COMPUTER METHODS IN ELECTRICAL POWER DISTRIBUTION FOR PETRONAS GAS INDUSTRIAL PLANT

NORAHIDA IBRAHIM

UNIVERSITI MALAYSIA PAHANG

COMPUTER METHODS IN ELECTRICAL POWER DISTRIBUTION FOR PETRONAS GAS INDUSTRIAL PLANT

NORAHIDA IBRAHIM

This thesis is submitted as partial fulfillment of the requirement
for the award of the
Bachelor of Electrical Engineering
(Power System)

Faculty of Electrical & Electronics Engineering
Universiti Malaysia Pahang

NOVEMBER, 2008

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

Signature : ____________________________

Name : NORHAFIDZAH BINTI MOHD SAAD

Date : _______07 NOVEMBER 2008________

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Signature : ________________________________

Author : NORAHIDA IBRAHIM __________

Date : 07 NOVEMBER 2008_______________

Dedicated to my beloved parents, sibling, supervisor and all of you
For giving a constant source of support and encouragement

ACKNOWLEDGEMENTS

First of all, thanks to my supervisor, Pn. Norhafidzah Mohd Saad because give me a generous amount of help and guidance which has provided me with practical experience in this PSM project and academic experience in the analysis of the power flow for industrial plant (Petronas Gas Kerteh) by using new software in the Universiti Malaysia Pahang that is SKM Power Tools for Windows.

I also thanked to En. Nazri from Petronas Gas Kerteh because give me the data to make my PSM project become complete. He also helped me to get the information of this project about the Petronas Gas Kerteh. Director VI Power Sdn. Bhd, Ir. Lee Chong Kiow that is important person which help me a lot when using this new software. I take great pride in my work, but where would I be without the help of my peers and colleagues.

I would like to thank also to En. Zahir, Pn. Nazriyah, En Farhan, En. Redzuan and all of the lecturer in FKEE for their accommodation, suggestion and opinion during the project progress in this university.

Special thank also to my family for their eternal support when I told them that I wanted to continue my education and especially friends for encouraging me done my research. Last, but not least, I would like to acknowledge the lot of support to Faculty of Electrical and Electronic Engineering, Universiti Malaysia Pahang in this research. Without their support the ideas could not have been realized.

ABSTRACT

Power system analysis software used to determine the amount use of power of the electrical power network for utility, industrial, and commercial industries. Along with all of the recent technological advances, there have been similar advances in power system analysis software. Engineers use this software to design, operate and control power systems. Such software allows engineers to solve power system analysis problems more easily. This analysis is intended as introductory information for Petronas Gas plant engineering wanting to acquire power system analysis software. Additionally, this analysis addresses how such software can be applied in the Petronas Gas industrial plant. This analysis is more focuses on the power flow analysis. A power flow will calculates the voltage drop on each feeder, the voltage at each bus, and the power flow in all branch and feeder circuits. It is worked by using the software of SKM Power Tools for Windows.

ABSTRAK

Perisian analisis sistem kuasa digunakan untuk menentukan penggunaan kuasa jumlah jaringan kuasa elektrik untuk utiliti, industri, dan industri-industri perdagangan. Sepanjang dengan semua kemajuan-kemajuan teknologi mutakhir, di sana telah sama kemajuan dalam perisian analisis sistem kuasa. Penggunaan jurutera-jurutera mereka bentuk perisian ini, beroperasi dan sistem-sistem kekuatan kuasa. Perisian seumpama membenarkan jurutera-jurutera untuk menyelesaikan masalah-masalah analisis sistem kuasa lebih senang. Analisis ini adalah dimaksudkan maklumat yang serupa asas untuk kejuruteraan kilang Petronas Gas inginkan untuk memperolehi perisian analisis sistem kuasa. Tambahan pula, alamat-alamat analisis ini perisian yang bagaimana seumpama boleh digunakan dalam kilang perindustrian Petronas Gas. Analisis ini adalah lebih menumpukan pada analisis aliran kuasa. Satu wasiat aliran kuasa mengira susutan voltan di setiap penyuap, voltan di setiap bas, dan aliran kuasa dalam cawangan keseluruhan dan litar-litar penyuap. Ia dikerjakan dengan menggunakan perisian SKM Power Tools for Windows.

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LIST OF ABBREVIATIONS

MWh	Mega Watt hour
PTW	Power Tools for Windows
kVA	Kilo Volt Amphere
kW	Kilo Watt
kVar	Kilo Volt Amphere Reactive
P	Real Power
Q	Reactive Power
%VD	Percent Voltage Drop
TNB	Tenaga Nasional Berhad

LIST OF APPENDICES

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JUDUL: **COMPUTER METHODS IN ELECTRICAL POWER DISTRIBUTION FOR PETRONAS GAS INDUSTRIAL PLANT**

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Power flow commonly referred to as load flow, are the backbone of power system analysis and design. They are necessary for planning, operation, economic scheduling and exchange of power between utilities. In addition, power flow analysis is required for many others analysis such as transient stability and contingency studies [1].

The availability of fast and large computers has somewhat eased the work load of the power system engineer. Routine calculation can now be accomplished more efficiently and more extensively. Advances in device and system modeling, as well as the developments I computational technique, have greatly enhanced the analysis and planning tasks [2].

The hand computational work to perform power system analysis is very complex, cumbersome, and time consuming. Power system analysis aid were first develop in the late 1920s. It provided the ability to determine system voltage levels during the normal and emergency condition, and to determine the behavior of the power system analysis [4].

Today's engineers have a wide variety of hardware and software tools to perform power system analysis. There are many software packages offered in power system analysis. Most software packages include the following calculations as basic features; load flow, short circuit, motor starting, and protective device coordination.

This analysis only addresses the power flow which is the most common software packages used in a Petronas Gas industry. SKM Power Tools is one of the software used for power flow analysis. The result will show all of the analysis needed.

1.2 Objective

The objective of this project are :

i. To study the electrical power distribution for Petronas Gas Industrial Plant at Kerteh.

ii. To model and simulate the load flow and analysis for single line diagram of Petronas Gas Kerteh by using SKM Power Tools software.

iii. To apply computer method for electrical power distribution for Petronas Gas Industrial Plant.

1.3 Scope of Project

The scope of this project are :

i. Case study on power system network (single line diagram) of Petronas Gas Kerteh.

iii. Analyze the power flow analysis for trial system.

iv. Model, simulate and analyze the power flow of electrical power system distribution in Petronas Gas using SKM Power Tools software.

1.4 Thesis Outline

For the thesis outline, it has five chapters. All the progress elements are divided into chapters and the details of each chapter are as follows:

i Chapter 1

a. Introduction: Explain detail about the general information of this thesis. The problem statement is stated here along with the relevant solution. It's to support the main objectives and the relevant of the proposed title.
b. Objective: The goal of the project is stated in here. It's consists of the aim that must be achieved at the end of the project.
c. Scope of work: The flow of work that will be implemented in this project. This step by step flow work is to keep the project's progress on track and to meet the objective.
d. Thesis outline: The overall elements needed in the thesis.

ii. Chapter 2

a. Literature review: The study on the others papers, journal, website citation and other dependable sources that related to the project. Literature review is crucial for every thesis not only to support the proposed title but also for guidelines and references on the conducted thesis.

iii. Chapter 3

a. Methodology: Describe in details about the scope of project. In this part, every step on how to approach the solutions to overcome the stated problems is described in details. Its shows how the work will be done. The details such as flow chart, schematic diagram are shown in here.

iv. Chapter 4

a. Expected result: State the expected results that will be achieved at the end of the project.

v. Chapter 5

a. Conclusion: Conclude the project's objectives and result achieved. The project success or failure is stated in here.
b. Suggestion: Give suggestion for the future of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is a study on the others papers, journal, website citation and other dependable sources that related to the project. It is crucial for every thesis not only to support the proposed title but also for guidelines and references on the conducted thesis.

2.2 Petronas Gas Power System

2.2.1 Introduction of Petronas Gas Power System

Figure 2.1 Petronas Gas Kerteh

Petronas Gas is one of the 18 investor-owned independent power producers supplying power to the three main utilities. There are also several mini utilities generating electricity or purchasing power from the main utilities for their own use and supply the excess power to consumers within certain dedicated areas. Petronas Gas generates electricity by co-generation and supplies to customers within the Gebeng and Kerteh petrochemical industrial areas. Petronas gas Kerteh generates about 1,228,540 MWh using gas turbine and gas petroleum as a fuel and distribute power to the consumers [8].

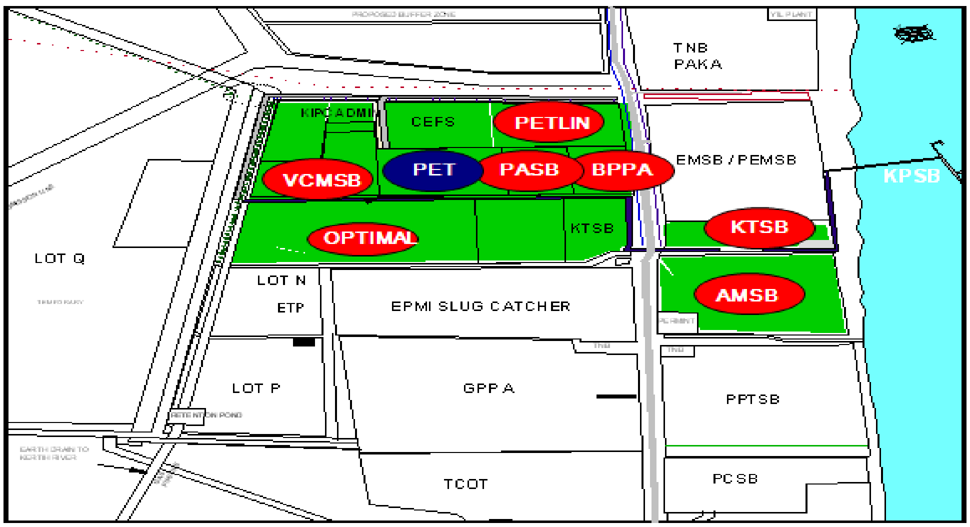


Figure 2.2 Kerteh Petrochemical area

2.2.2 Petronas Gas Power Generation

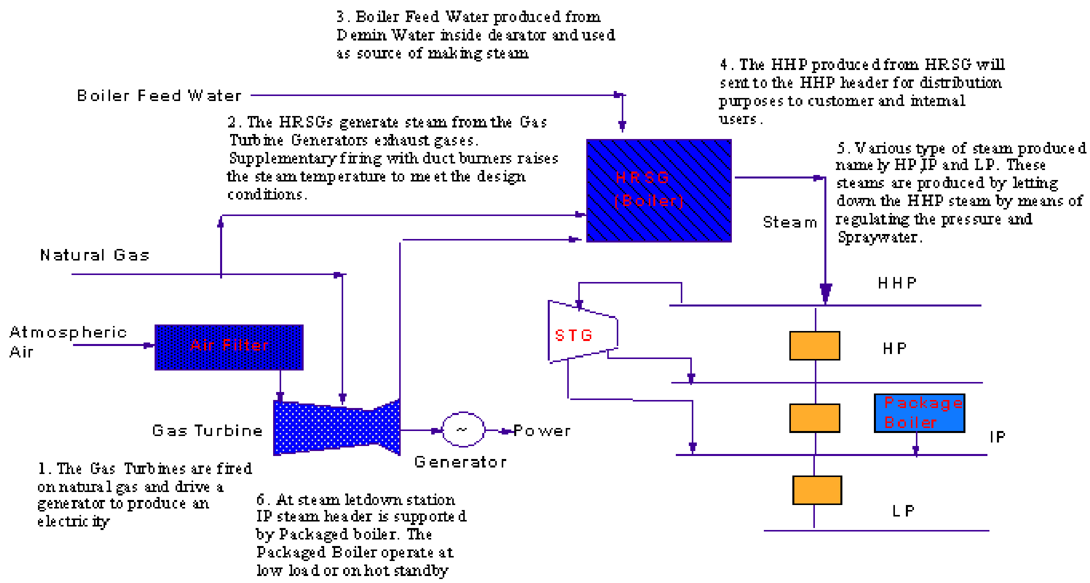


Figure 2.3 Flow of the Power Generation

A gas turbine extracts energy from a flow of hot gas produced by combustion of gas or fuel oil in a stream of compressed air. It has an upstream air compressor (radial or axial flow) mechanically coupled to a downstream turbine and a combustion chamber in between. Gas turbine may also refer to just the turbine element [3].

