

**MODELING STUDY POWER DISTRIBUTION SYSTEM NETWORK USING
DIGSILENT TOOLS SIMULATION SOFTWARE**

LUKMAN HAKIMI BIN WAHAB

UNIVERSITI MALAYSIA PAHANG

UNIVERSITI MALAYSIA PAHANG

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JUDUL: **MODELING STUDY POWER DISTRIBUTION SYSTEM NETWORK USING DIGSILENT POWER FACTORY 13.2 SIMULATION SOFTWARE**

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Saya LUKMAN HAKIMI (821222-03-5427)
(HURUF BESAR)

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17510 TANAH MERAH
KELANTAN**

NORHAFIDZAH BINTI MOHD SAAD

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LUKMAN HAKIMI BIN AB WAHAB

**This thesis is submitted as partial fulfillment of the requirement
for the award of the
Bachelor of Electrical Engineering
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**Faculty of Electrical & Electronics Engineering
Universiti Malaysia Pahang**

NOVEMBER, 2009

“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

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

ABSTRACT

The reason of power flow study is to determine the steady-state operating condition of the electrical power network. The steady-state can be determined by finding out the flow of active power and reactive power throughout the network and the voltages magnitudes and phase angle all nodes of the network. Load flow studies are used to ensure that electrical power transfer from generators to consumers through the grid system is stable, reliable and economic. Using a software allow engineers to solve power system analysis more easily. This project is to produce analyze the power system network plant. It worked by using Digsilent Power Factory. The result can be divide by two which are power flow analysis and short circuit analysis. The power flow will present each voltage at each component .Like low much voltage at the bus bar, including the loading at transformer, cabal, load and motor. Short circuit analysis will initialize the initial short circuit and the peak short circuit. This result from the analysis will be used for another issue such as the safe operation and future growth of the plant.

ABSTRAK

Analisa Kajian beban kuasa di gunakan untuk menentukan keadaan mantap system didalam rangkain system kuasa . Melalui kajian beban kuasa , sesuatu kuasa sahah and kuasa reaktif yang mengalir didalam aliran rangkain elektrik. Begitu jugak dengan magnitude voltan fasa dialam setiap nod dalam rangkain system beban kuasa. Kajian beban kuasa adalah untuk menentukan kuasa elektrik dari utility kepada generator , dan pengguna adalah stabil , berguna dan ekonomi. Hasil Daripada kajian analisa aliran kuasa boleh dipanjangkan kepada lagi kepada analisa kestabilan voltan. Menggunakan perisian berkomputer membenar seorang jurutera menganalisa masalah dengan lebih senang. Tujuan projek ini adalah untuk menganalisa kajian beban kuasa didalam kilang penapisan Petronas. Kajian ini dilakukan menggunakan perisian Dig silent power Factory. Keputusan Kajian terbahagi kepada dua iaitu kajian beban kuasa dan Litar pintas . Kajian Beban Kuasa akan menunjukkan voltan pada setiap bus bar termasuk beban pada transformer , kabel , dan beban pada moto . Untuk litar pintas ia menunjukkan keadaan normal dan keadaan yang paling tinggi untuk sesuatu aliran arus berlaku. Hasil yang diperolehi akan digunakan untuk mengkaji beberapa perkara lain termasuk jugak keadaan selamat dan penambahan pada system tersebut.

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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

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Power Flow studies, commonly refer to as load flow . Power flow studies are of great importance in planning and designing the future expansion of power system as well as determine the best operation of existing operation. The principal information obtained from 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. [1]. 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 [2].

An engineer who understand the operation of system under normal condition will be able to plan ahead for its safe operation and future growth . A good understanding of steady state condition allows engineer to play “ What if ? games .[3]

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 computational technique, have greatly enhanced the analysis and planning tasks [4].

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 [5].

1.2 Objective

The objectives 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 DigSilent 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. To model and simulate the load flow and short circuit analysis for single line diagram by using SKM Power Tools software.Disco.net (Trial System)
- ii. To study the electrical power distribution for Petronas Kerteh
- iii. To apply computer method for electrical power distribution for Petronas Kerteh Plant
 - Load Flow Analysis
 - Fault Analysis

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 Power Flow Analysis

One of the most common computational procedures used in power system analysis is the load flow calculation. The planning, design, and operation of power systems require such calculations to analyze the steady-state (quiescent) performance of the power system under various operating conditions and to study the effects of changes in equipment configuration. These load flow solutions are performed using computer programs designed specifically for this purpose. The basic load flow question is: Given the load power consumption at all buses of a known electric power system configuration and the power production at each bus .[1]

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 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 .

2.4 Fast-decouple Power Flow Solution

When solving large scale power transmission systems, an alternative strategy for improving computational efficiency and reducing computer storage requirements is the decoupled power flow method, which makes use of an approximate version of the Newton-Raphson procedure.

For large scale power system, usually the transmission lines have a very high X/R ratio. For such a system, real power changes ΔP are less sensitive to changes in voltage magnitude and are most sensitive to changes in phase angle $\Delta\delta$. Similarly, reactive power is less sensitive to changes in angle and most sensitive on changes in voltage magnitude. Incorporate of these approximations into the Jacobian matrix in Newton-Raphson power flow solution makes the elements of the submatrices J_{12} and J_{21} zero. [7]

We are then left with two separated systems of equations,

$$\begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \dots & \frac{\partial P_2}{\partial \delta_n} \\ \vdots & J_{11} & \vdots \\ \frac{\partial P_n}{\partial \delta_2} & \dots & \frac{\partial P_n}{\partial \delta_n} \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \vdots \\ \Delta\delta_n \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \end{bmatrix} \quad (2.48)$$

$$\begin{bmatrix} |V_2| \frac{\partial Q_2}{\partial |V_2|} & \dots & |V_n| \frac{\partial Q_2}{\partial |V_n|} \\ \vdots & J_{22} & \vdots \\ |V_2| \frac{\partial Q_n}{\partial |V_2|} & \dots & |V_n| \frac{\partial Q_n}{\partial |V_n|} \end{bmatrix} \begin{bmatrix} \frac{\Delta|V_2|}{|V_2|} \\ \vdots \\ \frac{\Delta|V_n|}{|V_n|} \end{bmatrix} = \begin{bmatrix} \Delta Q_2 \\ \vdots \\ \Delta Q_n \end{bmatrix} \quad (2.49)$$

In well-designed and properly operated power transmission system:

- i) Angular differences between typical buses of the system are usually so small.

$$\delta_{ij} = (\delta_i - \delta_j) \text{ very small that results,}$$

$$\cos \delta_{ij} \approx 1$$

$$\sin \delta_{ij} \approx 0.0$$

- ii) The line susceptances B_{ij} are many times larger than the line conductances G_{ij} so that $G_{ij} \sin \delta_{ij} \ll B_{ij}$.

- iii) The reactive power Q_i injected into any bus i of the system during normal operation is much less than the reactive power which would flow if all lines from that bus were short circuited to reference.

$$\text{That is } Q_i \ll |V_i|^2 B_{ii}.$$

In Equation 2.32 and Equation 2.41, the off diagonal elements of J_{11} and J_{22} are given by

$$|V_j| \frac{\partial Q_i}{\partial V_j} = -|V_j| |Y_{ij} V_i| \sin(\theta_{ij} + \delta_j - \delta_i) = \frac{\partial P_i}{\partial \delta_j} \quad (2.50)$$

Using the identity $\sin(\alpha + \beta) = \sin \alpha \cos \beta + \cos \alpha \sin \beta$ in Equation 2.50 gives us

$$\frac{\partial P_i}{\partial \delta_j} = |V_j| \left| \frac{\partial Q_i}{\partial |V_j|} \right| = -|V_i V_j| B_{ij} \cos(\delta_j - \delta_i) + G_{ij} \sin(\delta_j - \delta_i) \quad (2.51)$$

The approximation listed above then yield the off diagonal elements

$$\frac{\partial P_i}{\partial \delta_j} = |V_j| \left| \frac{\partial Q_i}{\partial |V_j|} \right| = -|V_i V_j| B_{ij} \quad (2.52)$$

The diagonal elements of J_{11} and J_{22} are shown in Equation 2.30 and Equation 2.40 respectively. Applying the inequality $Q_i \ll |V_i|^2 B_{ii}$ to those expressions yields

$$\frac{\partial P_i}{\partial \delta_i} \cong |V_i| \frac{\partial Q_i}{\partial \delta_i} \cong -|V_i|^2 B_{ii} \quad (2.53)$$

