESCRIPTION
KW	11KW
Pole	4
Volt.	415
Amp	20.5
Hz	50
Rpm	1456
Rating	S1
P.F.	0.84

BACK UP LUBE OIL PUMP A/B

ITEM	DESCRIPTION
KW	0.08KW
HP	1.58 WD 18
Volt.	120VDC
Amp	13
Hz	50
Rpm	1750/1800
Cycle	DC
Class	F

LIQUID FUEL PUMP A/B

ITEM	DESCRIPTION
HP	7.5
Volt	460
Amp	10.6
Hz	60
Rpm	1775
PHASE	3 PHASE

AC STARTER MOTOR A/B

ITEM	DESCRIPTION
HP	SPLL
Volt	460
Amp	180
Hz	60
Rpm	0.44
PHASE	3 PHASE

AC PRE/POST LUBE OIL PUMP A/B

ITEM	DESCRIPTION
HP	2
Volt	415
Amp	2.8
Hz	50
Rpm	1440
PHASE	3 PHASE

ENCLOSURE FAN #1 A/B

ITEM	DESCRIPTION
HP	15
Volt	230,380,415
Amp	42,24,3,21
Hz	50
Rpm	1460
PHASE	3 PHASE

ENCLOSURE FAN #2 A/B

ITEM	DESCRIPTION
HP	15
Volt	230,380,415
Amp	42,24,3,21
Hz	50
Rpm	1460
PHASE	3 PHASE

LIQUID FUEL BOAST PUMP A/B

ITEM	DESCRIPTION
HP	1
Volt	415
Amp	1.6
Hz	50
Rpm	1423
PHASE	3 PHASE

GTG A-LUBE OIL COOLER A/B

ITEM	DESCRIPTION
HP	5
Volt	1
Amp	2
Hz	60
Rpm	1475
DUTY	CONT

P 0301 A/Z, 0303 A/B/Z - BOILED FEED WATER

ITEM	DESCRIPTION
KW	5.5
Pole	2
Volt.	415
Amp	10
Hz	50
Rpm	2908
Rating	S1

P 0331 A/B-DRAIN FILTER PUMP

ITEM	DESCRIPTION
KW	1.1
Pole	
Volt.	415
Amp	2.3
Hz	50
Rpm	2842
Rating	S1

BURNER MOTOR-AGB

ITEM	DESCRIPTION
KW	2.4
Pole	2
Volt.	415
Amp	6.5-7.6
Hz	50
Rpm	2645
Rating	S1

FD FAN MOTOR-AGB

ITEM	DESCRIPTION
KW	22
Pole	2
Volt.	415
Amp	11
Hz	50
Rpm	2920
Rating	S1

OIL PUMP-AGB

ITEM	DESCRIPTION
KW	0.37
Pole	6
Volt.	415
Amp	1.05-0.37
Hz	50
Rpm	1430

AIR HANDLING UNIT

AHU-0931

ITEM	DESCRIPTION
KW	7.5
HP	10
Volt.	415
Amp	16.2
Hz	50
Rpm	1450
PHASE	3 PH IND. MOTOR

AHU-0921

ITEM	DESCRIPTION
KW	3
HP	4
Volt.	415
Amp	
Hz	50
Rpm	1430
PHASE	3 PHASE

AHU-0911

ITEM	DESCRIPTION
KW	11
HP	15
Volt.	415
Amp	
Hz	50
Rpm	1455
PHASE	3 PHASE

P 1141 A/B-MAKE UP WATER (SOFTENER)

ITEM	DESCRIPTION
KW	1.1
Volt.	415
Amp	2.3
Hz	50
Rpm	2848
Rating	S1

P 1101-MAKE UP WATER PUMP (C/TOWER)

ITEM	DESCRIPTION
KW	4
Volt.	415
Amp	7.2
Hz	50
Rpm	2866
Rating	S1

HYDRO BOOSTER PUMP 1&2 - GUARD HSE

ITEM	DESCRIPTION
KW	0.75
Volt.	415
Amp	1.6
Hz	50
Rpm	2844
Rating	S1

P 1102A/B-MAKE UP WATER FOR (C/TOWER)