Energy is released when compressed air is mixed with fuel and ignited in the combustor. The resulting gases are directed over the turbine's blades, spinning the turbine, and mechanically powering the compressor. Finally, the gases are passed through a nozzle, generating additional thrust by accelerating the hot exhaust gases by expansion back to atmospheric pressure [3].

As with all cyclic heat engines, higher combustion temperature means greater efficiency. The limiting factor is the ability of the steel, nickel, ceramic, or other materials that make up the engine to withstand heat and pressure. Considerable engineering goes into keeping the turbine parts cool. Most turbines also try to recover exhaust heat, which otherwise is wasted energy. Recuperators are heat exchangers that pass exhaust heat to the compressed air, prior to combustion. Combined cycle designs pass waste heat to steam turbine systems. A combined heat and power (co-generation) uses waste heat for hot water production [3], [8].

Mechanically, gas turbines can be considerably less complex than internal combustion piston engines. Simple turbines might have one moving part: the shaft/ compressor/ turbine/ alternative-rotor assembly not counting the fuel system [3].

More sophisticated turbines (such as those found in modern jet engines) may have multiple shafts (spools), hundreds of turbine blades, movable stator blades, and a vast system of complex piping, combustors and heat exchangers [3].

As a general rule, the smaller the engine the higher the rotation rate of the shaft(s) needs to be to maintain tip speed. Turbine blade tip speed determines the maximum pressure that can be gained, independent of the size of the engine. Jet engines operate around 10,000 rpm and micro turbines around 100,000 rpm [3].

Thrust bearings and journal bearings are a critical part of design. Traditionally, they have been hydrodynamic oil bearings, or oil-cooled ball bearings. This is giving way to foil bearings, which have been successfully used in micro turbines and auxiliary power units [3], [8].

2.3 Power System Analysis

2.3.1 Introduction

The planning, design, and operation of electric power systems require continuing and comprehensive analysis in order to determine system performance and evaluate alternative system expansion plans. Because of the increasing cost of system additions and modifications, it is imperative that utilities consider a range of design options [2]. In order to the important of the power flow analysis, this chapter will discuss the about the theory related to the load flow analysis.

2.3.2 Power Flow Analysis

In power engineering, the power flow analysis is an important tool involving numerical analysis applied to a power system. Unlike traditional circuit analysis, a power flow study usually uses simplified notation such as a one-line diagram and per-unit system, and focuses on various forms of AC power (ie: reactive, real, and apparent) rather than voltage and current. It analyses the power systems in normal steady-state operation. There exist a number of software implementations of power flow studies [5].

The great importance of power flow or load-flow studies is in the planning the future expansion of power systems as well as in determining the best operation of existing systems. The principal information obtained from the power flow study is the magnitude and phase angle of the voltage at each bus and the real and reactive power flowing in each line [5].

2.3.3 Basic of the power flow problem

The load flow problem is an important tool for design and operation of distribution systems. At the design stage, it is applied to ensure that the voltage and current standards are satisfactory under various conditions all over the network. At the operation stage, load flow is used to ensure that voltages and currents are within the predefined ranges for expected loads [5].

The goal of a power flow study is to obtain complete voltage angle and real power and voltage conditions. Once this information is known, real and reactive power flow on each branch as well as generator reactive power output can be analytically determined. Due to the nonlinear nature of this problem, numerical methods are employed to obtain a solution that is within an acceptable tolerance [5]. In this problems, there are some solution that can be use to solve this problems. This chapter only discuss detailed on the Newton-Raphson Method .

2.3.4 Newton-Raphson Method

Newton-Raphson method is found to be more practical and efficient for large power system. The number of iterations required to obtain a solution is independent of the system size, but more functional evaluations are required at each iteration [5].

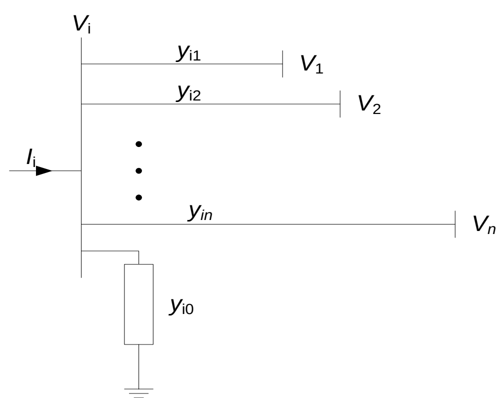


Figure 2.4 Typical bus power system

Figure 2.4 shown the typical bus power system. Base on the power flow equation, when the current entering bus *1*, it can be rewritten in terms of the bus admittance matrix as

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \tag{2.1}$$

The typical element Y_{ij} is

$$Y_{ij} = |Y_{ij}|\angle\theta_{ij} = |Y_{ij}|\cos\theta_{ij} + j|Y_{ij}|\sin\theta_{ij} = G_{ij} + jB_{ij} \tag{2.2}$$

The voltage at a typical bus *I* of the system in polar form is

$$V_i = |V_i|\angle\delta_i = |V_i|(\cos\delta_i + j\sin\delta_i) \tag{2.3}$$

Expressing Equation (2.1) in polar form, we have

$$I_i = \sum_{j=1}^{n} |Y_{ij}||V_j|\angle\theta_{ij} + \delta_j \tag{2.4}$$

The complex conjugate of the power injected at bus *I* is

$$\begin{aligned} P_i - jQ_i &= V_i^* I_i \\ &= V_i^* \sum_{j=1}^{n} Y_{ij} V_j \end{aligned} \tag{2.5}$$

Substitute Equation 2.4 into Equation 2.5 we get

$$\begin{aligned} P_i - jQ_i &= V_i^* \sum_{j=1}^{n} Y_{ij} V_j \\ &= |V_i|\angle -\delta_i \sum_{j=1}^{n} |Y_{ij}||V_j|\angle\theta_{ij} + \delta_j \\ &= \sum_{j=1}^{n} |Y_{ij} V_i V_j|\angle\theta_{ij} + \delta_j - \delta_i \end{aligned} \tag{2.6}$$

Separating Equation 2.6 into real and reactive parts, we obtain

$$P_i = \sum_{j=1}^{n} |Y_{ij} V_i V_j| \cos(\theta_{ij} + \delta_j - \delta_i) \tag{2.7}$$

$$Q_i = -\sum_{j=1}^{n} |Y_{ij} V_i V_j| \sin(\theta_{ij} + \delta_j - \delta_i) \tag{2.8}$$

Equation 2.7 and 2.8 constitute a polar form of the power flow equations. When *j* is set to be equal to *i* in Equation 2.7 and 2.8 and the corresponding terms are separated from the summations, we obtain;

$$P_i = |V_i|^2 G_{ii} + \sum_{\substack{j=1 \\ j \neq i}}^{n} |Y_{ij} V_i V_j| \cos(\theta_{ij} + \delta_j - \delta_i) \tag{2.9}$$

$$Q_i = -|V_i|^2 B_{ii} - \sum_{\substack{j=1 \\ j \neq i}}^{n} |Y_{ij} V_i V_j| \sin(\theta_{ij} + \delta_j - \delta_i) \tag{2.10}$$

Let P_{gi} denote the scheduled power being generated at bus I and P_{li} denote the scheduled power demand of the load at the bus. Then, $P_{i,sch}$ is the net scheduled power being injected into the network at bus *i*. The power mismatches for the typical load bus *I* is;

$$\Delta P_i = P_{i,sch} - P_{i,calc} = (P_{gi} - P_{\ell i}) - P_{i,calc} \tag{2.11}$$

$$\Delta Q_i = Q_{i,sch} - Q_{i,calc} = (Q_{gi} - Q_{\ell i}) - Q_{i,calc} \tag{2.12}$$

Mismatches occur when the calculated values $P_{i,calc}$ and $Q_{i,calc}$ do not coincide with the schedule values. If the calculated values $P_{i,calc}$ and $Q_{i,calc}$ match the scheduled values $P_{i,sch}$ and $Q_{i,sch}$ perfectly, then we say the mismatches ΔP_i and ΔQ_i are zero at bus *i*.

Equation 2.9 and Equation 2.10 constitute a set of non-linear algebraic equations in terms of the independent variables, voltage magnitude in per-unit, and phase angle in

radians. Expending the equations in Taylor's series about the initial estimate and neglecting all higher order terms yields the Newton-Raphson power flow equations:

$$\underbrace{\left[\begin{array}{ccc|ccc} \frac{\partial P_2}{\partial \delta_2} & \cdots & \frac{\partial P_2}{\partial \delta_n} & |V_2|\frac{\partial P_2}{\partial |V_2|} & \cdots & |V_n|\frac{\partial P_2}{\partial |V_n|} \\ \vdots & J_{11} & \vdots & \vdots & J_{12} & \vdots \\ \frac{\partial P_n}{\partial \delta_2} & \cdots & \frac{\partial P_n}{\partial \delta_n} & |V_2|\frac{\partial P_n}{\partial |V_2|} & \cdots & |V_n|\frac{\partial P_n}{\partial |V_n|} \\ \hline \frac{\partial Q_2}{\partial \delta_2} & \cdots & \frac{\partial Q_2}{\partial \delta_n} & |V_2|\frac{\partial Q_2}{\partial |V_2|} & \cdots & |V_n|\frac{\partial Q_2}{\partial |V_n|} \\ \vdots & J_{21} & \vdots & \vdots & J_{22} & \vdots \\ \frac{\partial Q_n}{\partial \delta_2} & \cdots & \frac{\partial Q_n}{\partial \delta_n} & |V_2|\frac{\partial Q_n}{\partial |V_2|} & \cdots & |V_n|\frac{\partial Q_n}{\partial |V_n|} \end{array}\right]}_{JACOBIAN\,MATRIX} \underbrace{\begin{bmatrix} \Delta\delta_2 \\ \vdots \\ \Delta\delta_n \\ \hline \frac{\Delta|V_2|}{|V_2|} \\ \vdots \\ \frac{\Delta|V_n|}{|V_n|} \end{bmatrix}}_{CORRECTIONS} = \underbrace{\begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \\ \hline \Delta Q_2 \\ \vdots \\ \Delta Q_n \end{bmatrix}}_{MISMATCHES} \quad (2.13)$$

The diagonal elements of J_{11} are

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{\substack{j=1 \\ j\neq i}}^{n} |Y_{ij}V_iV_j| \sin(\theta_{ij} + \delta_j - \delta_i) \quad (2.14)$$

By comparing this equations for Q_i in Equation 2.10 we obtain

$$\frac{\partial P_i}{\partial \delta_i} = -Q_i - |V_i|^2 B_{ii} \quad (2.15)$$

The off - diagonal elements of J_{11} are

$$\frac{\partial P_i}{\partial \delta_j} = -|Y_{ij}V_iV_j| \sin(\theta_{ij} + \delta_j - \delta_i) \quad (2.16)$$

The diagonal elements of J_{21} as follows

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{\substack{j=1 \\ j\neq i}}^{n} |Y_{ij}V_iV_j| \cos(\theta_{ij} + \delta_j - \delta_i) \quad (2.17)$$

By comparing this equations for P_i in Equation 2.9 we obtain

$$\frac{\partial Q_i}{\partial \delta_i} = P_i - |V_i|^2 G_{ii} \tag{2.18}$$

The off - diagonal elements of J_{21} as follows

$$\frac{\partial Q_i}{\partial \delta_j} = -|Y_{ij} V_i V_j| \cos(\theta_{ij} + \delta_j - \delta_i) \tag{2.19}$$

The diagonal elements of J_{12} as follows

$$|V_i| \frac{\partial P_i}{\partial V_i} = |V_i| \left[2|V_i| G_{ii} + \sum_{\substack{j=1 \\ j \neq i}}^{n} |V_j Y_{ij}| \cos(\theta_{ij} + \delta_j - \delta_i) \right] \tag{2.20}$$

Comparing Equation 2.20 with Equation 2.17 and Equation 2.18 yields

$$|V_i| \frac{\partial P_i}{\partial V_i} = \frac{\partial Q_i}{\partial \delta_i} + 2|V_i|^2 G_{ii} = P_i + |V_i|^2 G_{ii} \tag{2.21}$$

The off - diagonal elements of J_{12} as follows

$$|V_j| \frac{\partial P_i}{\partial V_j} = |V_j||Y_{ij} V_i| \cos(\theta_{ij} + \delta_j - \delta_i) \tag{2.22}$$

Comparison with Equation 2.19 yields

$$|V_j| \frac{\partial P_i}{\partial V_j} = -\frac{\partial Q_i}{\partial \delta_j} \tag{2.23}$$

Finally, the diagonal and off-diagonal of sub matrix J_{22} are as follows

$$\left|V_i\right|\frac{\partial Q_i}{\partial V_i} = -\frac{\partial P_i}{\partial \delta_i} - 2\left|V_i\right|^2 B_{ii} = Q_i - \left|V_i\right|^2 B_{ii} \tag{2.24}$$

$$\left|V_j\right|\frac{\partial Q_i}{\partial V_j} = -\left|V_j\right|\left|Y_{ij}V_i\right|\sin(\theta_{ij} + \delta_j - \delta_i) = \frac{\partial P_i}{\partial \delta_j} \tag{2.25}$$

2.4 Power System Modeling

All analysis in the engineering sciences starts with the formulation of appropriate models. A model, and in power system analysis we almost invariably then mean a mathematical model, is a set of equations or relations, which appropriately describes the interactions between different quantities in the time frame studied and with the desired accuracy of a physical or engineered component or system. Hence, depending on the purpose of the analysis different models of the same physical system or components might be valid [7].