Substitute Equation 2.52 and Equation 2.53 into Equation 2.48 and Equation 2.49, we obtain

$$\begin{bmatrix} -|V_2 V_2| B_{22} & -|V_2 V_3| B_{23} & \cdots & -|V_2 V_n| B_{2n} \\ -|V_2 V_3| B_{32} & -|V_3 V_3| B_{33} & \cdots & -|V_3 V_n| B_{3n} \\ \vdots & \vdots & \vdots & \vdots \\ -|V_2 V_n| B_{n2} & -|V_3 V_n| B_{n3} & \cdots & -|V_n V_n| B_{nn} \end{bmatrix} \begin{bmatrix} \Delta \delta_2 \\ \Delta \delta_3 \\ \vdots \\ \Delta \delta_n \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \vdots \\ \Delta P_n \end{bmatrix} \quad (2.54)$$

$$\begin{bmatrix} -|V_2 V_2| B_{22} & -|V_2 V_3| B_{23} & \cdots & -|V_2 V_n| B_{2n} \\ -|V_2 V_3| B_{32} & -|V_3 V_3| B_{33} & \cdots & -|V_3 V_n| B_{3n} \\ \vdots & \vdots & \vdots & \vdots \\ -|V_2 V_n| B_{n2} & -|V_3 V_n| B_{n3} & \cdots & -|V_n V_n| B_{nn} \end{bmatrix} \begin{bmatrix} \frac{\Delta |V_2|}{|V_2|} \\ \frac{\Delta |V_3|}{|V_3|} \\ \vdots \\ \frac{\Delta |V_n|}{|V_n|} \end{bmatrix} = \begin{bmatrix} \Delta Q_2 \\ \Delta Q_3 \\ \vdots \\ \Delta Q_n \end{bmatrix} \quad (2.55)$$

We can also modify Equation 2.54 and Equation 2.55 to two decoupled systems of equations for n-bus network.

$$\underbrace{\begin{bmatrix} -B_{22} & -B_{23} & \cdots & -B_{2n} \\ -B_{32} & -B_{33} & \cdots & -B_{3n} \\ \vdots & \vdots & \vdots & \vdots \\ -B_{n2} & -B_{n3} & \cdots & -B_{nn} \end{bmatrix}}_{B'} \begin{bmatrix} \Delta \delta_2 \\ \Delta \delta_3 \\ \vdots \\ \Delta \delta_n \end{bmatrix} = \begin{bmatrix} \frac{\Delta P_2}{|V_2|} \\ \frac{\Delta P_3}{|V_3|} \\ \vdots \\ \frac{\Delta P_n}{|V_n|} \end{bmatrix} \quad (2.56)$$

or

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \vdots \\ \Delta\delta_n \end{bmatrix} = -[B']^{-1} \begin{bmatrix} \frac{\Delta P_2}{|V_2|} \\ \frac{\Delta P_3}{|V_3|} \\ \vdots \\ \frac{\Delta P_n}{|V_n|} \end{bmatrix} \quad (2.57)$$

And

$$\underbrace{\begin{bmatrix} -B_{22} & -B_{23} & \cdots & -B_{2n} \\ -B_{32} & -B_{33} & \cdots & -B_{3n} \\ \vdots & \vdots & \ddots & \vdots \\ -B_{n2} & -B_{n3} & \cdots & -B_{nn} \end{bmatrix}}_{B'} \begin{bmatrix} \Delta|V_2| \\ \Delta|V_3| \\ \vdots \\ \Delta|V_n| \end{bmatrix} = \begin{bmatrix} \frac{\Delta Q_2}{|V_2|} \\ \frac{\Delta Q_3}{|V_3|} \\ \vdots \\ \frac{\Delta Q_n}{|V_n|} \end{bmatrix} \quad (2.58)$$

or

$$\begin{bmatrix} \Delta|V_2| \\ \Delta|V_3| \\ \vdots \\ \Delta|V_n| \end{bmatrix} = -[B']^{-1} \begin{bmatrix} \frac{\Delta Q_2}{|V_2|} \\ \frac{\Delta Q_3}{|V_3|} \\ \vdots \\ \frac{\Delta Q_n}{|V_n|} \end{bmatrix} \quad (2.59)$$

B_{ij} are the imaginary parts of the corresponding Y_{bus} elements.

2.5 Power System Modeling

Computer programs to solve load flows are divided into two types-static (offline) and dynamic (real time). Most load flow studies for system analysis are based on static network models. Real time load flows (online) that incorporate data input from the actual networks are typically used by utilities in automatic Supervisory Control And Data Acquisition (SCADA) systems. Such systems are used primarily as operating tools for optimization of generation, var control, dispatch, losses, and tie line control. This discussion is concerned with only static network models and their analysis. 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 [13].

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

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 [13]

2.5.1 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 2.0 The parameters above are specific for the line or cable configuration and are dependent on conductors and geometrical arrangements [13]

From the circuit in Figure 2.5.1 the telegraph equation is derived, and from this the lumped-circuit line model for symmetrical steady state conditions, Figure 2.1 This model is frequently referred to as the π -model, and it is characterized by the parameters [7];

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

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

$Z_{km} = R_{km} + jX_{km}$ = series impedance (Ω)

$Y_{km}^{sh} = G_{km}^{sh} + jB_{km}^{sh}$ = shunt admittance (siemens)

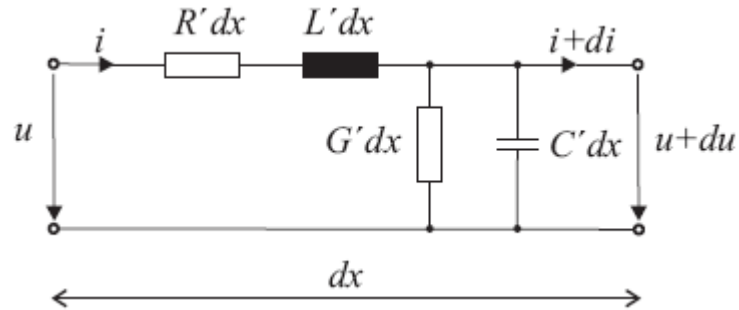


Figure 2.0 Equivalent circuit of a line element of length dx

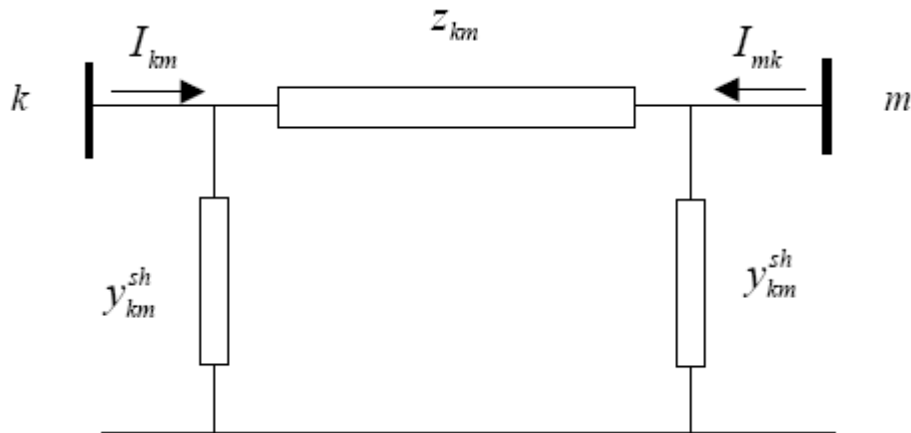


Figure 2.1 Lumped-circuit model (π -model) of a transmission line between nodes k and m

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 \underline{z}_{km} we will write z_{km} 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 [13].

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

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

With

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

And

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

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 [13];

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

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

where the complex voltages are

$$E_k = U_k e^{j\theta_k} \quad (2.3.6)$$

$$E_m = U_m e^{j\theta_m} \quad (2.3.7)$$

This can also be written in matrix form as

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

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 .

2.5.2 Transformer

Additional data is required for transformers. This can either be entered as part of the branch data or as a separate data category depending on the particular load flow program being used. This additional data usually includes the following:

- i. Tap setting in per unit
- ii. Tap angle in degrees
- iii. Maximum tap position
- iv. Minimum tap position
- v. Scheduled voltage range with tap step size or a fixed scheduled voltage using a continuous tap approximation

The last three data items are needed only for load tap changing (LTC) transformers that automatically vary their tap setting to control voltage on one side of the transformer.

The organization of transformer tap data requires an understanding of the tap convention used by the load flow program to ensure the representation gives the correct boost or buck in voltage. Transformers whose rated primary or secondary voltages do not match the system nominal (base kV) voltages on the terminal buses will require an off-nominal tap representation in the load flow (and possibly require corresponding adjustment of the transformer impedance).

2.5.3 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 2.2 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;

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

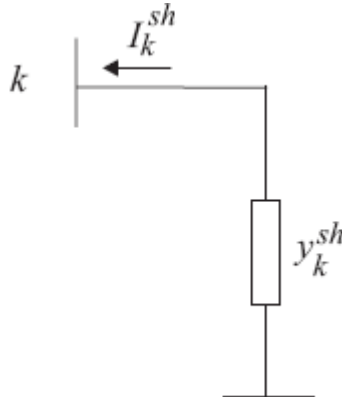


Figure 2.2 A shunt connected to bus k

2.5.4 Branch data

Data is also entered for each branch in the system. Here the term “branch” refers to all elements that connect two buses including transmission lines, cables, series reactors, series capacitors, and transformers. The data items include the following:

- i. Resistance
- ii. Reactance
- iii. Charging susceptance (shunt capacitance)
- iv. Line ratings
- v. Line in-service/out-of-service code
- vi. Line-connected shunts

lines are represented by a model with series resistance and reactance and one-half of the charging susceptance placed on each end of the line. The resistance, reactance, and susceptance are usually input in either per unit or percent, depending on program convention.