ITEM	DESCRIPTION
KW	7.5
Volt.	415
Amp	13.3
Hz	50
Rpm	2910
Rating	S1

P 0501A-AGB OIL SUPPLY PUMP

ITEM	DESCRIPTION
KW	0.55
Volt.	415
Amp	1.4
Hz	50
Rpm	1410
Rating	S1

P 0501Z-AGB OIL SUPPLY PUMP

ITEM	DESCRIPTION
KW	0.55
Volt.	415
Amp	1.4
Hz	50
Rpm	1410
Rating	S1

P 0502A/Z - GTG OIL SUPPLY PUMP

ITEM	DESCRIPTION
KW	1.5
Volt.	415
Amp	3.4
Hz	50
Rpm	1410
Rating	S1

P 0504A/Z - GTG OIL RETURN PUMP

ITEM	DESCRIPTION
KW	1.5
Volt.	415
Amp	3.4
Hz	50
Rpm	1402
Rating	S1

P 0503A/Z - AGB OIL RETURN PUMP

ITEM	DESCRIPTION
KW	0.55
Volt.	415
Amp	1.4
Hz	50
Rpm	1410
Rating	S1

HOSE REEL PUMP (DUTY PUMP)

ITEM	DESCRIPTION
KW	4
Volt.	415
Amp	9.7
Hz	50

SPRINKLER (STANDBY PUMP)

ITEM	DESCRIPTION
KW	16.5
RPM	3000

SPRINKLER (JOCKEY PUMP)

ITEM	DESCRIPTION
KW	2.2
Volt.	240
Amp	5.2
Hz	50

SPRINKLER (DUTY PUMP)

ITEM	DESCRIPTION
KW	15
Volt.	415
Amp	25.9
Hz	50

P 0431/2A,2B,2C,2Z -BOILER COMPOUND

ITEM	DESCRIPTION
KW	0.2
Volt.	415
Amp	0.67
Hz	50
Rpm	1435
Rating	CONT
Pole	4

P 0810 A/B-NEUTRALIZER BOILER DRAIN PUMP

ITEM	DESCRIPTION
KW	1.5KW/2HP
Volt.	230/240
Amp	1.72972973
Hz	50
Rpm	1400
Rating	S1
Pole	4

Appendix 8: Data of Loads Connected to Busbar MCC1, MCC2, MCC GTG A and MCC GTG

LOAD LIST FOR PLANT EQUIPMENT (1)