In principle, the complete telegraph equations could be used when studying the steady state conditions at the network nodes. The solution would then include the initial switching transients along the lines, and the steady state solution would then be the solution after the transients have decayed. However, such a solution would contain a lot more information than wanted and, furthermore, it would require a lot of computational effort. An algebraic formulation with the lumped-circuit line model, would give the same result with a much simpler model at a lower computational cost [7].

It is quite obvious what model that is the appropriate one, but in many engineering studies the selection of the "correct" model is often the most difficult part of the study. It is good engineering practice to use as simple models as possible, but of course not too simple. If too complicated models are used, the analysis and computations would be unnecessarily cumbersome. Furthermore, generally more complicated models need more parameters for their definition and to get reliable values of these require often extensive work [7].

2.4.1 Line and Cable

The equivalent π-model are recognize in order to make it easy to analyze. The general distributed model is characterized by the series parameters.

R' = series resistance/km per phase (Ω/km)
X' = series reactance/km per phase (Ω/km)
And the shunt parameters
B' = shunt susceptance/km per phase (siemens/km)
G' = shunt conductance/km per phase (siemens/km)

as depicted in Figure 2.5. The parameters above are specific for the line or cable configuration and are dependent on conductors and geometrical arrangements [7]

From the circuit in Figure 2.5 the telegraph equation is derived, and from this the lumped-circuit line model for symmetrical steady state conditions, Figure 2.6. This model is frequently referred to as the π-model, and it is characterized by the parameters [7];

$$Z_{km} = R_{km} + jX_{km}$$

$$Y_{km}^{sh} = G_{km}^{sh} + jB_{km}^{sh}$$

$Zkm = Rkm + jXkm$ = series impedance (Ω)
$Y_{km}^{sh} = G_{km}^{sh} + jB_{km}^{sh}$ = shunt admittance (siemens)

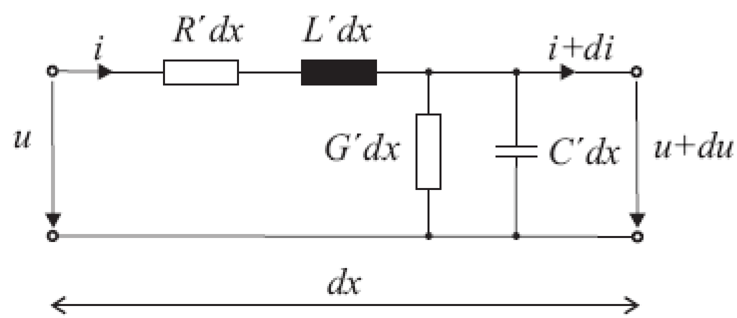


Figure 2.5 Equivalent circuit of a line element of length *dx*

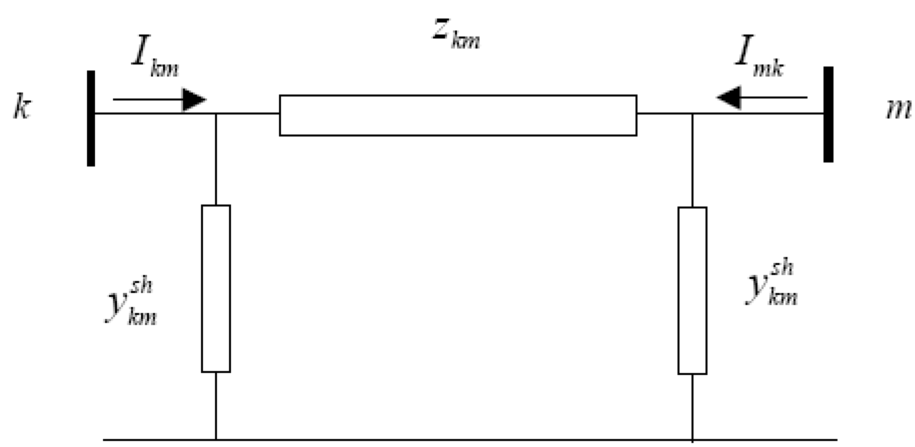


Figure 2.6 Lumped-circuit model (π-model) of a transmission line between nodes *k* and *m*

In the following most analysis will be made in the p.u. system. For impedances and admittance capital letters indicate that the quantity is expressed in ohms or siemens, and lower case letters that they are expressed in p.u. In these lecture notes complex quantities are not explicitly marked as underlined. This means that instead of writing zkm we will write zkm when this quantity is complex. However, it should be clear from the context if a quantity is real or complex. Furthermore, we will not always use specific type settings for vectors. Quite often vectors will be denoted by bold face type setting, but not always. It should also be clear from the context if a quantity is a vector or a scalar [7].

When formulating the network equations the node admittance matrix will be used and the series admittance of the line model is needed

$$y_{km} = z_{km}^{-1} - g_{km} + jb_{km} \qquad (2.3.1)$$

With

$$g_{km} = \frac{r_{km}}{r_{km}^2 + x_{km}^2} \qquad (2.3.2)$$

And

$$b_{km} = \frac{x_{km}}{r_{km}^2 + x_{km}^2} \qquad (2.3.3)$$

For actual submitter the series reactance x_{km} and the series resistance r_{km} are both positive, and consequently g_{km} is positive and b_{km} is negative. The shunt susceptance y_{km}^{sh} and the shunt conductance g_{km}^{sh} are both positive for real line sections. In many cases the value of g_{km}^{sh} is so small that it could be neglected [7].

The complex currents I_{km} and I_{mk} in Figure 2.2 can be expressed as functions of the complex voltages at the branch terminal nodes *k* and *m [7]*;

$$I_{km} = y_{km}\,(E_k - E_m) + y_{km}^{sh} E_k \qquad (2.3.4)$$

$$I_{mk} = y_{km}\,(E_m - E_k) + y_{km}^{sh} E_m \qquad (2.3.5)$$

where the complex voltages are

$$E_k = U_k e^{j\theta k} \qquad (2.3.6)$$

$$E_m = U_m e^{j\theta m} \qquad (2.3.7)$$

This can also be written in matrix form as

$$\begin{pmatrix} I_{km} \\ I_{mk} \end{pmatrix} = \begin{pmatrix} y_{km} + y_{km}^{sh} & y_{km} \\ y_{km} & y_{km} + y_{km}^{sh} \end{pmatrix} \begin{pmatrix} E_k \\ E_m \end{pmatrix} \qquad (2.3.8)$$

As seen the matrix on the right hand side of equation (2.3.8) is symmetric and the diagonal elements are equal. This reflects that the lines and cables are symmetrical elements [7].

2.4.2 Transformer

We will start with a simplified model of a transformer where we neglect the magnetizing current and the no-load losses. In this case the transformer can be modeled by an ideal transformer with turns ratio t_{km} in series with a series impedance z_{km} which represent resistive losses and the leakage reactance, see Figure 2.7 [7].

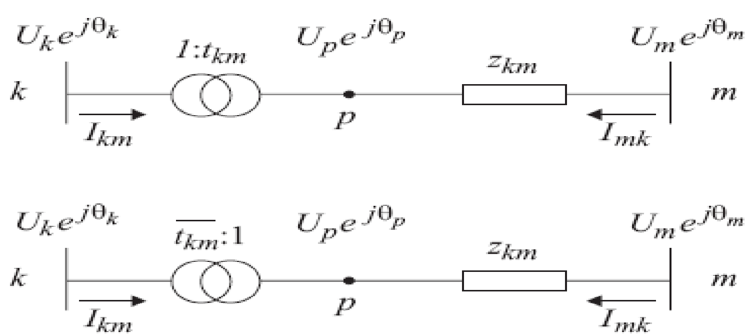


Figure 2.7 Transformer model with complex ratio t_{km}= $a_{km}^{ej\varphi km}$$(t_{km} = a_{km}^{-1e-ej\varphi km})$

2.4.2.1 In-Phase Transformer

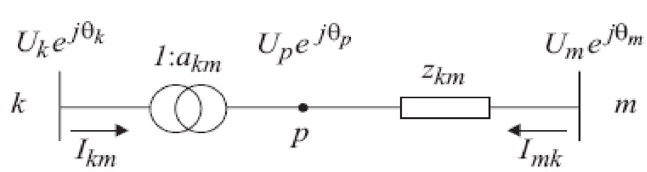


Figure 2.8 In-phase transformer model

Figure 2.8 shows an in-phase transformer model indicating the voltage at the internal - non-physical - node *p*. In this model the ideal voltage magnitude ratio (turns ratio) is [7],

$$\frac{U_p}{U_k} = a_{km} \tag{2.3.9}$$

Since $\theta_k = \theta_p$, this is also the ratio between the complex voltages at nodes *k* and *p*,

$$\frac{E_p}{E_k} = \frac{U_p e^{j\theta p}}{U_k e^{j\theta k}} = a_{km} \tag{2.3.10}$$

There are no power losses (neither active nor reactive) in the ideal transformer (the *k* - *p* part of the model), which yields

$$E_p I_{km}^* + E_p I_{mk}^* = 0 \tag{2.3.11}$$

Then applying equations (2.3.9) and (2.3.10) gives

$$\frac{I_{km}}{I_{mk}} = -\frac{|I_{km}|}{|I_{mk}|} = -a_{km} \tag{2.3.12}$$

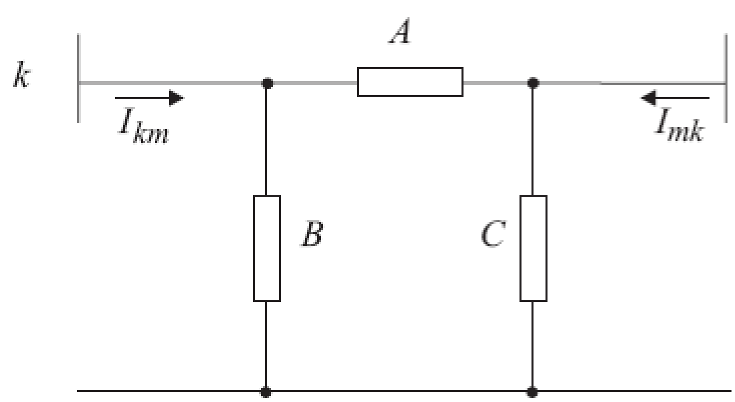


Figure 2.9 Equivalent π model for in-phase transformer

which means that the complex currents I_{km} and I_{mk} are out of phase by 180◦ since a_{km} $\in$ R. Figure 2.5 represents the equivalent π-model for the in-phase transformer in Figure 2.8. Parameters *A*, *B*, and *C* of this model can be obtained by identifying the coefficients of the expressions for the complex currents I_{km} and I_{mk} associated with the models of Figures 2.8 and 2.9. Figure 2.8 gives [7];

$$I_{km} = -a_{km}y_{km}\left(E_m - E_p\right) = (a_{km}^2 y_{km})E_k + (-a_{km}y_{km})E_m \quad (2.3.13)$$

$$I_{mk} = y_{km}\left(E_m - E_p\right) = (-a_{km}y_{km})E_k + (y_{km})E_m \quad (2.3.14)$$