Line rating are normally input in amperes or MVA. Current ratings can be converted to with the formula:

$$\text{rating}_{\text{MVA}} = \frac{\sqrt{3} \times \text{kV}_{\text{BASE}} \times \text{rating}_{\text{A}}}{1000}$$

A series reactor, series capacitor, or transformer would not have a charging susceptance term. The modeling of the charging susceptance is often ignored for short overhead lines and industrial plant systems.

2.5.5 Generator data

Generator data is entered for each generator in the system including the system swing generator. The data defines the generator power output and how voltage is controlled by the

generator. The data items normally entered are as follows:

- i. Real power output in MW
- ii. Maximum reactive power output in Mvar (i.e., machine maximum reactive limit)
- iii. Minimum reactive power output in Mvar (i.e., machine minimum reactive limit)
- iv. Scheduled voltage in per unit
- v. Generator in-service/out-of-service code

Other data items that may be included are the generator MVA base and the generator's internal impedance for use in short-circuit and dynamic studies. The use of the above data items to determine the generator voltage and reactive power. Some programs may allow a generator to regulate a remote bus voltage.

2.6 Summary

It should be evident to designers and operators of industrial plant electrical systems, as well as to utility system engineers, that a tool that predicts the performance of their electrical systems under various operating conditions that can actually be encountered before these conditions occur is of value. 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. When solving large scale power transmission systems, an alternative strategy for improving computational efficiency and reducing computer storage requirements is the decoupled power flow method, which makes use of an approximate version of the Newton-Raphson procedure. Today, it have a lot of software to analysis the power flow. SKM Power Tools for Windows , Dig Silent and also PSCAD 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 and Dig Silent. Dig SILENT stands for Digital Simulator for Electrical Network . It is a computer aided design engineering tool for the analysis of power systems . It supports both the load flow calculations and transient stability analysis of electrical networks. Dig Silent's development was started in Germany in 1976 . Its version 7 was the world's first power system analysis software to have an integrated graphical one-line interface [14]. In this thesis, Dig SILENT educational version 13.2 was used. The new **Dig SILENT Power Factory** software is an integrated power system analysis tool that combines reliable and flexible system modeling capabilities, with state-of-the-art solution algorithms and a unique database management concept

3.2 Flow Chart of the Project

3.3 Load Flow Calculation in Dig SILENT

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

3.3.1 Creating a new project

Before any simulation can be performed in Dig SILENT, a project must be created. The project can be created by left clicking on *File* on the main menu bar as shown in figure 3.2 below and then selecting *new* on the drop down menu that appears.

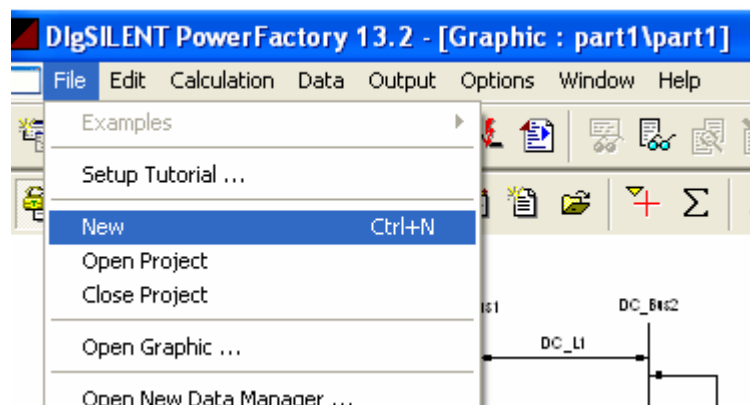


Figure 3.2 Creating a new project 1

3.3.2 Build a System

A small window shown in figure 3.3 below, appears and a new project is created by choosing the project option on it.

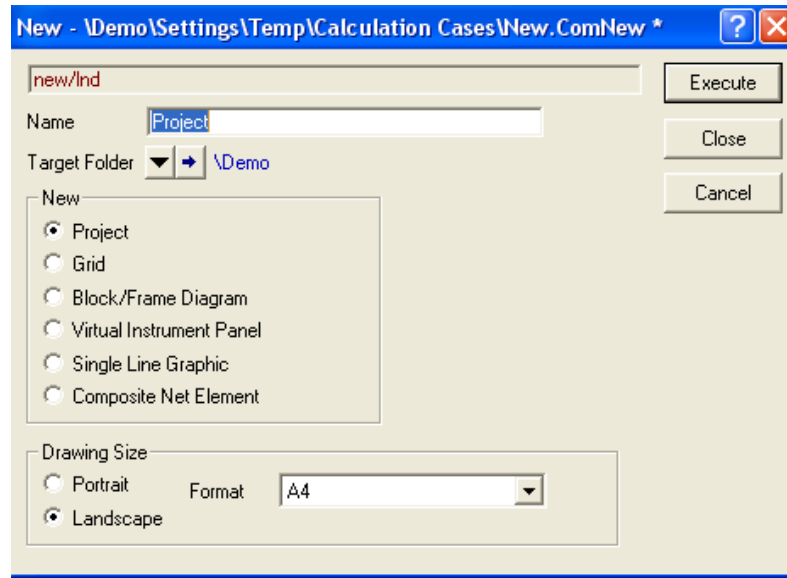


Figure 3.3 Execute Project

The grid dialogue window shown in figure 3.4 below will appear.

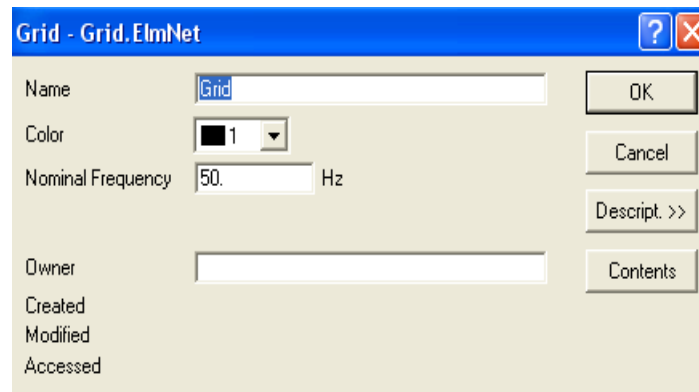


Figure 3.4 The grid dialogue

It can be renamed and then the ok button should be pressed in order to activate the new project. The project will have a *workspace* (a window that is normally used for displaying single line graphs of power system components, results graphs and other virtual instruments) with one single line graph window. There is an option to add more single line graph windows and other windows such as virtual instrument panels. A virtual instrument panel is a window that is used to display graphs and other virtual instruments.

3.3.3 Step 2: Creating a single line graph

A single line graph is a graphic display of power system components that have been connected together to form a power system. It is created by selecting components in the graphic tool box on the left of the Dig Silent's window and then joining them together. The Dig Silent's tool box has got a wide range of commonly used power system components which include but are not limited to synchronous machines, HVDC converters, transmission lines and loads. The Dig Silent's window is shown in figure 3.5 on the next page.

