POWER SYSTEM ANALYSIS USING POWER SYSTEM COMPUTER AIDED DESIGN (PSCAD)

NORLAILA BINTI ABU TAIB

B010710165

2009/2010

POWER FLOW ANALYSIS USING

POWER SYSTEM COMPUTER AIDED DESIGN

(PSCAD)

NORLAILA BINTI ABU TAIB

A report submitted in partial fulfillment of the requirements for the degree

Of Bachelor of Electrical Engineering (Power Industries)

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

YEAR

2009/2010

"I hereby declare that I have read through this report entitle *"Power Flow Analysis Using PSCAD"* and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature : ....

Supervisor's Name : FARHAN BIN HANAFFI

Date : 10/05/2010

I declare that this report entitle *"Power Flow Analysis using PSCAD"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : NORLAILA ABU TAIB

Date : 10/05/2010

ACKNOWLEDGEMENT

All praises to the Almighty Allah S.W.T. the sustainer of the world and may there be His blessing to all messengers and his last messenger, the Prophet Muhammad S.A.W. and his family, companions and followers and the entire believer till the end of time. Alhamdullillah, it is obvious that this final report could not be accomplished alone. It is a result of many contributions of individual who is directly contributes in making this final report successful. I would like to take this opportunity to express my gratitude to individuals in particular whose help and guidance has made for preparing this Final Year Project 1 Report.

First of all, I would like to convey my deepest utmost to my supervisor, Encik Farhan Bin Hanaffi for his encouragement and valuable advice, suggestion, comments, and guidance throughout the stages of this project and for his willing to provide a precious time in making this final report success. I also would like to express my special thanks and appreciation to my close friend who has been directly and indirectly involve in helping, sharing knowledge, guidance, and support in completing it. Besides that, I would like to thank to all person in TNB such as Ir. Hj. Rosman B. yahya and Ms. Teo in helping preparing all the data to complete the analysis.

Finally yet importantly, I would like to give a special and greatest thank to my parents and my family for their moral support, understanding, motivation and patience, in which without their support and love I may not be able to complete this dissertation. May Allah S.W.T. reward you all with the best here in this world and thereafter.

Amin.

ABSTRACT

Power system consists of four basic components, which are generation, transmission, distribution and load. When dealing with power system, power flow studies required to put into the consideration. In the new era of technologies, there are many software has been develop to help us in solving problems regarding to the power flow studies such as ERACS, CAPE and PSCAD. Power flow studies commonly referred as load flow, which is the backbone of power system analysis and design. There are necessary for planning, operation, economic scheduling and exchange of power between utilities. In addition, when dealing with power flow studies we required to pay an attention on power flow computation consists of imposing specified power and input voltage of the system network. Load flow system typically performs for minimum and maximum load condition to establish the full voltage range at each point of network. For this purpose in this project, PSCAD has been choosing to analyze power flow in network system. Besides, Power System Computer Aided Design (PSCAD) is one of the new software developed which capable of providing the power flow information of independent subsystem simultaneously. It has a powerful featured of changing the power level of generator and loads locally or globally.

ABSTRAK

Sistem kuasa terdiri daripada empat komponen utama., iaitu penjanaan, penghantaran, pembahagian dan beban. Bila berurusan dengan system kuasa, aliran sistem kuasa harus dipertimbangkan. Dalam era teknologi yang baru, terdapat pelbagai perisian yang telah dibangunkan bertujuan untuk membantu dalam menyelesaikan permasalahan sistem kuasa seperti ERACS, CAPE dan PSCAD. Aliran sistem kuasa juga merujuk kepada aliran beban, dimana ianya merupakan tulang belakang kepada analisis dan rekabentuk sistem kuasa itu sendiri. Terdapat beberapa keperluan untuk perancangan, operasi, plan ekonomi dan pertukaran diantara syarikan pembekal. Kajian aliran kuasa kebiasannya melibatkan perlaksanaan untuk keadaan minimum dan maksimum keadaan beban untuk menetaokan keadaan beban antara titik dalam sistem.untuk tujuan kajian ini, *"Power System Computer Aided Design (PSCAD)"* telah di pilih. PSCAD merupakan salah satu perisian yang telah dibina untuk tujuan kajian aliran kuasa yang mana ianya berkemampuan untuk menyediakan maklumat kajian aliran kuasa secara berterusan. Ianya mempunyai kebolehan untuk melakukan penukaran kuasa pada penjana dan beban dalam sistem.