LOAD LIST FOR MCC-1

No.	Equipment Name	Volt (V)	Rated Capacity (kW)	Power Factor	Eff	kVA Rating (kVA)	MCCB (A)	Normal (A)	Start Up (A)	Start Up (sec)	Starting Method	Stage	Remarks
1	AC-0131A	415	44.00	1.00	1.00	44.00	100	10.5	–	–	P.S	1A	
2	CT-0231A 1	415	11.00	0.84	0.89	14.71	40	20.5	143.5	2.0	DOL	1A	
3	CT-0231A 2	415	11.00	0.84	0.89	14.71	40	20.5	143.5	2.0	DOL	1A	
4	CT-0231A 3	415	11.00	0.84	0.89	14.71	40	20.5	143.5	2.0	DOL	1A	
5	CT-0231A 4	415	11.00	0.84	0.89	14.71	40	20.5	143.5	2.0	DOL	1A	
6	P-0131A	415	132.00	0.86	0.95	161.57	400	224.8	519.3	6.0	人 − △	1A	SP
7	P-0231A	415	90.00	0.89	0.94	107.58	250	149.7	1,047.9	4.0	人 − △	1A	SP
8	EC-0121A	415	414.80	0.85	0.90	542.22	1000	754.3	5,280.1	4.0	P.S	1A	
9	P-0121A	415	15.00	0.83	0.90	20.08	63	27.9	195.3	4.0	DOL	1A	
10	EC-0121B	415	414.80	0.85	0.90	542.22	1000	754.3	5,280.1	4.0	P.S	1A	
11	P-0121B	415	15.00	0.83	0.90	20.08	63	27.9	195.3	4.0	DOL	1A	
12	P-0111A(as EC)	415	75.00	0.86	0.94	92.78	200	129.1	903.7	4.0	人 − △	1A	SP
13	P-0112A(as TES)	415	90.00	0.89	0.94	107.58	250	149.7	1,047.9	4.0	人 − △	1A	SP
14	P-1101	415	4.00	0.91	0.85	5.17	40	7.2	50.4	4.0	DOL	1A	
15	P-1102A	415	7.50	0.90	0.87	9.58	40	13.3	93.1	4.0	DOL	1A	
16	CU-0410 (Spare)	–	–	–	–	–	–	–	–	4.0	–	–	Air Driven Pump
17	CU-0421	415	0.20	0.85	0.90	0.26	40	0.4	2.8	4.0	P.S	1A	
18	CU-0422A & B	415	1.00	0.85	0.90	1.31	40	1.8	12.6	4.0	P.S	1A	
19	CU-0431 & 0432	415	2.14	0.85	0.90	2.80	40	3.9	27.3	4.0	P.S	1A	
20	B-0301A	415	15.00	0.85	0.90	19.61	63	27.3	191.1	4.0	P.S	1A	
21	P-0301A	415	5.50	0.90	0.86	7.11	40	9.9	69.3	4.0	DOL	1A	
22	P-0301Z	415	5.50	0.90	0.86	7.11	40	9.9	69.3	4.0	DOL	1A	Stand by
23	Z-0440	415	4.00	1.00	1.00	4.00	40	5.6	39.2	4.0	P.S	1A	
24	P-1141A	415	1.10	0.84	0.78	1.68	20	2.3	16.1	4.0	DOL	1A	
25	P-1141B	415	1.10	0.84	0.78	1.68	20	2.3	16.1	4.0	DOL	1A	
26	P-0331A	415	1.10	0.84	0.78	1.68	20	2.3	16.1	4.0	DOL	1A	
27	P-0503A	415	0.55	0.75	0.73	1.00	15	1.4	9.8	4.0	DOL	1A	
28	P-0501A	415	0.55	0.75	0.73	1.00	15	1.4	9.8	4.0	DOL	1A	
29	B-0303A	415	1.50	0.85	0.94	1.88	20	2.6	18.2	4.0	P.S	1A	
30	P-0303A	415	11.00	0.89	0.90	13.73	40	19.1	133.7	4.0	DOL	1A	
31	P-0502A	415	1.50	0.78	0.79	2.43	20	3.4	23.8	4.0	DOL	1A	
32	P-0504A	415	1.50	0.78	0.79	2.43	20	3.4	23.8	4.0	DOL	1A	
33	Building (EMSB)	415	153.20	1.00	1.00	153.20	400	213.1	1,491.7	4.0	P.S	1A	
			1552.54			1373.21							

1547.04 1366.29

Start Up

A : Starting Current

sec : Starting to Normal (Design) Speed

: Pending

SP : Pump Space Heater 240V, 200W

Starting Method

P.S : Power Supply (to equipment)

DOL : Direct On Line

人 − △ : Star – Delta

1934.61 kVA

1552.54 kW

1547.04 kW

UNIVERSITI TEKNOLOGI PETRONAS

CADANGAN MEMBINA SEBUAH LOJI PENJANAAN DAN SISTEM PENDINGINAN UNGKUNGAN UNTUK UNIVERSITI TEKNOLOGI PETRONAS DIATAS LOT-LOT 13157 MUKIM BOTA DAN TANAH KERAJAAN PLOT 1 MUKIM BOTA SERTA PLOT 2 MUKIM LAYANG – LAYANG DAERAH PERAK TENGAH DI BANDAR SRI ISKANDAR PERAK DARUL RIDZUAN

Building Owner :

GAS DISTRICT COOLING (M) SDN. BHD.

Level 46,Tower 1, Petronas Twin Towers P O Box 12444 KLCC 50088 Kuala Lumpur Tel. : (603) 5817824 Fax : (603) 5817600

Project Management Consultant :

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17, Jalan SS 4C/5, Taman Rasa Sayang, 47301 Petaling Jaya, Selangor Darul Ehsan Tel. : 03-703 3038 Fax : 03-703 2783

EPCC Contractor :

SHINRYO (MALAYSIA) SDN. BHD. (95463-A)

Menara IA One (Letterbox 22-77) Suite 31.01, Level 31 22, Jalan P. Ramlee 50250 Kuala Lumpur Tel. : 03-2166 8966 Fax : 03-2166 2214

REFERENCE DRAWING NO.