Or in metric form:

$$\begin{pmatrix} I_{km} \\ I_{mk} \end{pmatrix} = \begin{pmatrix} a_{km}^2 y_{km} & -a_{km}^2 y_{km} \\ -a_{km}^2 y_{km} & y_{km} \end{pmatrix} \begin{pmatrix} E_k \\ E_m \end{pmatrix} \quad (2.3.15)$$

As seen the metric on the right hand side of eq. (2.3.15) is symmetric, but the diagonal elements are not equal when $a_{km}^2 \neq 1$. Figure 2.9 provides mow the following [7]:

$$I_{km} = (A + B)E_k + (-A)E_m \quad (2.3.16)$$

$$I_{mk} = (-A)E_k + (A + C)E_m \quad (2.3.17)$$

Or in metric form

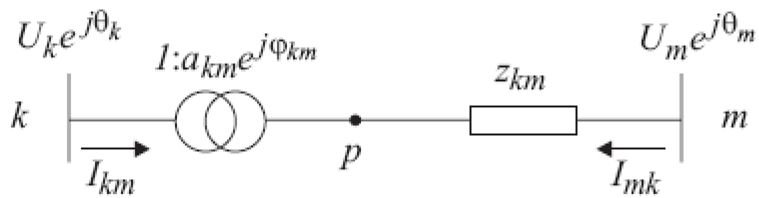
$$\begin{pmatrix} I_{km} \\ I_{mk} \end{pmatrix} = \begin{pmatrix} A + B & -A \\ -A & A + C \end{pmatrix} \begin{pmatrix} E_k \\ E_m \end{pmatrix} \quad (2.3.18)$$

Identifying the matrix elements from the matrices in equations (2.3.15) and (2.3.18) yields

$$A = a_{km}y_{km} \quad (2.3.19)$$

$$B = a_{km}(a_{km} - 1)y_{km} \quad (2.3.20)$$

$$C = (1 - a_{km})\, y_{km} \quad (2.3.21)$$



$$\theta_p = \theta_k + \varphi_{km}$$

$$U_p = a_{km} U_k$$

Figure 2.10 Phase-shifting transformer with t_{km} = $a_{km}^{ej\varphi km}$

Phase-shifting transformers, such as the one represented in Figure 2.10, are used to control active power flows; the control variable is the phase angle and the controlled quantity can be, among other possibilities, the active power flow in the branch where the shifter is placed. A phase-shifting transformer affects both the phase and magnitude of complex voltages E_p and E_k, without changing their ratio,

$$\frac{E_p}{E_k} = t_{km} = a_{km} e^{j\varphi km} \tag{2.3.22}$$

Thus, $\theta_p = \theta_k + \emptyset_{km}$ and U_p = $a_{km}U_k$ using equations (2.3.11) and (2.3.22),

$$\frac{I_{km}}{I_{mk}} = -t_{km}^{*} = -a_{km} e^{-j\varphi km} \tag{2.3.23}$$

As with in-phase transformers, the complex currents I_{km} and I_{mk} can be expressed in terms of complex voltages at the phase-shifting transformer terminals:

$$I_{km} = -t_{km}^{*} y_{km} \left(E_m - E_p \right) = (a_{km}^{2} y_{km}) E_k + (-t_{km}^{*} y_{km}) E_m \tag{2.3.24}$$

$$I_{mk} = y_{km} \left(E_m - E_p \right) = (-t_{km} y_{km}) E_k + (y_{km}) E_m \tag{2.3.25}$$

Or in metric form

$$\begin{pmatrix} I_{km} \\ I_{mk} \end{pmatrix} = \begin{pmatrix} a_{km}^2 & -t_{km}^* y_{km} \\ -t_{km} y_{km} & y_{km} \end{pmatrix} \begin{pmatrix} E_k \\ E_m \end{pmatrix} \quad (2.3.26)$$

If no parallel paths exist, the phase-shifting has no significance. The introduced phase-shift can in such a case been seen as a shift of the phase angle of the reference node. Y-Δ connected transformers are often used to provide zero-sequence de-coupling between two parts of the system, and not for active power flow. For active power flow control usually phase-shifting much lower than 30◦ is needed. Often the phase-shifting could be varied to cope with different loading situations in the system.

2.4.3 Shunt Element

The modeling of shunt elements in the network equations is straight forward and the main purpose here is to introduce the notation and the sign convention to be used when formulating the network equations. As seen from Figure 4.7 the current from a shunt is defined as positive when injected into the bus. This means that,

$$I_k^{sh} = -y_k^{sh} E_k \quad (2.3.27)$$

with E_k being the complex voltage at node *k*. Shunts are in all practical cases either shunt capacitors or reactors. From eq. (2.3.27) the injected complex power is;

$$S_k^{sh} = P_k^{sh} + jQ_k^{sh} = -\left(y_k^{sh}\right) * |E_k| = -\left(y_k^{sh}\right) * U_k^2 \quad (2.3.28)$$

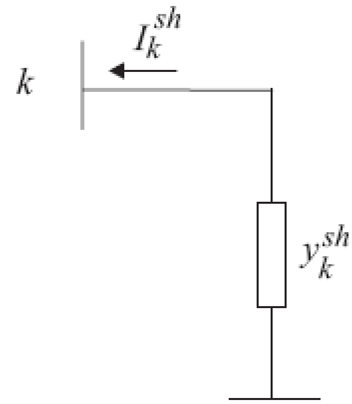


Figure 2.11 A shunt connected to bus *k*

2.4.4 Loads

Load modeling is an important topic in power system analysis. When formulating the load flow equations for high voltage systems, a load is most often the in feed of power to a network at a lower voltage level, for example a distribution network. Often the voltage in the distribution systems is kept constant by controlling the tap-positions of the distribution transformers which means that power, active and reactive, in most cases can be regarded as independent of the voltage on the high voltage side. This means that the complex power $E_k \ (I_k^{load})$ is constant, for example independent of the voltage magnitude U_k. Also in this case the current is defined as positive when injected into the bus, see Figure 4.8. In the general case the complex load current can be written as [7];

$$I_k^{load} = I_k^{load}(U_k) \tag{2.3.29}$$

where the function I_k^{load} describes the load characteristics. More often the load characteristics are given for the active and reactive powers;

$$P_k^{load} = P_k^{load}(U_k) \tag{2.3.30}$$

$$Q_k^{load} = Q_k^{load}(U_k) \quad (2.3.21)$$

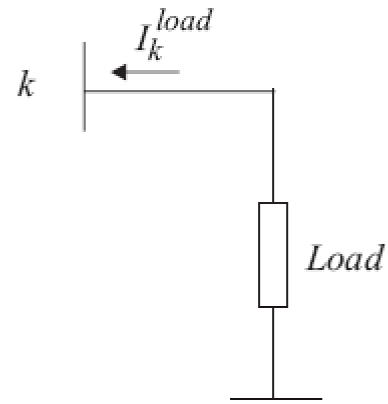


Figure 2.12 Model of a load connected to bus

2.4.5 Generators

Generators are in load flow analysis modeled as current injections, as shown in figure below. In steady state a generator is commonly controlled so that the active power injected into the bus and the voltage at the generator terminals are kept constant. This will be elaborated later when formulating the load flow equations. Active power from the generator is determined by the turbine control and must of course be within the capability of the turbine generator system. Voltage is primarily determined by the reactive power injection into the node, and since the generator must operate within its reactive capability curve it is not possible to control the voltage outside certain limits. The reactive capability of a generator depends on a number of quantities, such as active power, bus voltage and other operating conditions [7].

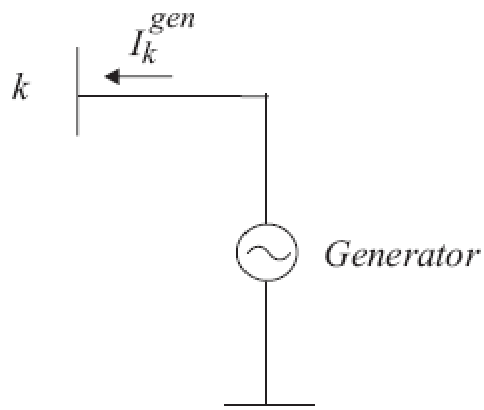


Figure 2.13 Model of a generator connected to bus *k*.

2.5 Summary

The power flow problem is an important tool for design and operation of distribution systems The goal of a power flow study is to obtain complete voltage angle and real power and voltage conditions. To obtain the power flow, hand calculation also useable such as Newton-Raphson, Fast-Decouple and also Gauss Seidel method. Today, it have a lot of software to analysis the power flow. SKM Power Tools for Windows is the most popular software that industry used for the analysis power system network. Planning on how to modeling the system is an important part before use the software. It is because a different software have a different requirement.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will explain about the method used for this project. It also discuss on how to model and simulate the trial system by using SKM Power Tools for Windows. After doing the trial, the same way will be implemented to the real system of Petronas Gas Kerteh.

3.2 Flow Chart of the Project

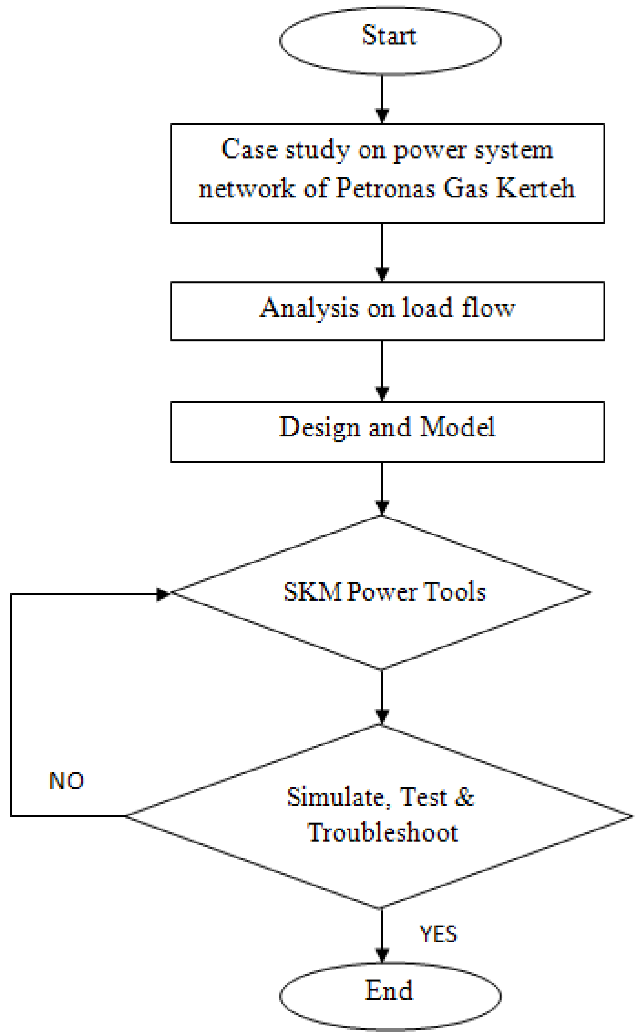


Figure 3.1 Flow Chart of the Project

3.3 Software Usage (SKM POWER TOOLS for WINDOWS)

When start a new project, first set the application options to ensure that working with the correct engineering standard and units of measurement.

3.3.1 Start Power* Tools for Windows (PTW)

To start PTW, the **PTW32** icon was clicked. Make sure that no project are open by clicking **Project>Close**. Then click the **Project>New** command.