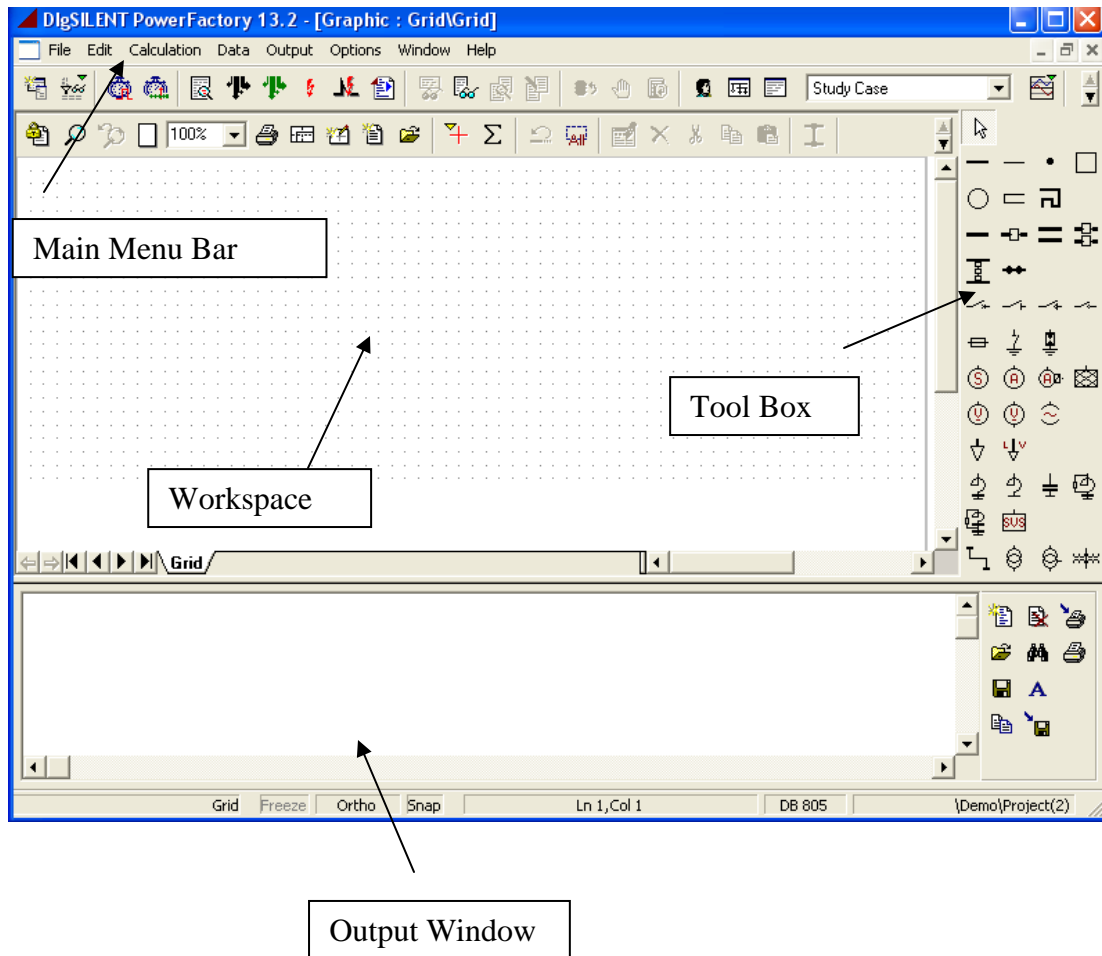


Figure 3.5 DigSILENT's window

3.3.4 Performing the actual calculation

The load flow can be performed in two ways, which are;

- i. By clicking calculation on the main menu bar and then choosing load flow.
- ii. By clicking the load flow button on the tool bar.

When either of the actions described in the previous page is performed, the window shown in figure 3.6 below pops up.

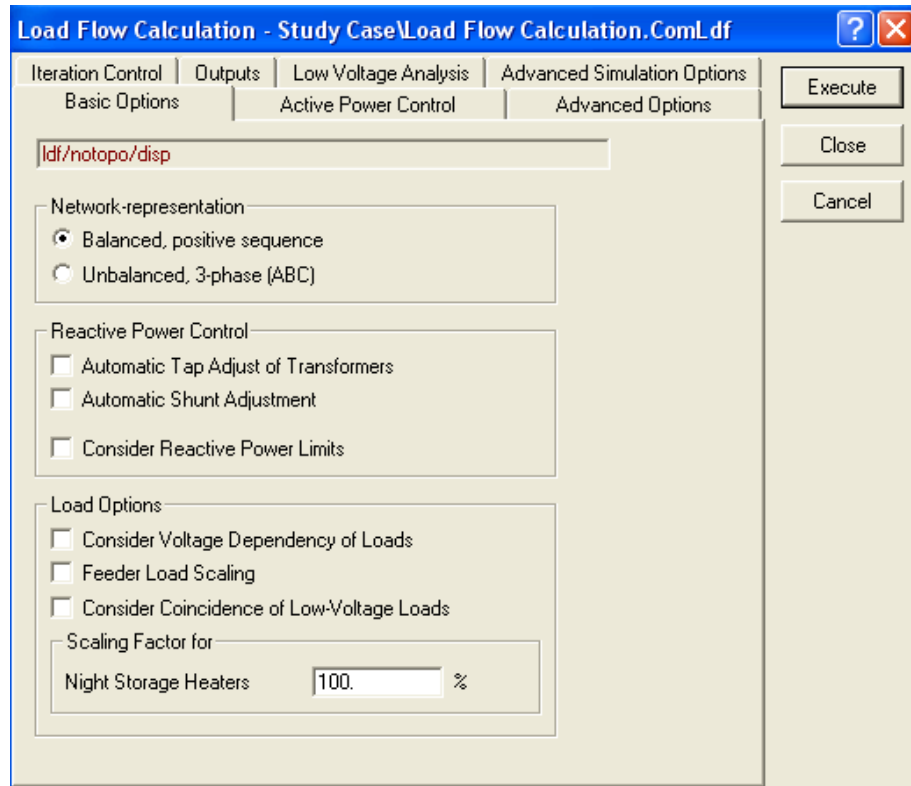


Figure 3.6 : Performing a load flow calculation

The user can then choose the desired calculation options and then continue with the calculation by pressing the execute button. The user has an option to perform a calculation for a balanced positive sequence network representation or an unbalanced three phase network representation. The *balanced, positive sequence* option performs load-flow calculations for a one-phase, positive sequence network representation and it is only valid for balanced networks while the *unbalanced 3 phase (ABC)* option performs load-flow calculations for multi-phase network Representation and is suitable for analyzing unbalances of 3-phase systems [14].

After performing a load flow, a message appears in the output window, stating whether the calculation has been successful or not. If the calculation was not successful

the source of the error is stated in the message. If the error occurred in the calculation due to a wrong or bad configuration of one of the power system components, double clicking the error message causes the *edit window* of that component to pop up. The parameters of that component can then be edited accordingly.

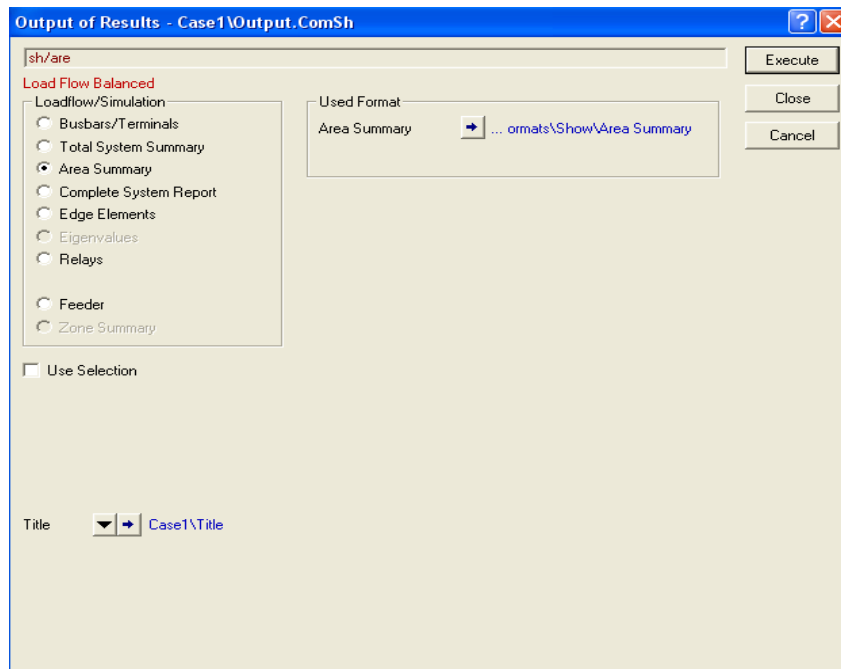


Figure 3.7 : Viewing the output results

The user can then choose the desired output documentation method as it can be seen from figure 3.7 above. An ideal option for a load flow calculation is the Busbar/Terminal option, which gives the following data for all bus bars and terminals

- i. Voltage magnitudes and angles in p.u. and in standard units.
- ii. Active and Reactive power magnitudes in p.u. and in standard units.
- iii. Rated bus voltages in standard units.
- iv. Power factor
- v. Current
- vi. Percentage line loading

When the execute button is pressed, the load flow data appears in the output window. The data can be saved and be opened later using other software applications such as *Notepad*. Although the data is in tabular form, opening it with Microsoft offices excel makes it illegible. This makes it difficult to document it for analysis and reports.

3.4 Overview of SKM POWER TOOLS for WINDOWS

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

3.4.1 Creating a single line graph

The electrical palette on the right of the SKM window contains a variety of common components such as transmission lines and cables and the control palette contains components such as *output channels* and *real constants*. The *drag and drop* method can be used to drag these components from their respective palettes into the edit window. The components can then be joined together to form a required power system

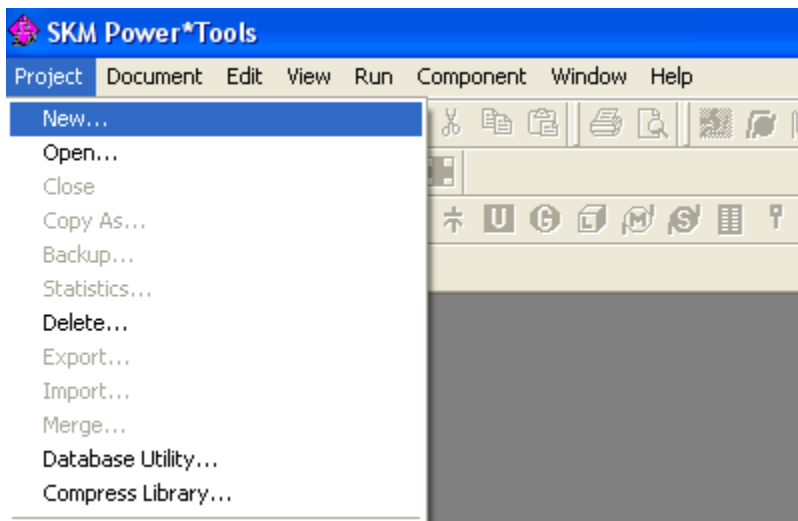


Figure 3.8 Using the Project>New command

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.