TABLE OF CONTENTS

CHAPTER	TITLE			PAGE
	ACKNOWLEDGEMENT			iv
	ABSTRACT			v
	ABSTRAK			vi
	TABLE OF CONTENT			vii
	LIST OF TABLE			ix
	LIST OF FIGURE			xi
	LIST OF APPENDIX			
1	**INTRODUCTION**			
	1.1	Project Background		1
	1.2	project Objective		1
	1.3	Project Scope		2
	1.4	Problems Statement		2
	1.5	Project Outline		3
2	**POWER SYSTEM OVERVIEW**			
	2.1	Introduction		4
	2.2	Electrical Industrial Structure		5
	2.3	Modern Power System		6
	2.4	Summary		8
3	**POWER FLOW ANALYSIS**			
	3.1	Introduction		10
	3.2	Advantages Over Various Methods		10
	3.3	Power Flow Problems		11
	3.4	Power Flow Analytical Solution		12
		3.4.1	Bus Admittance Matrix	14
		3.4.2	Complex Power Flow	18
		3.4.3	G-S Method	19
	3.5	Summary		20
4	**POWER FLOW STUDY USING PSCAD**			
	4.1	Introduction		21
	4.2	Power System Computer Aided Design		21
	4.3	General Program Discription		22

	4.4	Program Operation	22
	4.5	Important Program Features	24
	4.6	System to be simulate	24
	4.6.1	Single Line Diagram of PPU Krubong	25
	4.7	Summary	29
5	**PROJECT METHODOLOGY**		
	5.1	Introduction	30
	5.2	Project Completing Stages	30
	5.3	Methods of Load Flow Analysis - GS Method	32
	5.4	Methods of simulation using PSCAD	35
	5.5	Summary	36
6	**RESULT**		
	6.1	Introduction	37
	6.2	Result	37
	6.2.1	Lines Flows	39
	6.2.2	Lines Losses	40
	6.2.3	Voltage Drop	41
	6.2.4	Power Factor	42
	6.3	Summary	43
7	**ANALYSIS AND DISCUSSION**		
	7.1	Introduction	44
	7.2	Analysis and discussion	44
	7.2.1	Lines Flows	45
	7.2.2	Lines Losses	48
	7.2.3	Voltage Drop	49
	7.2.4	Power Factor	50
	7.3	Summary	51
8	**CONCLUSION AND RECOMMENDATION**		52
	REFERENCES		53
	APPENDIXES A		54
	APPENDIXES B		60
	APPENDIXES C		61
	APPENDIXES D		62
	APPENDIXES E		63
	APPENDIXES F		65

LIST OF TABLE

TABLE	TITLE	PAGE
4.1	List of SSU at PPU Krubong	27
4.2	List of Load connected to the PPU Krubong.	27
4.3	List of Line connected to the PPU Krubong	28
4.4	Data of transformer connected to the PPU Krubong	29
6.1	PPU Krubong line's Power flow	39
6.2	PPU Krubong lines losses.	40
6.3	Voltage drop at each line at Krubong system	41
6.4	Power Factor used by the System	42

LIST OF FIGURE

FIGURE	TITLE	PAGE
2.1	Per-Capita consumption of Electrical Energy	5
2.2	Types of Power Plant in Malaysia	6
2.3	Power system interconnected	7
3.1	Basic chart of bus types and bus data.	13
3.2	Basic diagram of power flow solution methods	14
3.3	Simple Power System Diagram	15
3.4	Admittance diagram of simple system	15
4.1	Program Operation Flowchart	23
4.2	PPU Krubong's Single Line Diagram	26
5.1	Project Methodology	31
5.2	Gauss-seidel's Flowchart	34
5.3 (a)	Methods of Krubong simulation using PSCAD	35
5.3 (b)	Methods of Krubong simulation using PSCAD	36
7.1	PPU Krubong Lines Flows	46
7.2	PPU Krubong Lines Flows	47
7.3	PPU Krubong Lines Losses	48
7.4	Voltage Drop at each line of Krubong System	49
7.5	Power factor of Krubong System	51