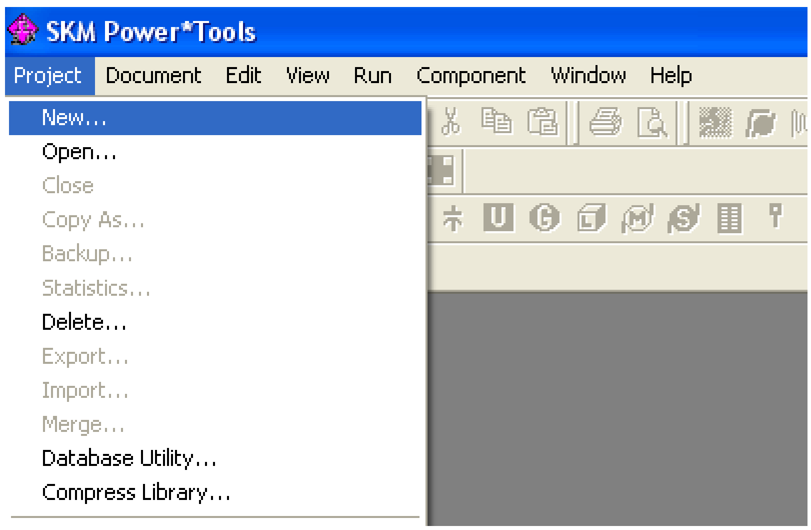


Figure 3.2 Using the Project>New command

3.3.2 Build a System

PTW provide two building tools which use to create Projects: the One-line Diagram, which use to build the electrical system and the Component Editor which use to enter component data.

The Tutorial in the Project Name bon was typed and the Save button was clicked.

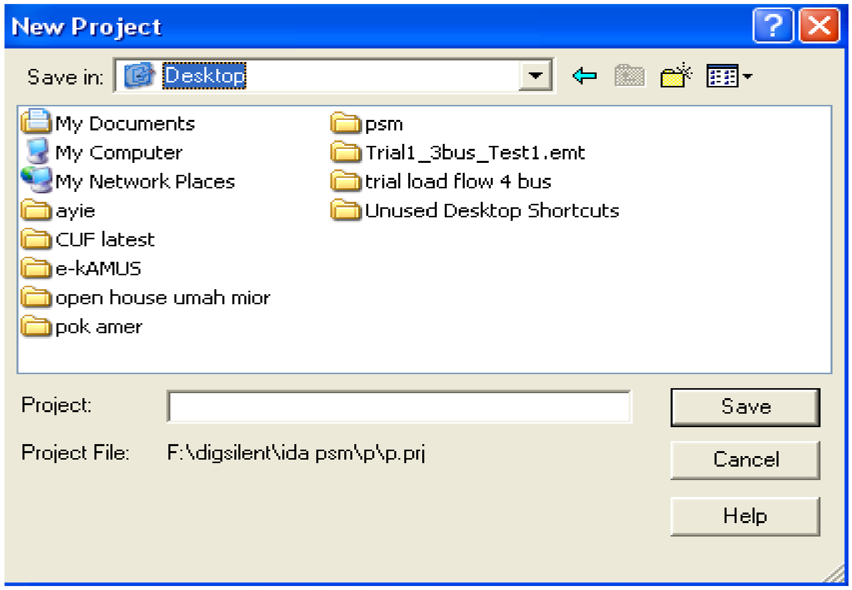


Figure 3.3 Create the Tutorial Project

A Project will build using One-Line Diagram when One-Line Diagram and Component Editor dialog box appear.A component was added by clicking one of the component buttons on the toolbar. The components will arrange like an actual single line diagram for the system.

Figure 3.4 Toolbar Icon

Then, several components and their connection was entered on the one-line diagram.

3.3.3 Enter Component Data

To enter the component data, double clicking left mouse button on the component then Component Editor will appear. All the necessary value was entered.

i. Bus Data

Double click left mouse button on the bus symbol for BUS-0001. The dialog window will appear. Insert the suitable value.

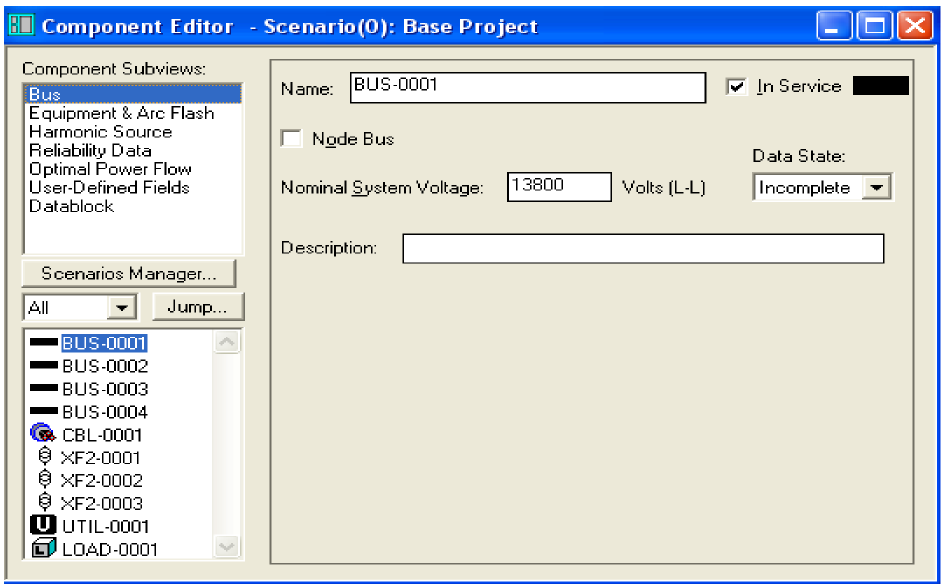


Figure 3.5 Enter voltage for bus

ii. Cable Data

The type of cable was selected from the library. After the cable linked to the library, the description and impedance fields are grey indicating that the values are referenced from the library. To edit this values locally break the link with the library by un-checking the Link to the Lib check box.

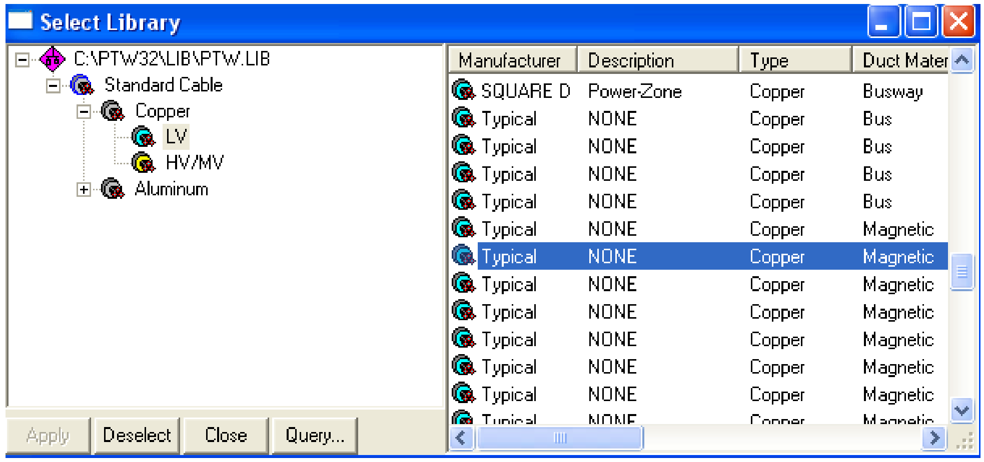


Figure 3.6 Select type of Cable

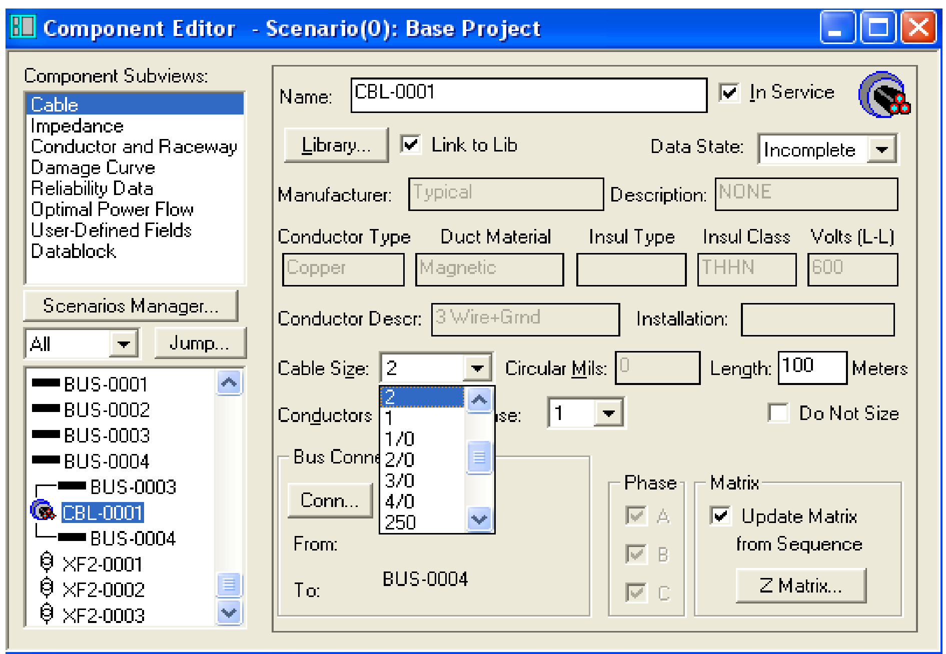


Figure 3.7 Enter Cable Size and Length

iii Transformer Data Input

Type of transformer was selected from the Library. If the data in this library is not available, we can create our own library. Here, 1000 in the Nominal kVA was selected after select type of transformer from the library. This is also screen where we would change the connections, taps and voltage ratings.

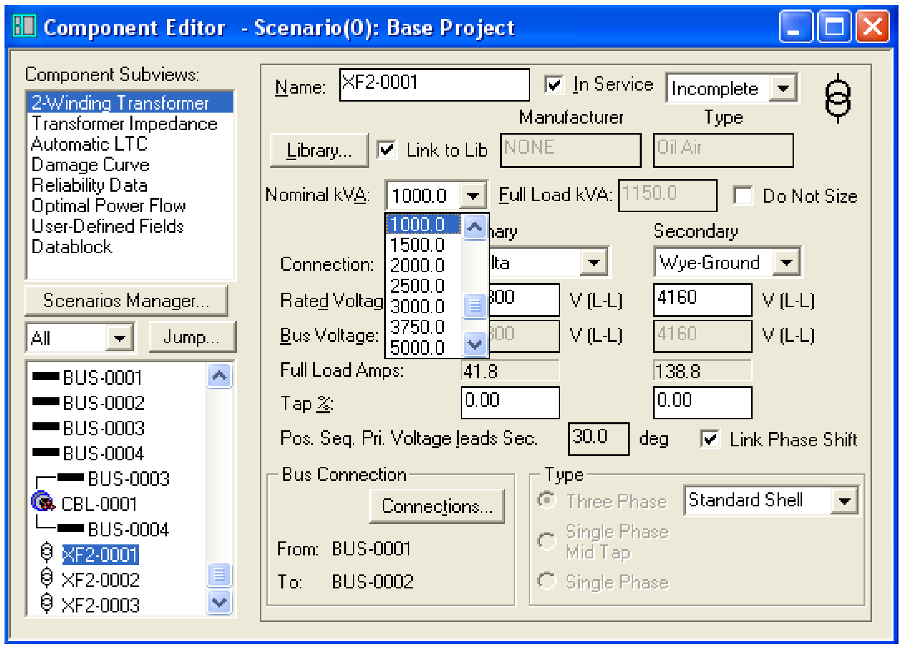


Figure 3.8 Specify the Transformer Size

iv Utility Data Input

The Utility Component UTIL-0001 was entered and entered the data as shown in figure below. The available utility fault contribution can be entered in MVA, KVA, Amps or as an equivalent per unit impedance. The per unit voltage can be used to control pre-fault voltage and load flow source voltage in front of or behind the utility impedance. The equivalent per unit impedance display will be updated when the component is saved.