3.4.2 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.

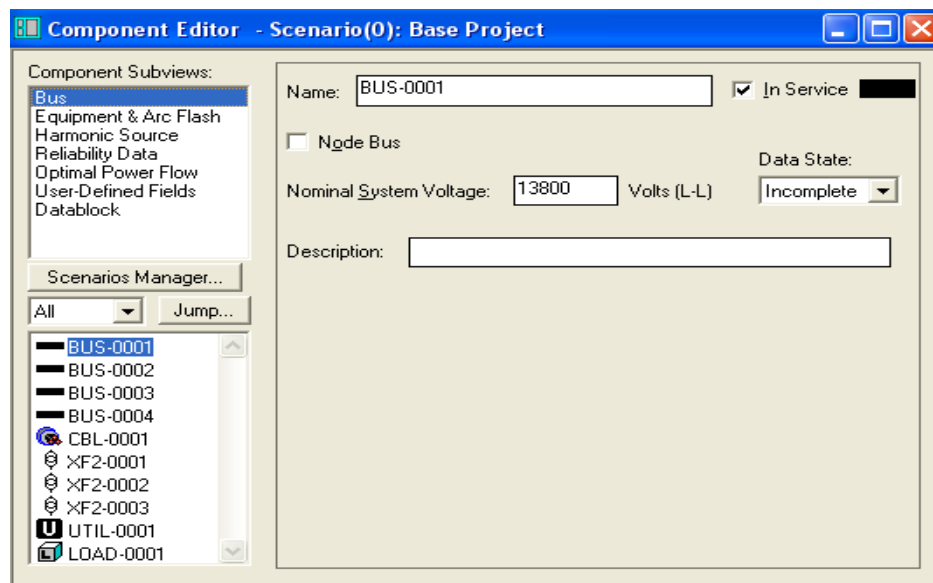


Figure 3.9 Enter voltage for bus

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.

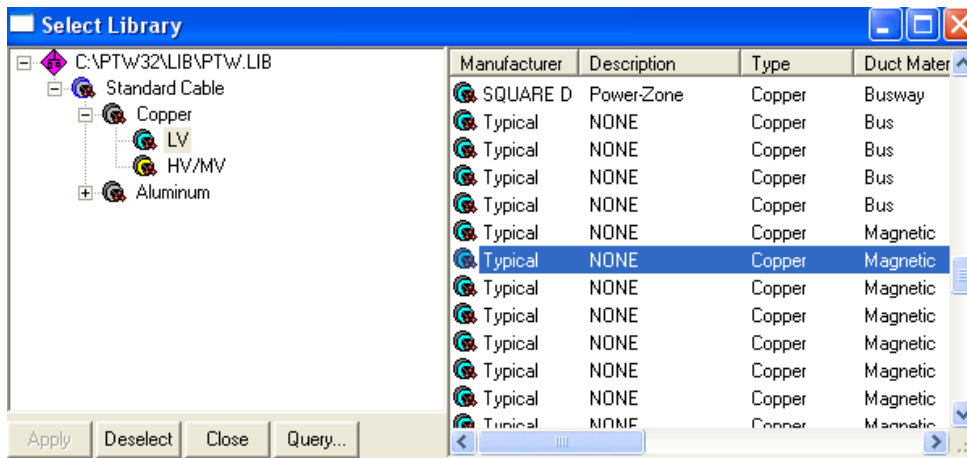


Figure 3.10 Select type of Cable

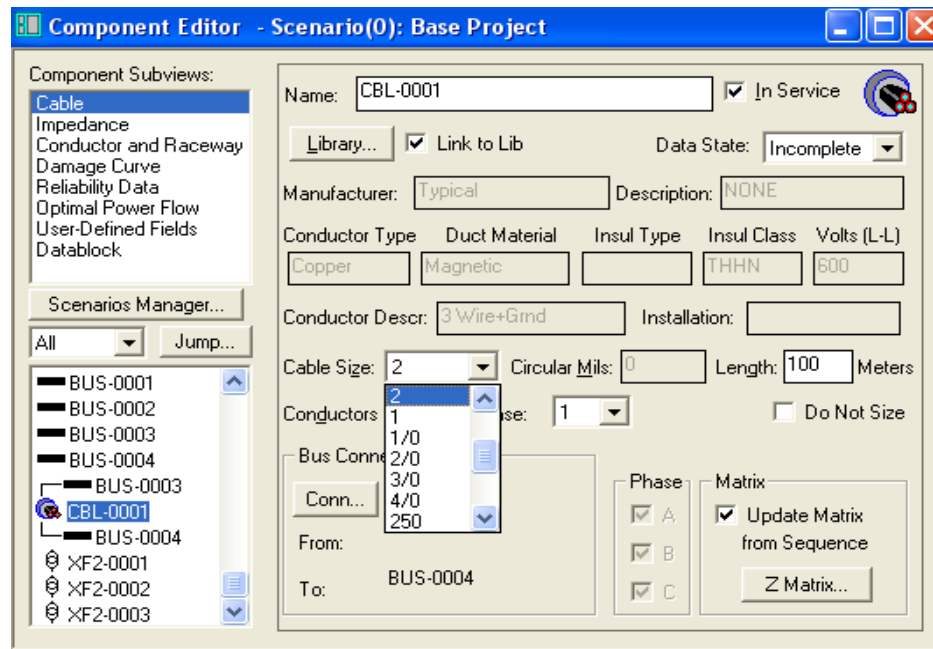


Figure 3.11 Enter Cable Size and Length

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, the value 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.

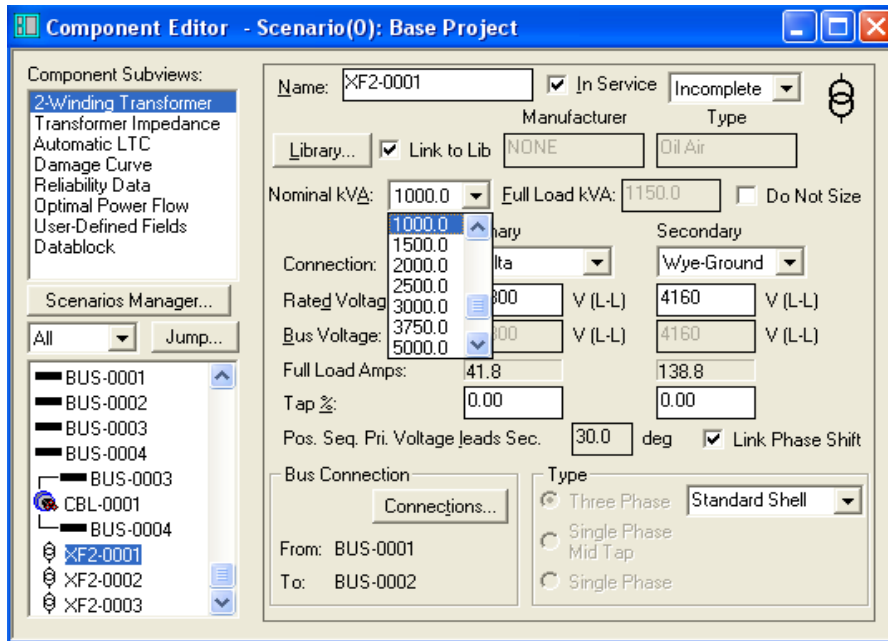


Figure 3.12 Specify the Transformer Size

iv Utility Data Input

The Utility Component UTIL-0001 was entered and entered the data as shown in figure 3.13 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.