Rev.	Description	Drawn	Date
A	AS BUILT	ZAIDI	26.03.03
1	RE-ISSUED FOR APPROVAL	KAM	26.12.01
0	ISSUED FOR APPROVAL	KAM	30.10.01

[A] APPROVED ☑

[B] APPROVED WITH COMMENTS ☐

[C] REVIEWED ☐

[D] REJECTED, REVISED AND RESUBMIT ☐

APPROVAL OF THIS DOC. AND/OR DATA IS ONLY CONFORMANCE WITH DESIGN INTENT AND WITH THE INFORMATION CALLED FOR BY THE CONTRACT DOC. THIS APPROVAL SHALL NOT RELIEVE THE CONTRACTOR OF HIS CONTRACTUAL OBLIGATION AND SHALL NOT CONSTITUTE A BASIS FOR CHANGE ORDER

APPROVAL		Signature	Date
PMC	C & S		
	Mech		
	E & I	[signature]	
GDC	C & S		
	Mech		
	E & I	[signature]	
PMC Project Manager		[signature]	28/07/03
GDC Project Manager		[signature]	

Project Title :

COGENERATION / DISTRICT COOLING PLANT PROJECT UNIVERSITY TECHNOLOGY PETRONAS, TRONOH PERAK DARUL RIDZUAN CIVIL / BUILDING WORKS, CHILLER PLANT AND COGENERATION PLANT

Drawing Title :

415kV LOAD SCHEDULE (1)

AS BUILT

Scale : NTS		CodFile : ASMUTPE010RA	
Drawn By : ZAIDI		Approved By:	
Designed By : AZIAN		Date : 26.03.03	
Drawing Number : A/SM/UTP/E/010		Revision A	

LOAD LIST FOR PLANT EQUIPMENT (2)

LOAD LIST FOR MCC-2

No.	Equipment Name	Volt (V)	Rated Capacity (kW)	Power Factor	Eff	kVA Rating (kVA)	MCCB (A)	Normal (A)	Start Up (A)	Start Up (sec)	Starting Method	Stage	Remarks
1	AC-0131B	415	44.00	1.00	1.00	44.00	100	–	–	–	P.S	1A	
2	CT-0231B 1	415	11.00	0.84	0.89	14.71	40	20.4	142.8	2.0	DOL	1A	
3	CT-0231B 2	415	11.00	0.84	0.89	14.71	40	20.4	142.8	2.0	DOL	1A	
4	CT-0231B 3	415	11.00	0.84	0.89	14.71	40	20.4	142.8	2.0	DOL	1A	
5	CT-0231B 4	415	11.00	0.84	0.89	14.71	40	20.4	142.8	2.0	DOL	1A	
6	P-0131B	415	132.00	0.86	0.95	161.57	400	225.5	902.0	6.0	人 – △	1A	SP
7	P-0231B	415	90.00	0.89	0.94	107.58	250	149.0	596.0	6.0	人 – △	1A	SP
8	EC-0121C	415	414.80	0.85	0.90	542.22	1000	–	–	–	P.S	1A	
9	P-0121C	415	15.00	0.83	0.90	20.08	63	28.0	196.0	2.0	DOL	1A	
10	EC-0121D	415	414.80	0.85	0.90	542.22	1000	–	–	–	P.S	1A	
11	P-0121D	415	15.00	0.83	0.90	20.08	63	28.0	196.0	2.0	DOL	1A	
12	P-0111B	415	75.00	0.86	0.94	92.78	250	128.8	512.0	6.0	人 – △	1A	SP
13	P-0112B	415	90.00	0.89	0.94	107.58	250	149.0	596.0	6.0	人 – △	1A	SP
14	P-1102B	415	7.50	0.90	0.87	9.58	40	13.3	93.1	2.0	DOL	1A	
15	Z-0801	415	1.50	0.85	0.90	1.96	20	–	–	–	P.S	1A	
16	P-0801A	415	1.50	0.78	0.79	2.43	20	3.4	23.8	2.0	DOL	1A	
17	P-0801B	415	1.50	0.78	0.79	2.43	20	3.4	23.8	2.0	DOL	1A	
18	P-0331B	415	1.10	0.84	0.78	1.68	20	2.3	16.1	2.0	DOL	1A	
19	P-0501Z	415	0.55	0.75	0.73	1.00	15	1.4	9.8	2.0	DOL	1A	Stand by
20	P-0503Z	415	0.55	0.75	0.73	1.00	15	1.4	9.8	2.0	DOL	1A	Stand by
21	B-0303B	415	1.50	0.85	0.94	1.88	20	–	–	–	P.S	1A	
22	P-0303B	415	11.00	0.89	0.90	13.73	40	19.1	133.7	2.0	DOL	1A	
23	P-0303Z	415	11.00	0.89	0.90	13.73	40	19.1	133.7	2.0	DOL	1A	Stand by
24	P-0502Z	415	1.50	0.78	0.79	2.43	20	3.4	23.8	2.0	DOL	1A	Stand by
25	P-0504Z	415	1.50	0.78	0.79	2.43	20	3.4	23.8	2.0	DOL	1A	Stand by
26	Building (MDB-1)	415	151.42	1.00	1.00	151.42	400	–	–	–	P.S	1A	
27	Air Compressor	415	15.00	0.83	0.90	20.08	63	28.0	–	–	DOL	1A	
			1541.72			1922.73							
			1526.62										