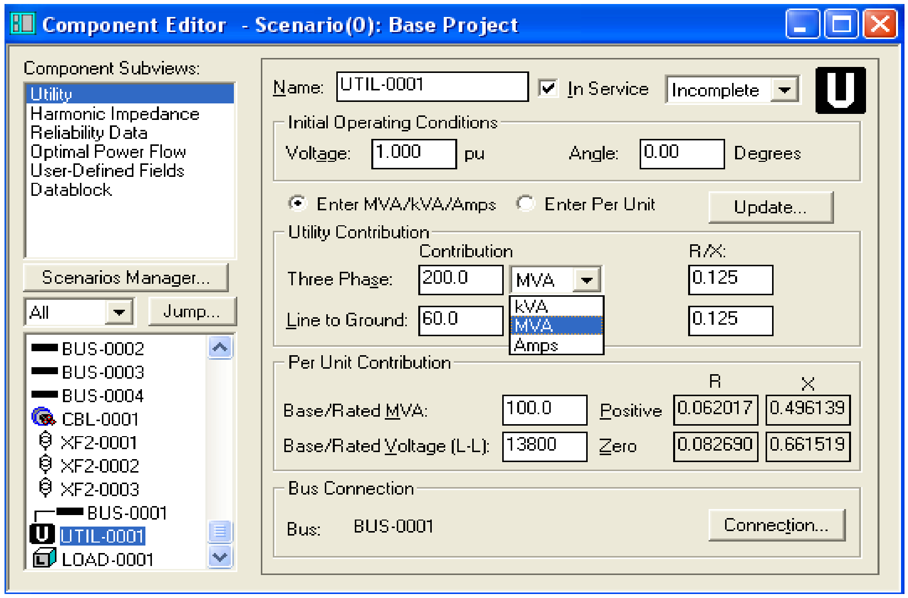


Figure 3.9 Utility fault contribution and voltage entry

v Load Data Input

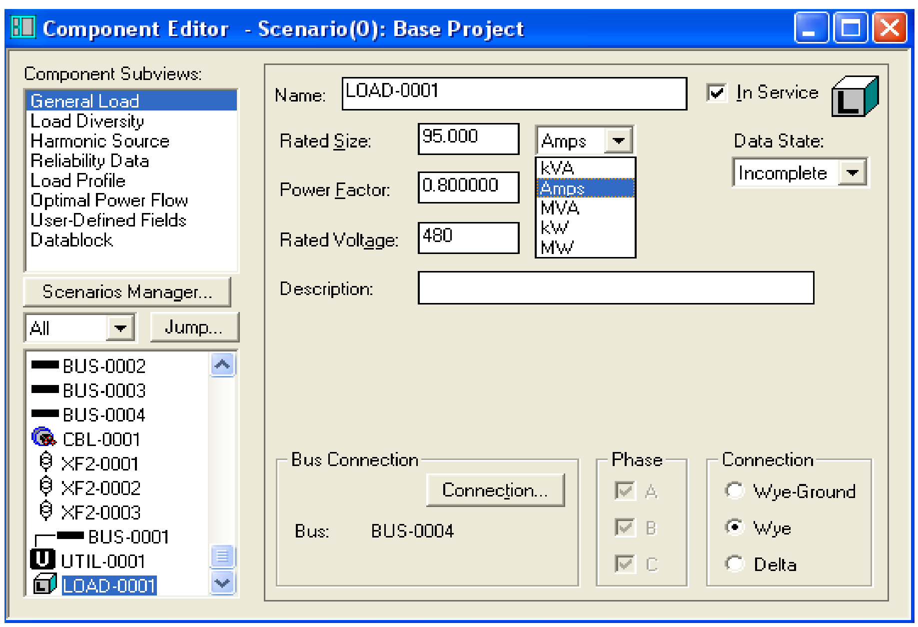


Figure 3.10 Load data entry

After all of the component data was inserted, the Component Editor (**Document>Close**) was closed. Check input data with using the data block display. With the One-Line displayed, the **Run>Datablock** Format was selected.

Then, the Input **Data>Apply>Close button** was selected. The sample Input Data format will display selected input data field next to each component on the one-line. The data block display can be removed using the **View>Datablock** menu option or by using the Tonggle Datablock Icon.

vi Run System Studies

When the data was matches, the Run>Balanced System studied menu option for each study was selected.

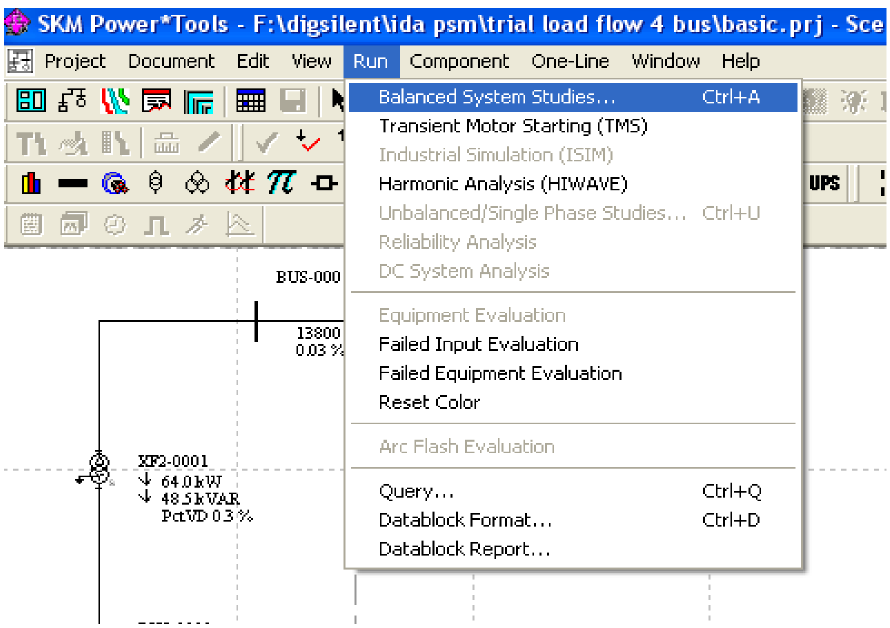


Figure 3.11 Running system studies on the power system network

Once study menu that appears allows you to select the studies to be run, enter report names and specify solution options for each study. The type was selected as shown in figure below. If one or more of the study options are grayed-out and not available in your licensed version, you can continue with the tutorial but recognize you may need to substitute reports and data block references in the rest of the tutorial with reports and data blocks for the studies you have run.

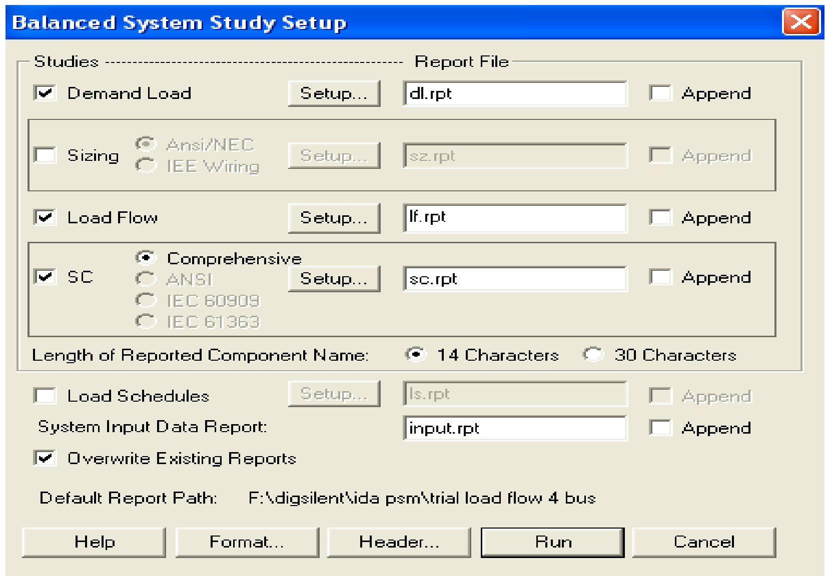


Figure 3.12 Study selection and setup screen

The Study Message window will appear while the studies are running and will remain on the screen after the studies are complete. Review the study log to make sure there are no Fatal Errors reported. Fatal Error will occur if some critical data are missing from the input data. Click on the Close button to close the Study Message Window.

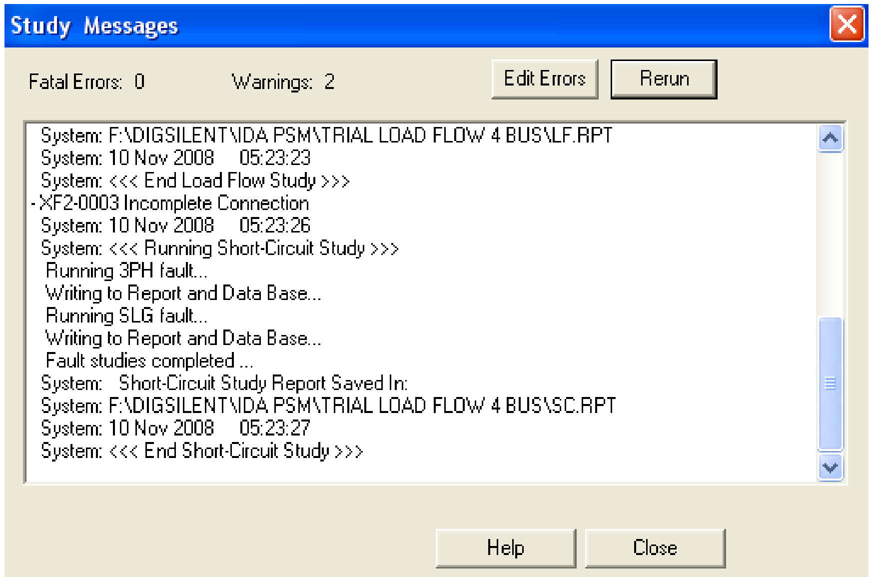


Figure 3.13 Study Message Window

If errors are reported, the Edit Errors button was clicked to display the components that cause the errors.

3.4 Review Study Results

There are several ways to review results and the methods that choose to use for the projects will depend upon the stage of the project and the personal preferences of the people involved.

1. To view a report, go to the Document>Report menu. Open dialog box will appear. Choose one report file for each study that run and open it.
2. The multi-page study report will appear. The study reports are individual text files stored in the project folder.

3.5 Summary

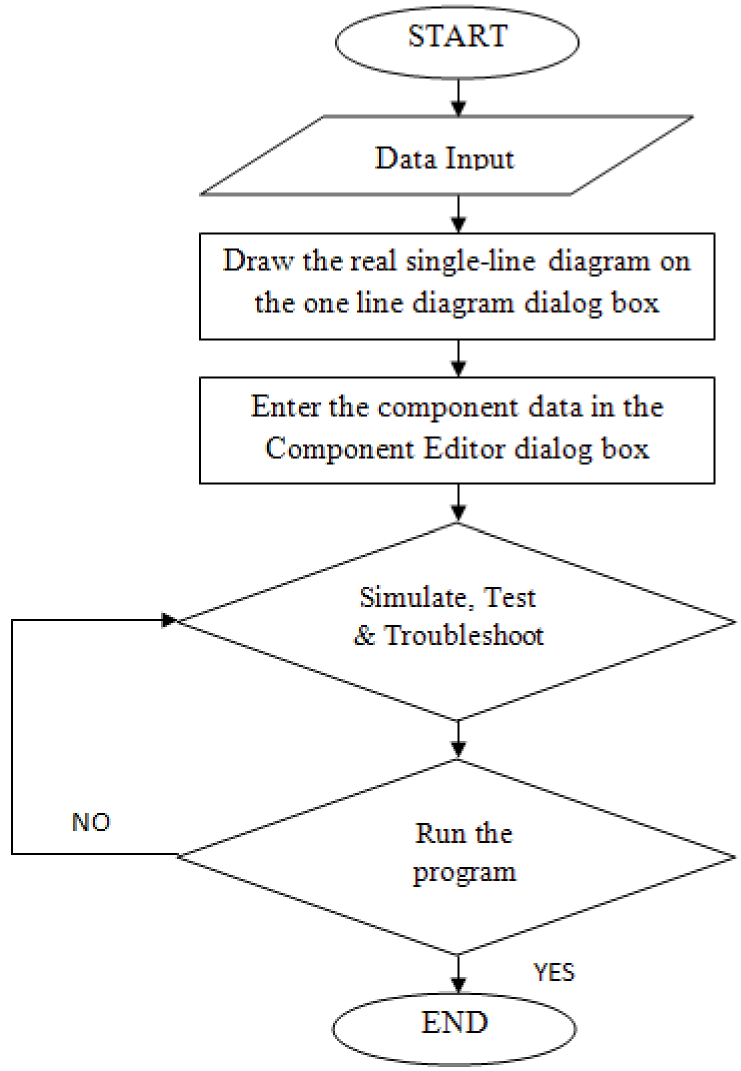


Figure 3.14 Flow-chart of software usage

This system can use until the maximum number of bus is 50 bus. The same way on how to use the system are implemented for the real system of Petronas Gas Kerteh.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

Petronas Gas power flow analysis has done by using SKM Power Tools for Window. Before doing the analysis on the real single line diagram, we do some trial for a simple single line diagram. The purpose of doing this analysis is to make sure that the analysis from the software is same with the real condition. This train system analysis is done also to make sure that the requirement for the other system that we used is correct. Two trial analysis is done. For diagram 4.1, the basic system is from tutorial book. The other analysis is to compare when we used the motor. For the real system of Petronas Gas, it will show in this analysis and the result also shows the different when the generator is used.