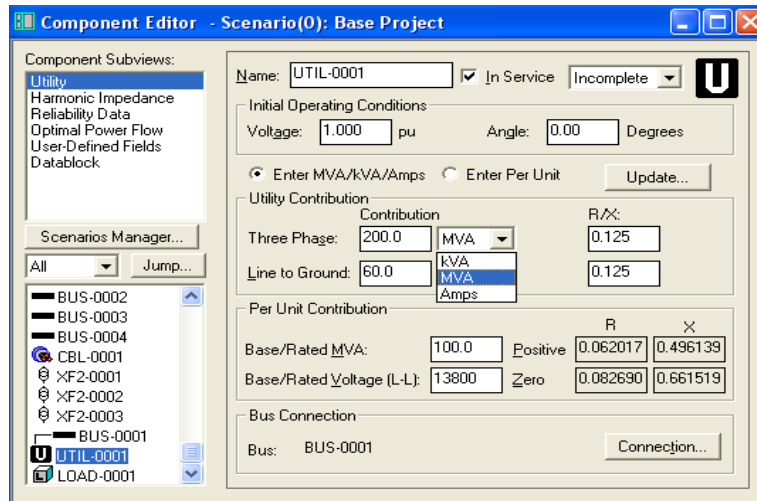


Figure 3.13 Utility fault contribution and voltage entry

iv. Run System Studies

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

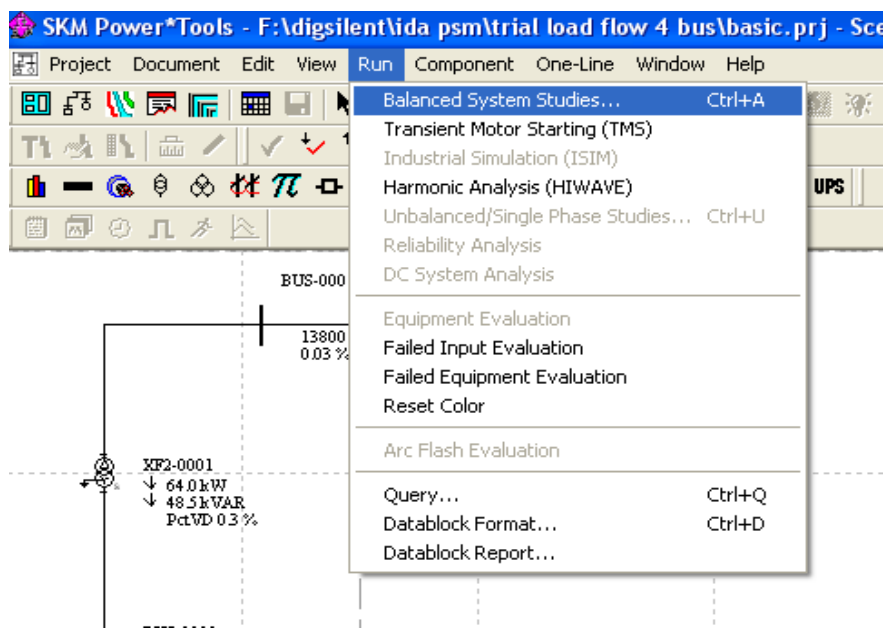


Figure 3.14 Running system studies on the power system network

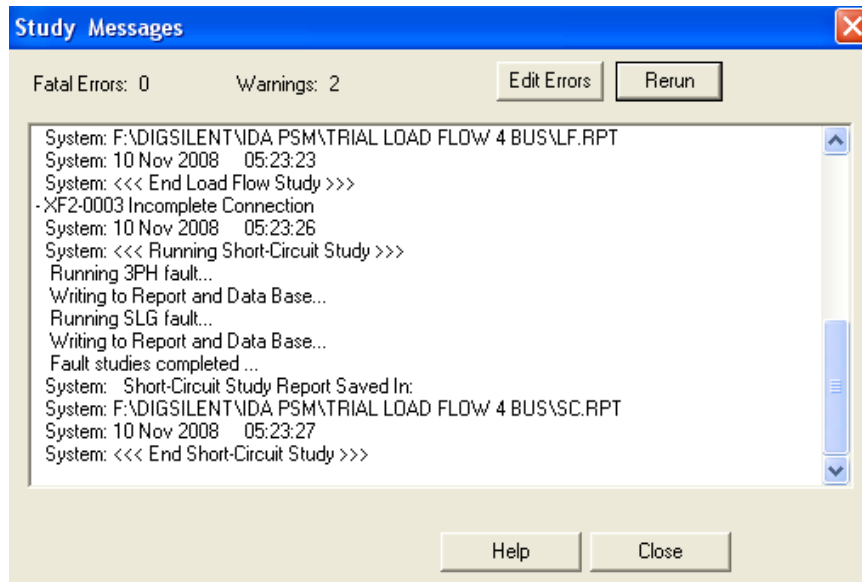
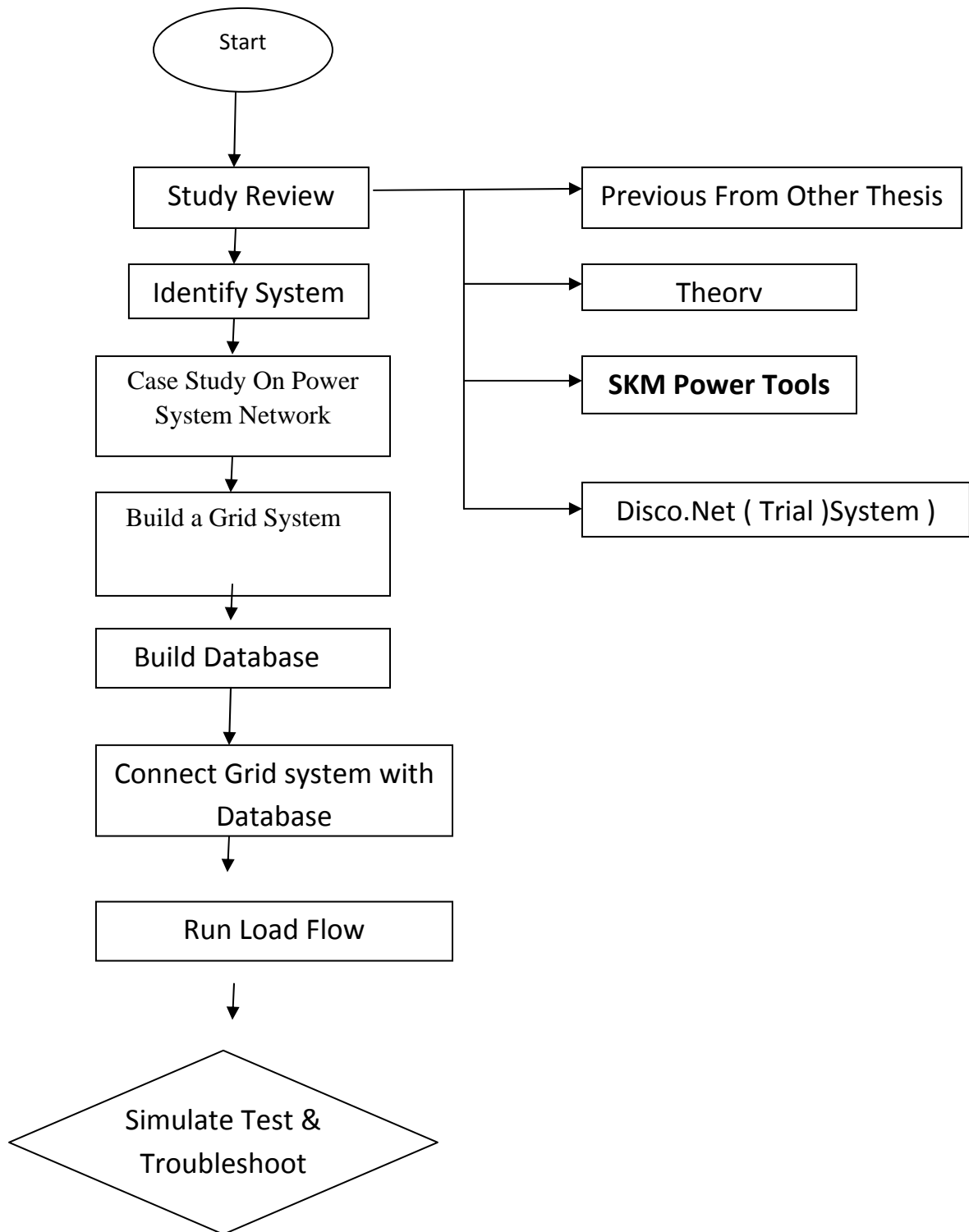
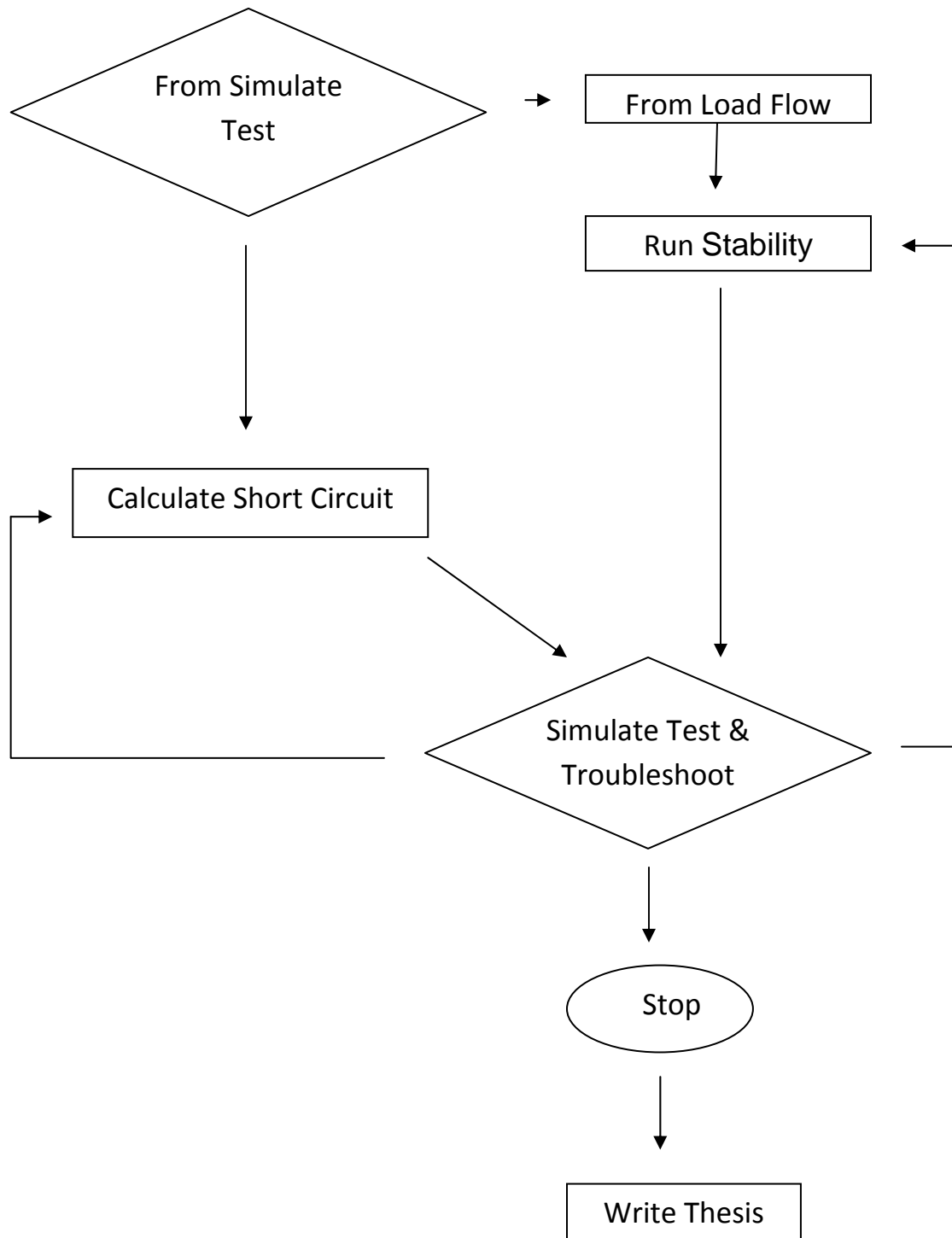