LIST OF APPENDIXES

APPENDIXES	TITLE	PAGE
A	Example of Power Flow calculation	53
B	Single Line Diagram of PPU Krubong	54
C	Simplified of PPU Krubong syatm	60
D	Cable Datasheet (XLPE)	61
E	Transformers (11/0.433KV)	62
F	Transformers (33/11KV)	63
G	Project Planning	65

CHAPTER 1

INTRODUCTION

1.1 Project background

Power system consists of four basic components, which are generation, transmission, distribution and load. When dealing with power system, power flow studies required to put into the consideration. In the new era of technologies, there are many software has been developed to help in solving problems regarding to the power flow study such as ERACS, CAPE and PSCAD. Power flow studies commonly referred as a load flow, which is the backbone of power system analysis and design. There are necessary for planning, operation, economic scheduling and exchange of power between utilities. In addition, power flow computation studies consists of imposing specified power and input voltage of the system network should be put into the consideration. Load flow system typically performs for minimum and maximum load condition to establish the full voltage range at each point of network. In this project, PSCAD has been choosing to analyze power flow in PPU Krubong system. Power System Computer Aided Design (PSCAD) is one of the new software developed which capable of providing the power flow information of independent subsystem simultaneously. It has a powerful featured of changing the power level of generator and loads locally or globally.

1.2 Project Objective

This project involved in load flow analysis using PSCAD for Pencawang Pembahagian Utama Krubong from Tenaga Nasional Berhad. The objectives of this project are:

i. To study power flow at Pencawang Pembahagi Utama Krubong.

ii. To compute the power flow at Krubong area using PSCAD.

iii. To apply power flow computation and equation in analysis to PPU Krubong.

iv. To analyze and study the result from the simulation.

1.3 Project scope

This project is focusing on analyzing the load flow of Single line diagram for Krubong system, which is supply to the area of industrial and residential. Scopes of this proposed project are:

i. In analyze the power flow at PPU Krubong using PSCAD software.

ii. Compute and analyze the power flow for PPU Krubong at each bus and line.

iii. Calculate and analyze losses at each line in PPU Krubong system.

iv. Calculate and analyze voltage drop at each lines.

v. Study and analyze power factor for the consumers.

1.4 Problem statement

In a modern power system, power flow study is an important analysis. In power system, there are several problems occur in determine the power flow at each bus. The problem in power flow analysis is normally in determining the steady state operating condition of the network at PPU Krubong. Besides that, power flow data is important in TNB Maintenance purpose such as breakdown and shutdown at PPU Krubong network system. A load flow study is usefully for TNB Cable sizing and system improvement at PPU Krubong. Besides that, power flow analysis is important of TNB power system planning and operation at PPU Krubong, especially in system modification and power system improvement and stability.

1.5 Thesis Outline

In this report, it will consist of seven chapters. First chapter is an introduction chapter. In this chapter consists of five subtitles, which are project background, project objective, project scope, problems statement and project outline. Second chapter is power system overview. Which are explain about power system in industrial structure, power system generation, transmission, distribution and power system load. The third chapter explains on power flow analysis. In power flow analysis consists of an introduction, bus admittance matrix, power flow problems, and analytical formulation of complex power system, power flow solution methods and power system analysis using PSCAD. Project methodology is the next chapter that will be discuss in this thesis. Result and discussion will be discussed in chapter five. In that chapter, the discussion about PPU Krubong single line diagram, data collected and all result obtained from the simulation will be discussed. The conclusion of the project will be discussed in last chapter of the report.

CHAPTER 2

POWER SYSTEM OVERVIEW

2.1 Introduction

Description of power system will be discussed in this chapter. In Power system network consists of four components, which are power generation, transmission, distribution and power system load [1]. Each part of the components will be discussed in this chapter including their function of each component.

In Malaysia, There are five types of power plant, which is Combined Cycle GT, Conventional Thermal (coal), open cycle Gas Turbine, Hydroelectric Gas Turbine and Conventional Thermal (Oil/Gas). In Malaysia, there are a few organization that responsible in generate electricity such as, Independent Power Producer (IPP), Tenaga Nasional Berhad (TNB), Sabah Electricity Sdn. Bhd, and SESCO.