4.2 Trial System

Figure 4.1 shows the single line diagram for trial system analysis which has done from the manual book of SKM Power Tools for Windows. From the result, it shows that the value for real power and reactive power when the simulation is running.

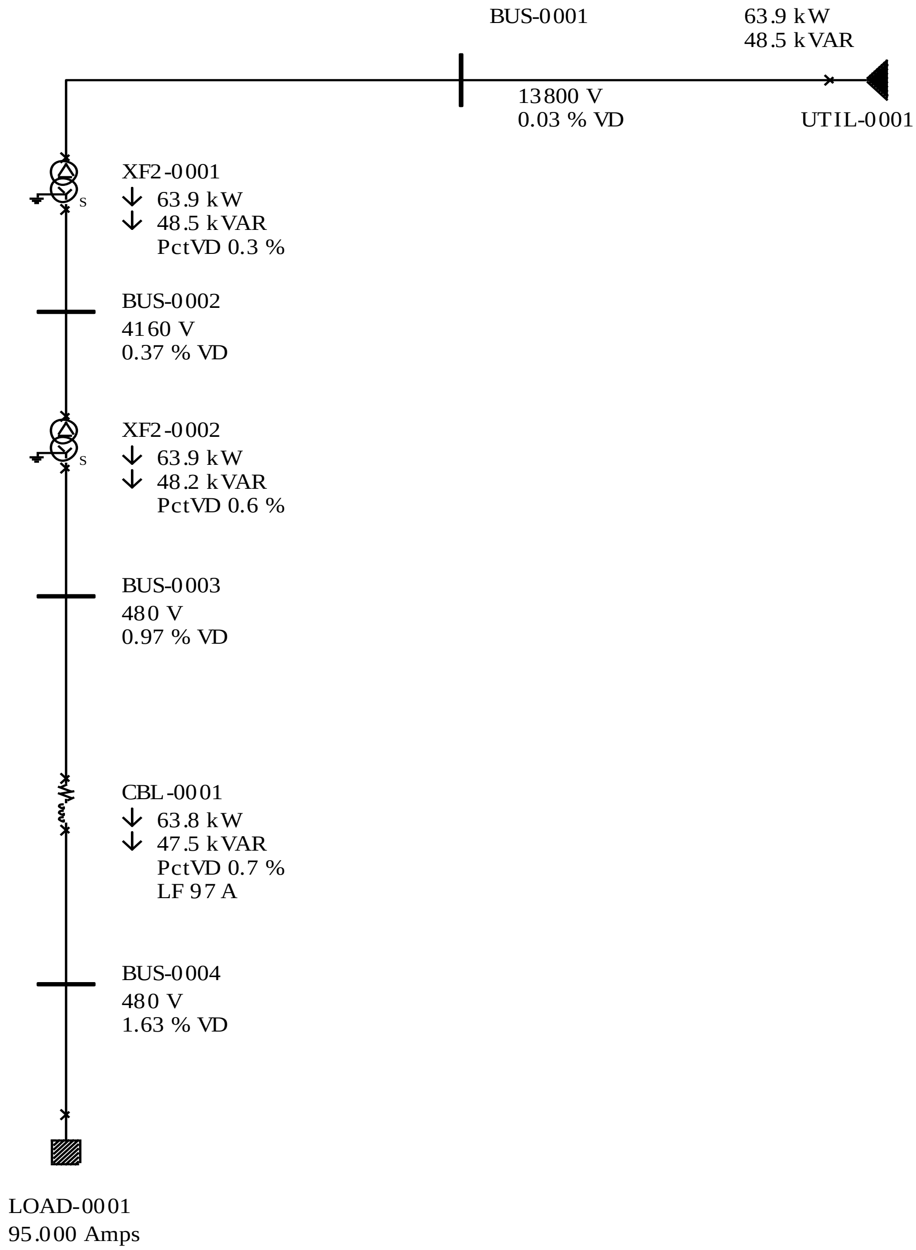


Figure 4.1 Trial system form manual book

Table 4.1 : 4-Bus Branch Data

No	From Bus	To Bus	Real Power (kW)	Reactive Power (kVar)
1	1	2	63.9	48.5
2	2	3	63.9	48.2
3	3	4	63.8	47.5

Figure 4.2 shows the single line diagram for trial system analysis which have a motor. For this analysis, the result for real power and reactive power is different when motor starting and motor running. When motor starting, the value for real power and reactive power is larger than motor running. It is because, motor starting needs more power to start the machine. Figure 4.2 will shows the result of the simulation.

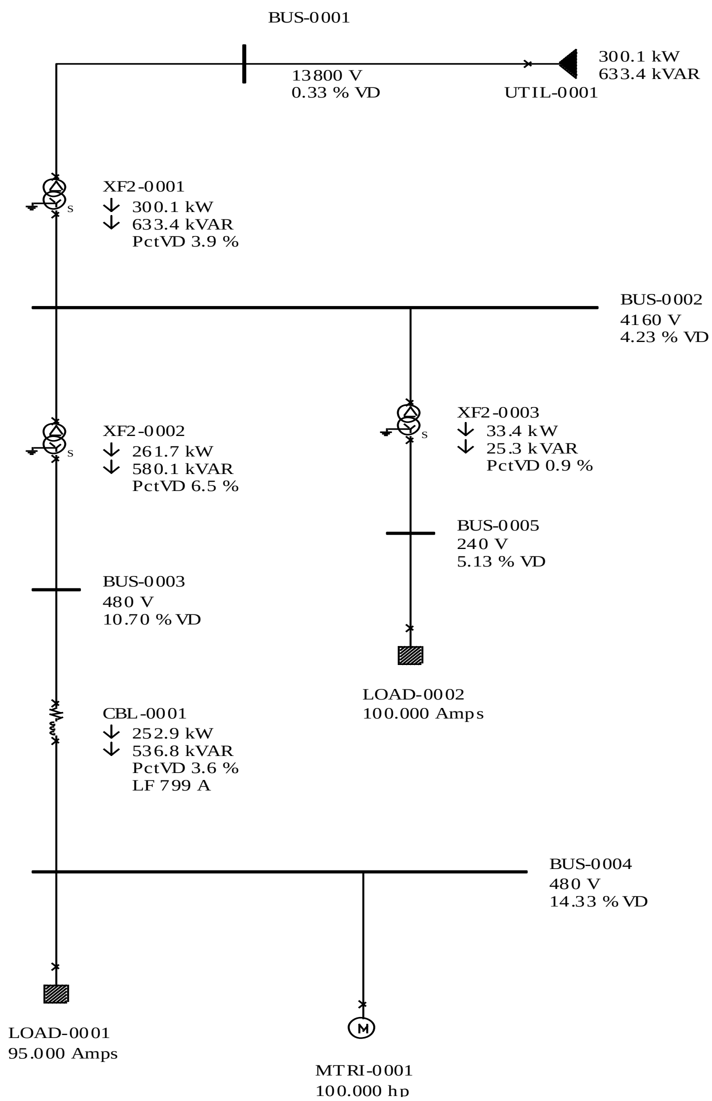


Figure 4.2 Trial system when have a motor

Table 4.2 : Real Power and Reactive Power when motor starting and running

No	From bus	To bus	Motor Running		Motor Starting	
			(kW)	(kVar)	(kW)	(kVar)
1	1	2	195.0	151.1	300.1	633.4
2	2	3	160.9	122.3	261.7	580.1
3		5	33.4	25.3	33.4	25.3
4	3	4	160.8	118.2	252.9	536.8

4.3 Result Power Flow Analysis for real System (Petronas Gas)

This single line diagram is come from Petronas Gas Kerteh. This system actually have 1 utility, 3 generator, 64 buses, 41 cables, 22 2-winding transformer, 14 general loads and 12 motors. The system have been simplified because the software in the University Malaysia Pahang is limited. The maximum bus is 50. After re-design, the system only have 48 buses. Below is the diagram and result for bus and branch data. From the result that at table 4.3 and table 4.3, there have some different between the real system because we already re-design the single-line diagram to fulfill the requirement of the software. The full result of this new real system single-line diagram shown in Appendix C.