Figure 3.15 Study Message Window

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

3.2 Flow Chart of the Project





CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

The single line diagram of Petronas Gas power distribution network has been modeled using DigSilent . 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. Base on network Disco.net (trial System) , we try to modeling the network using SKM power tools. Base on information are and data given, the single line diagram is show in Appendix 1 . 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. This study case divide by two system:

- i. Load Flow Study Case
- ii. Short Circuit Study Case

4.2 Trial System

Appendix 1 shows the single line diagram for trial system (Disco.net) analysis which has done SKM Power Tools for Windows. From the result, it shows that the value for real power and reactive power when the simulation is running. Appendix 1 shows the single line diagram for trial system analysis which have a motor at the paper mill and chem. For this analysis, the result for real power and reactive power is different when we using the motor is not running at initial condition. If the initial motor is running the load flow will different because motor will drain more power. The appendix II show the result of the trial System .

Table 4.0 : 47-Bus Branch Data

No	Terminal	Rated Voltage(v)	Bus Voltage	PU Volt
1	Aloe	11,000	10,686	0.97
3	CDROM	11,000	10,661	0.97
4	CHEM	11,000	10,661	0.97
5	COWAN	11,000	10,674	0.97
6	DISK	11,000	10,661	0.97
7	DURIAN	11,000	10,702	0.97
8	FABRIC	11,000	10,661	0.97
9	HOSPITAL	11,000	10,647	0.97
10	JAYA	11,000	10,696	0.97
11	KELAPA	11,000	10,685	0.97
12	KG BOH	11,000	10,666	0.97
13	KG TOH	11,000	10,691	0.97
14	MHYDRO	11,000	10,746	0.97
15	PAPER MILL	11,000	10,629	0.97
16	PAPER MILL 1	11,000	10,632	0.97
17	PLASTIC	11,000	10,668	0.97
18	PUCHONG	11,000	10,654	0.97
19	RTM	11,000	10,677	0.97
20	SAMUA	11,000	10,629	0.97
21	SHIELD	11,000	10,621	0.97
22	SUN	11,000	10,679	0.97
23	TEH	11,000	10,644	0.97
24	0001	132,000	130,326	0.999
25	0002	11,000	10,712	0.97
26	0003	11,000	10,715	0.97
27	0006	433	403	0.93
28	0007	433	393	0.91
29	0009	433	411	0.95
30	0011	433	416	0.96
31	0013	433	398	1.021
32	0014	11,000	10,640	0.97
33	0015	433	407	5.90
34	0017	433	412	0.95
35	0019	433	416	0.96
36	0021	433	417	0.96
37	0024	433	407	0.94
38	0026	433	419	0.97

39	0028	433	406	0.94
40	0030	433	415	0.96
41	0033	433	411	0.95
42	0034	433	408	0.94
43	0036	433	416	0.96
44	0038	433	419	0.97
45	0040	433	419	0.97
46	0042	433	401	0.93
47	0044	433	382	0.88

Figure 4.1 shows the single line diagram for trial system analysis which have a motor and load . At the trial system it been initialize that it use a static load and for the motor the steady state is 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 and it will caused high voltage drop at the bus . For the design trial system (Disco.net) the criteria the design must be following Voltage criteria, such as defined in IEEE Std-141-1993 and also Voltage drop base on IEC 60065 . IEC 60065 has define the voltage at any point of the system under normal conditions shall not depart from the declared voltage by more than +5% 01-10%. . In this cases voltage at terminal 0044 has reach the limitation where the voltage drop is reaching 11.79 % . The main caused is the selection of type of cabal is not correct so high voltage losses at the cabal and voltage reaching busbar will reduce certain value . Base on standard ieee the voltage drop on the cabel did not exceed 2 ½ %.

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 Malaysis 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 4.1, 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 III.

Table 4.1 : Bus Data and voltage On The busbar

No	Terminal	Rated Voltage	Bus Voltage	PU Volt
1	132kV CUF 2M-SB0-01	132	131.88	0.999
3	21-SB1-01A	33	32.41	0.982
4	25-SB2-01A (2)	11	11.21	1.019
5	25-SB2-01A (3)	11	11.29	1.027
6	21-SB2-01A (2)	11	11.23	1.021
7	21-SB2-01A (3)	11	11.29	1.027
8	25-MC3-01A(1)	3.0	3.02	1.006
9	25-MC3-01A(2)	3.0	3.05	1.018
10	21-MC4-01B(B1)	0.415	0.42	1.006
11	25-MC4-01B(3)	0.415	0.42	1.005
12	25-MC4-01B(4)	0.415	0.42	1.011
13	25-MC4-01B(5)	0.415	0.42	1.011
14	25-MC4-01B(6)	0.415	0.42	1.012
15	22-MC4-01A(9)	0.415	0.42	1.009
16	22-MC4-01A(10)	0.415	0.42	1.003
16	0001	132	131.88	0.999
17	0002	132	131.88	0.999
18	0003	33	32.42	0.982
19	0004	11	11.21	1.019
20	0005	33	32.39	0.982
21	0006	11	11.21	1.019
22	0007	11	11.21	1.019
23	0008	11	11.23	1.021
24	0009	3	3.05	1.018
25	0010	33	32.41	0.982
26	0011	11	11.24	1.022
27	0012	33	32.41	0.982
28	0013	11	11.23	1.021
29	0014	33	32.41	0.982
30	0015	11	11.29	1.027
31	0016	11	11.21	1.019
32	0017	0.415	0.420	1.015
33	0018	11	10.80	0.982
34	0019	11	10.80	0.982
35	0020	0.415	0.420	1.013

36	0021	0.415	0.420	1.013
37	0022	0.415	0.420	1.012
38	0023	11	11.21	1.019
39	0024	11	11.23	1.021
40	0025	11	11.21	1.019
41	0026	0.415	0.420	1.015
42	0028	11	11.24	1.021
43	0029	0.415	0.420	1.011
44	0030	11	11.23	1.021
45	0031	0.415	0.420	1.011
46	0032	11	11.23	1.021
47	0033	0.415	0.420	1.013
48	0034	11	11.21	1.019

4.3.1 Load Flow analysis

A load flow solution determines the bus voltages and the flows in all branches for a given set of conditions. A load flow study is a series of such calculations made when certain equipment are set at different values, or circuit configurations are changed by opening or closing breakers, adding or removing a line, etc. From the result, the value of real power and reactive power at bus 132kV and bus 33kV is the same as the result from Petronas Gas. Starting from bus 11kV, the value of real power, reactive power, voltage angle, and all of the data is different because the DigSilent Power Factory at Universiti Malaysia Pahang is limited. For this problem, the Petronas Gas single line diagram has been re-designed to fulfill the requirements of the software.

Petronas Gas Kerteh has 3 generators. At normal conditions, this system only uses 2 generators. All of these three generators are used when the system makes a maintenance. This system also gets power from the utility, which is TNB. Because of the Petronas Gas generating its own electricity, the generator and the utility must operate at the same time. If not enough power from the generator, the losses will increase.

Generally, the study engineer has predefined sets of criteria that the system must meet. These include the following:

- i. Voltage criteria, such as defined in IEEE Std-141-1993
- ii. Voltage drop based on IEC 60065
- iii. Flows on lines and transformer must be within defined thermal ratings
- iv. Generator reactive outputs must be within the limits defined by the generator capability curves

Performing a series of load flow cases and analyzing the results provides operating intelligence in a short time that might take years of actual operating experience to obtain.