2.2 Electrical Industrial Structure.

Electrical energy occupies the top grade in energy hierarchy. The percapita consumption of electrical energy in some of the countries is shown in figure 2.1. The data has been gathered from 2001. In Norway, power consumption about 25000KWh, while in Canada about 16000KWh. The power consumption in USA, Japan, UK and Malaysia decreased, which is about 13000KWh, 8000KWh, 72000KWh and 2800KWh respectively.

In 2005, total installed electrical capacity in Malaysia is 17,314 MW. 10,760MW from total installed capacity is provided by TNB. While Independent Power Producer (IPP) provides about 6554MW, 37.86% from total installed capacity. The national maximum demand in Malaysia is about 12,023 MW which is 5291MW lower that total installed capacity, which is equal to 30% safety margin to meet the national maximum load demand. In the year 2007, the maximum capacity is 13000MW the maximum load demand growth from year to year depends on the increasing of the load. In 2008, it's reach around 15000MW per year.

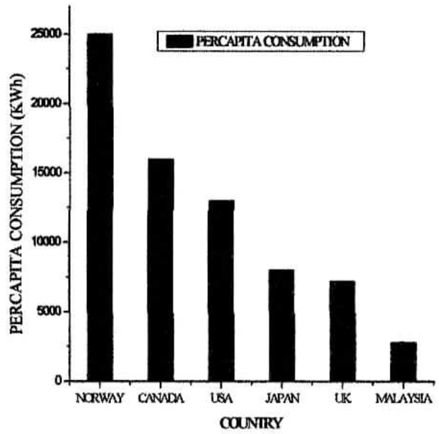

Figure 2.1: Per-Capita consumption of Electrical Energy

Combined Cycle Gas Turbine, Conventional Thermal (coal), open cycle Gas Turbine, hydroelectric Turbine and conventional thermal (Oil/Gas) are the most popular types of power plant in Malaysia. Total generated electricity for Combined Cycle Gas Turbine is about 46%, while 21% of total generated electricity is contribute by Conventional Thermal (coal), 13% from open cycle Gas Turbine, Hydroelectric Gas Turbine contribute 11% and conventional thermal (Oil/Gas) contribute about 9% as shown in figure 2.2.

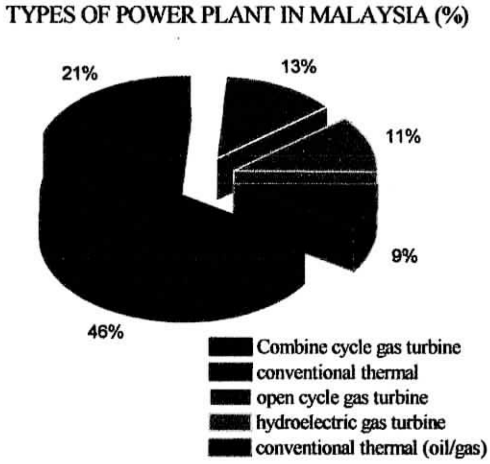

Figure 2.2: Types of Power Plant in Malaysia

2.3 Modern Power System

Power system network is interconnected network between the generation system, transmission line, distribution and load as shown in figure 2.3. Generation, transmission, distribution and loads are four basic of physical components in power system.

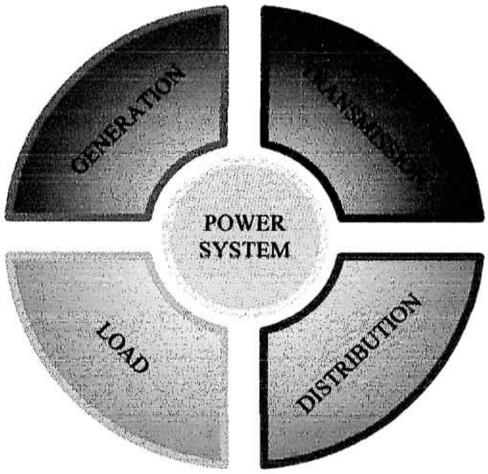

Figure 2.3: Power system interconnected

Power system network components can be divided into four components, which is:

i. Generation	Generation of power system is process of converting another form of energy into an electrical energy, such as hydro, wind and tidal.
ii. Transmission	Transmission line is components used to transmitted electricity to the distribution side before reach to the consumers.
iii. Distribution	In this stage, electricity will be distributed to the consumer using distribution line.
iv. Loads	This is the final stage of power system delivery. Loads consist of three types, commercial, industrial and residential.