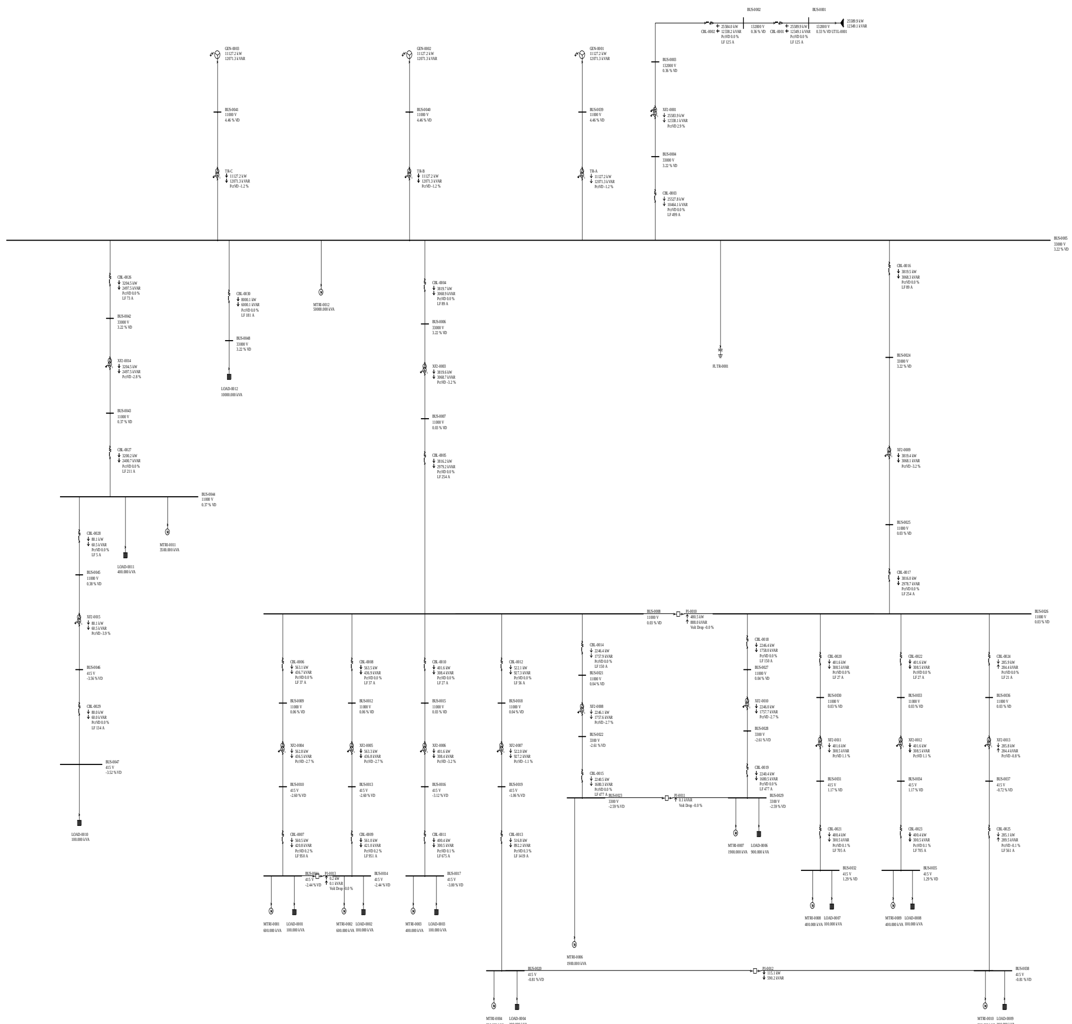


Figure 4.3 Real System Single Line Diagram

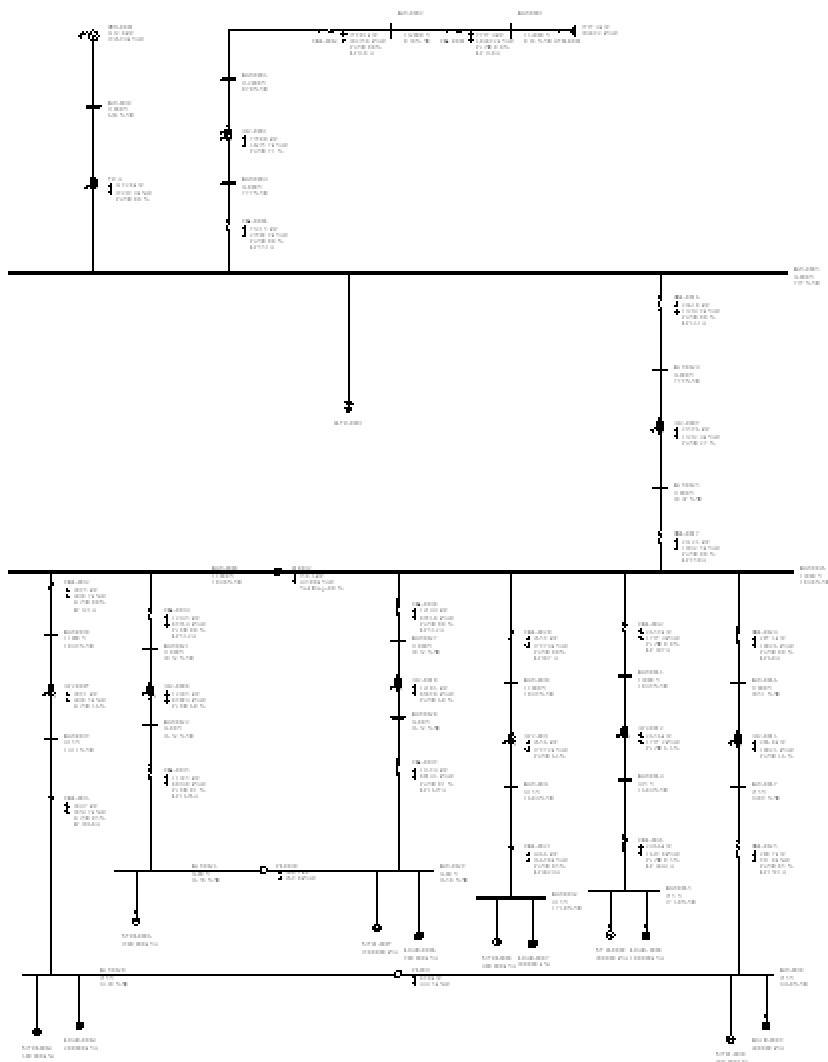


Figure 4.4 Real System (a)

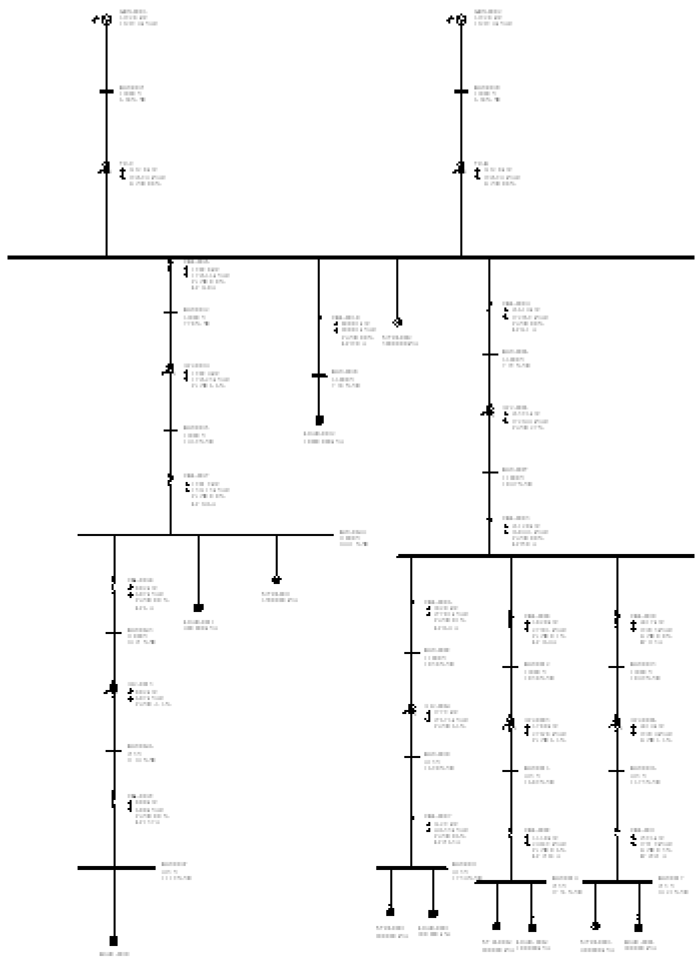


Figure 4.5 Real System (b)

4.3.1 Bus Data

Table 4.3 : Bus Data

No	Bus Name	Base Volt (kV)	PU Volt
1	0001	132	0.9960
2	0002	132	0.9955
3	0003	132	0.9955
4	0004	33	0.9667
5	0005	33	0.9666
6	0006	33	0.9666
7	0007	11	0.9985

8	0008	11	0.9985
9	0009	11	0.9981
10	0010	0.415	1.0247
11	0011	0.415	1.0231
12	0012	11	0.9981
13	0013	0.415	1.0247
14	0014	0.415	1.0231
15	0015	11	0.9985
16	0016	0.415	1.0299
17	0017	0.415	1.0287
18	0018	11	0.9984
19	0019	0.415	1.0094
20	0020	0.415	1.0068
21	0021	11	0.9983
22	0022	3.3	1.0248
23	0023	3.3	1.0246
24	0024	33	0.9666
25	0025	11	0.9985
26	0026	11	0.9985
27	0027	11	0.9983
28	0028	3.3	1.0248
29	0029	3.3	1.0246
30	0030	11	0.9984
31	0031	0.415	0.9871
32	0032	0.415	0.9858
33	0033	11	0.9984
34	0034	0.415	0.9871
35	0035	0.415	0.9858
36	0036	11	0.9984
37	0037	0.415	1.0059
38	0038	0.415	1.0068
39	0039	11	0.9552
40	0040	11	0.9552
41	0041	11	0.9552
42	0042	33	0.9666
43	0043	11	0.9950
44	0044	11	0.9950
45	0045	11	0.9950
46	0046	0.415	1.0343
47	0047	0.415	1.0339
48	0048	33	0.9666

4.3.2 Branch Data

Table 4.4 : Branch Data

No	From Bus	To Bus	P (kW)	Q (kVar)	% VD
1	0001	0002	44294.6	13459.1	0.05
2	0002	0003	44278.8	13429.9	0.00
3	0003	0004	44278.6	13429.7	2.88
4	0004	0005	44129.3	8447.5	0.00
5	0005	0006	3819.7	3069.3	0.00
6		0024	3819.6	3068.8	0.00
7		0042	3204.5	2497.8	0.00
8		0048	8000.1	6000.1	0.00
9	0006	0007	3916.6	3069.2	-3.19
10	0007	0008	3816.2	2979.5	0.00
11	0008	0009	563.1	436.7	0.04
12		0012	563.5	436.9	0.03
13		0015	401.6	308.4	0.00
14		0018	521.8	925.8	0.01
15		0021	2246.4	1758.1	0.02
16	0009	0010	526.8	436.6	-2.66
17	0010	0011	560.5	420.8	0.17
18	0012	0013	563.3	436.8	-2.66
19	0013	0014	561.0	421.0	0.17
20	0015	0016	401.6	308.4	-3.15
21	0016	0017	400.4	300.5	0.12
22	0018	0019	521.7	925.8	-1.09
23	0019	0020	516.5	890.7	0.25
24	0021	0022	2246.1	1757.8	-2.65

25	0022	0023	2240.5	1680.3	0.02
26	0024	0025	3819.4	3068.6	-3.19
27	0025	0026	3816.0	2979.0	0.00
28	0026	0027	2246.4	1758.2	0.02
29		0030	401.6	308.5	0.00
30		0033	401.6	308.5	0.00
31		0036	286.1	-282.9	0.00
32	0027	0028	2246.1	1757.9	-2.65
33	0028	0029	2240.4	1680.5	0.02
34	0030	0031	401.6	308.5	1.14
35	0031	0032	400.4	300.5	0.13
36	0033	0034	401.6	308.5	1.14
37	0034	0035	400.4	300.5	0.13
38	0036	0037	286.1	-283.0	-0.75
39	0037	0038	285.3	-288.0	-0.09
40	0039	0005	4919.7	12520.7	-1.15
41	0040	0005	4919.7	12520.7	-1.15
42	0041	0005	4919.7	12520.7	-1.15
43	0042	0043	3204.5	2497.7	-2.84
44	0043	0044	3200.2	2400.7	0.00
45	0044	0045	80.1	60.5	0.00
46	0045	0046	80.1	60.5	-3.93
47	0046	0047	80.0	60.0	0.04

4.4 Discussion

After all of the analysis have done, some of the require things must be discussed. Load flow analysis refer to the loads, real power, reactive power, voltage p.u and also voltage angle at each bus and each branch. In this real system analysis, is have some differences to the value of the real power and reactive power. From the result, the value of real power and reactive power at bus 132kV and bus 33kV is same as the result from Petronas Gas. Start from bus 11kV the value of real power, reactive power, voltage angle and all of the data is different because the SKM Power Tools for Windows at Universiti Malaysia Pahang is limited. For this problem, the Petronas Gas single line diagram have been re-design to fulfill the requirement of the software.

Petronas Gas Kerteh have 3 generator. At normal condition, this system only use 2 generator. All of this three generator use when the system make a maintenance. This system also get the power from the utility that is TNB. Bacause of the Petronas Gas generates their own electricity, the generator and the utility must operate at the same time. If not enough power from the generator, the losses will increase.

For this software, the value of the component must be entered. So the planning are require to make sure that the simulation will running. Some of the planning are, suitable type of cable, suitable type of transformer that must follow the requirement of the software.

4.5 Summary

Load flow analysis that have been done for Petronas Gas give a full result that related to the power flow. This analysis is important to make sure that the system always in a good condition.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Conclusion

The planning, design and operation of a power system require continual and comprehensive analysis to evaluate current system performance and to determine the effectiveness of alternate plans for future plant expansion.

Mathematical calculation methods were developed to study the electrical the electrical distribution system under some conditions. The calculations allowed operators to determine how best to maximize the operations of their electrical systems. Performing calculations by hand methods is complex and time consuming.

Software has been developed for the personal computer to relieve the system engineer of the repetitive, complex, and time-consuming calculations. The engineer can use the time savings to better plan, design and evaluate the electrical system. Today's software is easy to use. Software has significantly reduced the time required to perform system studies.

Power flow is the most important of the power system study that has been introduced and explain detail. Choice of a particular method in any situation is compromise between the various criteria of goodness of the load flow methods.

If the system is very sensitive to reactive power flows, i.e. the voltages change considerably with change in load and network configuration, the computer program may diverge. It is preferable to allow the reactive power outputs of the generators to be initially without limit to ensue the initial convergence. Convergence having be attained, the computer evaluates the real and reactive power flow in each branch of the system, along with losses ,absorption of vars and any other information that may be required.

RECOMMENDATION

SKM Power Tools for Windows is one of the software that use for planning, design and analyze the electrical power system network. The result from this analysis will give an accurate value base on the trial and the real system that have been used. This software also have more data such as transformer, cable and the other component. It also allow us to create our own library.

Power flow is one of the most analysis that must be evaluate. It is because from the power flow we can know the performance of the power system network. Besides, the other analysis also important to make sure that the system become more efficient and more accurate. For the future recommendation, the other analysis like transient stability, short circuit, arc, harmonics and other analysis must be analyze. It is because, when doing more analysis, student will able to see the real of the system network.

From the software and the analysis, student should able to handle the software. It is because most of the industry use the software and need the analysis of the power system network.

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