Start Up
A : Starting Current
sec : Starting to Normal (Design) Speed
: Pending
SP : Pump Space Heater
240V, 200W

Starting Method
P.S : Power Supply (to equipment)
DOL : Direct On Line
人 – △ : Star – Delta

full load = 1541.72kW
1922.73kVA
1148.91kVAr

standby = 1902.14kVA
1526.62kW
1134.71kVAr

UNIVERSITI TEKNOLOGI PETRONAS

CADANGAN MEMBINA SEBUAH LOJI PENJANAAN DAN SISTEM PENDINGINAN UNGKUPAN UNTUK UNIVERSITI TEKNOLOGI PETRONAS DIATAS LOT-LOT 13157 MUKIM BOTA DAN TANAH KERAJAAN PLOT 1 MUKIM BOTA SERTA PLOT 2 MUKIM LAYANG – LAYANG DAERAH PERAK TENGAH DI BANDAR SRI ISKANDAR PERAK DARUL RIDZUAN

Building Owner :

GAS DISTRICT COOLING

GAS DISTRICT COOLING (M) SDN. BHD.
Level 48,Tower 1, Petronas Twin Towers
P O Box 12444 KLCC
50088 Kuala Lumpur
Tel. : (603) 5817824
Fax : (603) 5817600

Project Management Consultant :

MAJUTEK PERUNDING
17, Jalan SS 4C/5, Taman Rasa Sayang, 47301 Petaling Jaya, Selangor Darul Ehsan
Tel. : 03-703 3038 Fax : 03-703 3783

EPCC Contractor :

SHINRYO (MALAYSIA) SDN. BHD.
(95463-A)
Menara TA One (Letterbox 22-77)
Suite 31.01, Level 31
22, Jalan P. Ramlee
50250 Kuala Lumpur
Tel. : 03-2166 8966
Fax : 03-2166 3214

REFERENCE DRAWING NO.

Rev.	Description	Drawn	Date
A	AS BUILT	ZADI	26.03.03
1	RE-ISSUED FOR APPROVAL	XAM	26.12.01
0	ISSUED FOR APPROVAL	XAM	30.10.01

- [A] APPROVED ☑
- [B] APPROVED WITH COMMENTS ☐
- [C] REVIEWED ☐
- [D] REJECTED, REVISED AND RESUBMIT ☐

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APPROVAL		Signature	Date
PMC	C & S		
	Mech		
	E & I	[signature]	17/7/03
GDC	C & S		
	Mech		
	E & I	[signature]	
PMC Project Manager		[signature]	28/07/03
GDC Project Manager		[signature]	

Project Title :

COGENERATION / DISTRICT COOLING PLANT PROJECT
UNIVERSITY TECHNOLOGY PETRONAS, TRONOH PERAK DARUL RIDZUAN
CIVIL / BUILDING WORKS, CHILLER PLANT AND COGENERATION PLANT

Drawing Title :

415kV LOAD SCHEDULE (2)

AS BUILT

Scale : NTS	CadFile : ASMUIPE01IRA
Drawn By : ZADI	Approved By: [signature]
Designed By : AZIAN	Date : 26.03.03
Drawing Number :	Revision