4.4 Short Circuit Analysis

Table 4.2 : 3 Phase Short Circuit

No	Terminal	I ^{”k} (initial Short Circuit) kA	Ip (Maksimum Short Circuit) kA	Ib (Breaking Current) kA
1	21-SB1-01	38.31	101.56	32.86
3	25-SB2-01A	13.62	35.31	13.25
4	25-MC3-01A	16.60	42.13	15.77
5	21-SB2-01A	9.70	25.29	9.23
6	21-MC4-01B	26.24	53.21	26.64
7	25-MC4-01B	27.32	57.68	25.81
8	25-SW4-01B	40.60	92.87	38.69
9	22-MC4-01A	33.46	72.59	30.74
10	25-SW4-01A	40.75	92.86	38.83
11	132Kv CUF 2M-SB0	32.13	70.87	32.13
16	0001	45.90	131.73	45.90
17	0002	32.11	70.80	32.11
18	0003	38.32	101.26	32.84
19	0004	29.03	65.90	26.77
20	0005	13.64	35.38	13.27
21	0006	13.50	34.60	13.13
22	0007	16.76	42.74	15.92
23	0008	13.83	34.12	13.36
24	0009	16.88	42.57	16.04
25	0010	37.62	98.07	32.41
26	0011	14.33	38.03	13.85
27	0012	29.77	72.74	27.29
28	0013	9.75	25.46	9.28
29	0014	29.63	72.33	27.33
30	0015	7.99	15.41	7.72
31	0016	46.56	101.14	46.56
32	0017	0.415	0.420	1.015
33	0018	104.03	276.64	88.79
34	0019	106.64	283.22	90.94
35	0020	44.06	102.85	42.66
36	0021	38.22	88.99	36.75
37	0022	45.14	106.49	43.26
38	0023	12.77	29.83	12.44
39	0024	13.19	29.82	12.78

40	0025	13.48	34.27	13.11
41	0026	45.32	106.49	43.44
42	0028	13.98	34.30	13.51
43	0029	46.40	108.12	43.76
44	0030	13.14	29.57	12.72
45	0031	46.26	107.67	43.81
46	0032	13.14	29.57	12.72
47	0033	45.14	34.27	43.26
48	0034	13.48	11.21	13.11

Even the best designed electric systems occasionally experience short circuits resulting in abnormally high currents. Over current protective devices, such as circuit breakers and fuses, should isolate faults at a given location safely with minimal circuit and equipment damage and minimal disruption of the plant's operation. Other parts of the system, such as cables, busways, and disconnecting switches, shall be able to withstand the mechanical and thermal stresses resulting from maximum flow of short-circuit current through them.

The magnitudes of short-circuit currents are usually estimated by calculation, and equipment is selected using the calculation results. The maximum calculated short-circuit current values are used for selecting interrupting devices of adequate short-circuit rating, to check the ability of components of the system to withstand mechanical and thermal stresses, and to determine the time-current coordination of protective relays. The minimum values are used to establish the required sensitivity of protective relays. Using digsilent it will calculate base on the of load flow. There were three short circuit it will calculate .

The first one is (I_k'') . it is a a steady state short circuit . I_k'' is the initial symmetrical short-circuit current as the ac symmetrical component of a prospective (available) short duration current applicable at the instant of short circuit if the impedance remains at zero-time value . The peak making current i_p , is the major loop of the current in a pole of a circuit breaker during the transient period following the initiation of current during a making operation . This the highest value reached in a phase in a polyphase circuit. If the high current flow than the i_p ,the system will out of service or explode . Short circuit breaking current i_b is the highest short circuit that circuit breaker shall be capable of breaking , under the conditions of used and behavior prescribed in IEC . So to design the circuit the value , short circuit breaking current must be consider, the operating of circuit breaker must operate at this rate value .

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. Using this analysis we determine the safe operation and future growth. . All the analysis make base on (IEC 60909-0 2001)

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Conclusion

The planning, design, and operation of industrial and/or commercial power systems require several studies to assist in the evaluation of the initial and future system performance, system reliability, safety, and the ability to grow with production and/or operating requirements. The studies most likely to be needed are load flow studies, cable ampacity studies, short-circuit studies, coordination studies, stability studies, and routine motor starting studies.

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.

For a plant engineer to solve a power system analysis problem, he or she must be thoroughly familiar with the fundamentals of power electrical engineering. He or she can then analyze the problem, prepare the necessary equivalent circuits and obtain appropriate system data before using a computer program to perform repetitive calculations. Failure to use a valid analytical procedure to establish a sound basic approach to the problem could lead to disastrous consequences in both the design and operation of a system.

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.

5.2 RECOMMENDATION

Dig silent is one of the 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. The Dig SILENT PowerFactory software is an integrated power system analysis tool that combines reliable and flexible system modeling capabilities, with state-of-the-art solution algorithms and a unique database management concept.

For future recommendation , carry out the study on a effect of DG and Power Quality on the Petronas Plant. DG technologies include micro turbines, gas turbines, fuel cells, and renewable energy sources like mini/micro hydro, wind, and photovoltaic. If the Petronas Use a DG where it's the best need to install be install. The study focus on the Impact of wind turbines and Photovoltaic on load voltage quality and grid active and reactive power losses associated with the DG technology. In Digsilent the have model DG (Wind Power) so the user did not have to model the DG .

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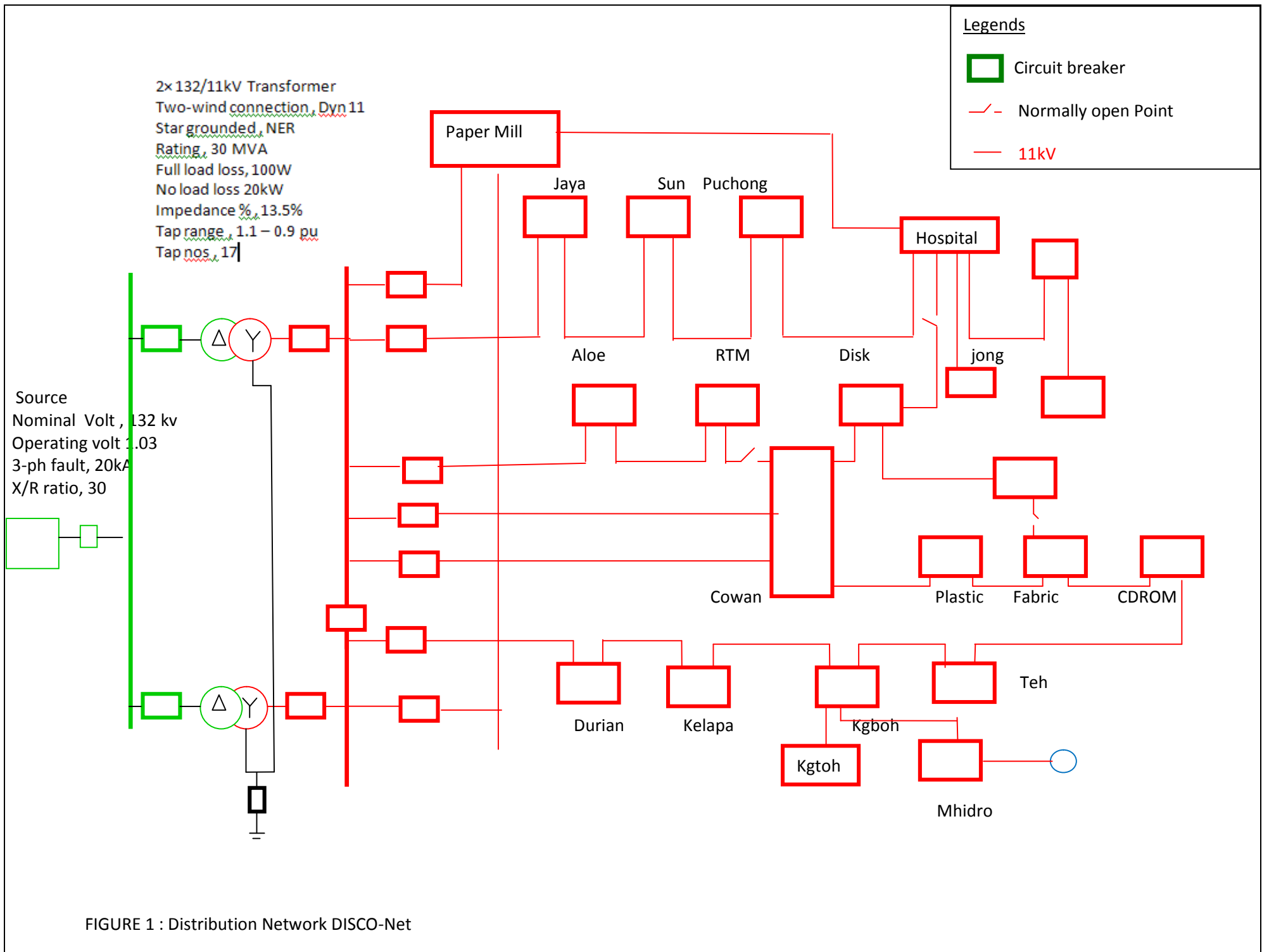


FIGURE 1 : Distribution Network DISCO-Net