LOAD LIST FOR MCC-GTG-A

No.	Equipment Tag	Phase	Supply Volt (V)	Connect Load (kW)	Start Method	P.F	Eff.	Capacity (kVA)	Normal Equip. Current (A)	Start-up Equip. Current (A)	Start-up Time (sec)	MCCB Size (A) In	Stage	Remarks
1	FOR GTG													
1-a	ENCLOSURE VENT FAN NO. 1	3	415	7.50	DOL	0.85	0.98	9.0	12.5	87.50	4.00	25	1A	
1-b	ENCLOSURE VENT FAN NO. 2	3	415	7.50	DOL	0.85	0.98	9.0	12.5	87.50	4.00	25	1A	
2	DIRECT AC STARTER MOTOR	3	415	(55.00)	INV	0.85	0.98	(66.0)	91.8			315	1A	Stand by
3	PRE-POST LUBE PUMP	3	415	1.50	DOL	0.85	0.98	1.8	2.5	17.50	4.00	16	1A	
4	MAIN LIQUID FUEL PUMP	3	415	5.60	INV	0.85	0.98	6.7	9.3			20	1A	
5	LUBE OIL COOLER FAN	3	415	3.75	DOL	0.85	0.98	4.5	6.3	44.10	4.00	20	1A	
6	LIQUID FUEL BOOST PUMP	3	415	0.75	DOL	0.85	0.98	0.9	1.3	9.10	4.00	16	1A	
7	LUBE OIL TANK HEATER	3	415	4.50	P.S	1.00	1.00	4.5	6.3	44.10	4.00	20	1A	
													1A	
8	LP		415									ELCB 63A	1A	
	ENCLOSURE VENT FAN HEATER	R1	240	0.025	-	1	1	0.000	0.000	-		6	1A	
	ENCLOSURE VENT FAN HEATER	Y1	240	0.025	-	1	1	0.000	0.000	-		6	1A	
	DIRECT AC STARTER MOTOR HEATER	B1	240	0.196	-	1	1	0.200	0.300	-		6	1A	
	PRE-POST LUBE PUMP HEATER	R2	240	0.025	-	1	1	0.000	0.000	-		6	1A	
	MAIN LIQUID FUEL PUMP HEATER	Y2	240	0.025	-	1	1	0.000	0.000	-		6	1A	
	LUBE OIL COOLER FAN HEATER	B2	240	0.025	-	1	1	0.000	0.000	-		6	1A	
	ENCLOSURE LIGHT	R3	240	0.450	-	0.85	0.98	0.500	0.700	-		6	1A	
	BATTERY CHARGER	Y3	240	0.025	-	0.85	0.98	0.000	0.000	-		32	1A	
	LIQUID FUEL BOOST PUMP HEATER	B3	240	0.060	-	1	1	0.100	0.100	-		6	1A	
	GENERATOR HEATER	R4	240	1.88	-	1	1	2.300	3.200	-		6	1A	
	SPARE	Y4										16	1A	
	SPARE	B4		88.836				105.5				16	1A	
	SPARE	R5										16	1A	
	SPARE	Y5										16	1A	
	SPARE	B5										16	1A	
	SPARE	R6										16	1A	
	SPARE	Y6										16	1A	
	SPARE	B6										16	1A	

full load = 88.836 kW
= 105.5 kVA
= 56.91 kVAr

- Stand by = 33.836 kW
= 39.5 kVA
= 20.38 kVAr

LOAD LIST FOR PLANT EQUIPMENT (6)

LOAD LIST FOR MCC-GTG-B

No.	Equipment Tag	Phase	Supply Volt (V)	Connect Load (kW)	Start Method	P.F	Eff.	Capacity (kVA)	Normal Equip. Current (A)	Start-up Equip. Current (A)	Start-up Time (sec)	MCCB Size (A) In	Stage	Remarks
1	FOR GTG													
1-a	ENCLOSURE VENT FAN NO. 1	3	415	7.50	DOL	0.85	0.98	9.00	12.50	87.50	4.00	25	1A	
1-b	ENCLOSURE VENT FAN NO. 2	3	415	7.50	DOL	0.85	0.98	9.00	12.50	87.50	4.00	25	1A	
2	DIRECT AC STARTER MOTOR	3	415	55.00	INV	0.85	0.98	66.00	91.80			315	1A	Stand by
3	PRE-POST LUBE PUMP	3	415	1.50	DOL	0.85	0.98	1.80	2.50	17.50	4.00	16	1A	
4	MAIN LIQUID FUEL PUMP	3	415	5.60	INV	0.85	0.98	6.70	9.30			20	1A	
5	LUBE OIL COOLER FAN	3	415	3.75	DOL	0.85	0.98	4.50	6.30	44.10	4.00	20	1A	
6	LIQUID FUEL BOOST PUMP	3	415	0.75	DOL	0.85	0.98	0.90	1.30	9.10	4.00	16	1A	
7	LUBE OIL TANK HEATER	3	415	4.50	P.S	1.00	1.00	4.50	6.30	44.10	4.00	20	1A	
													1A	
8	LP		415									ELCB 63A	1A	
	ENCLOSURE VENT FAN HEATER	R1	240	0.025	-	1	1	0.00	0.00	-		6	1A	
	ENCLOSURE VENT FAN HEATER	Y1	240	0.025	-	1	1	0.00	0.00	-		6	1A	
	DIRECT AC STARTER MOTOR HEATER	B1	240	0.196	-	1	1	0.20	0.30	-		6	1A	
	PRE-POST LUBE PUMP HEATER	R2	240	0.025	-	1	1	0.00	0.00	-		6	1A	
	MAIN LIQUID FUEL PUMP HEATER	Y2	240	0.025	-	1	1	0.00	0.00	-		6	1A	
	LUBE OIL COOLER FAN HEATER	B2	240	0.025	-	1	1	0.00	0.00	-		6	1A	
	ENCLOSURE LIGHT	R3	240	0.450	-	0.85	0.98	0.50	0.70	-		6	1A	
	BATTERY CHARGER	Y3	240	0.025	-	0.85	0.98	0.00	0.00	-		32	1A	
	LIQUID FUEL BOOST PUMP HEATER	B3	240	0.060	-	1	1	0.10	0.10	-		6	1A	
	GENERATOR HEATER	R4	240	1.88	-	1	1	2.30	3.20	-		6	1A	
	SPARE	Y4		88.836				105.5				16	1A	
	SPARE	B4										16	1A	
	SPARE	R5										16	1A	
	SPARE	Y5										16	1A	
	SPARE	B5										16	1A	
	SPARE	R6										16	1A	
	SPARE	Y6										16	1A	
	SPARE	B6										16	1A	

33.836

NOTE :

1. PS : Power Supply
   DOL : Direct On-Line
   S/D : Star-Delta
   INV : Inverter Drive
   Stand by : During GTG starting only
2. Voltage Drop
   Vd=(Vl x Ib x 1 x cosØ)/1000V
   For AC circuit conductors of sizes <16mm2
   Vd=(Vr cosØ + Vx sinØ) x Ib X l)/1000V
   For AC circuit, conductors of sizes <25mm2
3. Starting power factor of motor load, load cosØ =0.43 approximately

UNIVERSITI TEKNOLOGI PETRONAS

Building Owner :

GAS DISTRICT COOLING

GAS DISTRICT COOLING (M) SDN. BHD.

Project Management Consultant :

MAJUTEK PERUNDING

EPCC Contractor :

SHINRYO (MALAYSIA) SDN. BHD.

REFERENCE DRAWING NO.

Rev.	Description	Drawn	Date
A	AS BUILT	ZAIDI	21.04.03

[A] APPROVED ✓
[B] APPROVED WITH COMMENTS
[C] REVIEWED
[D] REJECTED, REVISED AND RESUBMIT

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APPROVAL		Signature	Date
PMC	C & S		
	Mech		
	E & I		
GDC	C & S		
	Mech		
	E & I		
PMC Project Manager			
GDC Project Manager			

Project Title :

COGENERATION / DISTRICT COOLING PLANT PROJECT
UNIVERSITY TECHNOLOGY PETRONAS, TRONOH PERAK DARUL RIDZUAN
CIVIL / BUILDING WORKS, CHILLER PLANT AND COGENERATION PLANT

Drawing Title :

415kV LOAD SCHEDULE (4)

AS BUILT

Scale : NTS	CadFile : ASMUIPE013RA
Drawn By : ZAIDI	Approved By:
Designed By : AZIAN	Date : 21.04.03
Drawing Number :	Revision