Each components of power system contribute difference function in delivery electricity. At the beginning of the delivery stage, electricity will be generate through the generation plant then transmitted through transmission line to the customer using distribution line.

Power system generation is process of converting mechanical energy into an electrical energy. Power system generation is one of the important components in power system. In power generation, its generate electricity in low voltage condition before it's transmitted through the transmission line. In power system generation there are consists of many types such as diesel power plant, hydroelectric power plant, steam power plant and others. In Malaysia, most of the generation plant is hydroelectric power generation.

A second component in power system is power transmission. Transmission line used to transmit electricity to the distribution side. Transmission line is connected between generation side and distribution side. At transmission side voltage has been step-up to the desired level 132, 275 and 500KV before it's transmitted. Standard transmission voltages are established in united stated by the American national standard institute (ANSI). Transmission voltage operates at more than 60KV are standardize at 69KV, 115KV, 138KV, 161KV, 230KV, 345KV, 500KV and 765KV [2].

In a modern power system, load can be divided into three categories, which is residential, commercial and industrial load. For a large industrial system may serve from the transmission system involved 11KV, 22KV and 33KV system. But for small load system are serve from primary distribution network which involved 415V and 240V. In industrial loads, basically use composite loads and induction motor. Apart from that, large industrial load will be supply by the high voltage power system normally 11KV, 22KV and33Kv in Malaysia. For commercial and residential loads system, consists of largely of lighting, heating, and cooling. These loads are independent of frequency and consume negligible small reactive power.

2.4. Summary

Summary of this chapter, power system can be divided into four types. Firstly is power system generation, second is power system transmission, third is power system distribution and the last one is power system loads.

CHAPTER 3

POWER FLOW ANALYSIS

3.1 Introduction

In the previous chapter, four major components of power system have been discussed. This chapter will be discussed on power flow analysis in power system network. Power flow is total number of power that flow through each line in power system network. To determine the load flow at each bus bar and line, hand calculation or software simulations are used. Steady state condition of normal operation is important to determine power flow at power system network. Further explanation on power flow analysis will be done in this chapter.

3.2 Advantages over various methods

According to abhijit chakrabarti and sunita halder [3] stated that, G-S algorithm convergence is slower and it is conventional to use acceleration factor for spending up the convergence process. However, if it increases too much, the system may diverge.

In this study, a G-S method has been choosing to solve the power flow problems. There are some advantages of using G-S method:

i. It is one of the simplest methods in power flow studies.

ii. G-S methods do have definite tutorial value, particularly for the beginner.

iii. G-S method can be conveniently used for load flow study in small power system.

iv. G-S method may be used for even large system to obtain first approximation solution.

3.3 Power Flow Problems

According to the power system analysis written by Arthur r. Bergen and Vijay Vital [4], power flow problems may now stated with some precision. The formulation is based on operational consideration of the power industry as well as mathematical consideration. Further discussion about these considerations will be done.

In power system network, consists of many busses. Each buss contributes difference function between each others. Besides that, every bus will be named according to the types of busses, such as slack bus, load bus and voltage controlled bus. The types of bus and corresponding parameters are being specified as under

i. **Load bus (PQ bus):** The total injection power (Pi+jQi) is specified and normally the load is constant power type and remains unaffected by small variations in bus voltage.

ii. **Slack bus**: This type of bus arises because the system losses are not known in the advance before the load flow calculated. Any generating bus may choose as slack bus. Which is may assume to supply line losses.

iii. **Voltage controlled bus**: The total injected power is specified, while the voltage magnitude is maintain. This type of bus usually corresponds to a generator bus or even a load bus where the bus voltage is fixed.

There are four components that required to study in power flow analysis, which are voltage magnitude, voltage angle, real power and reactive power. These four components flow in each individual lines and bus bar. Load flow required to be run for the following cases:

i. In power system planning

ii. In additional or outage of transmission line or other equipment

iii. When a new load centre is establish or when the network remains unchanged but load grows.

3.4 Power Flow Analytical Solution

In any power flow studies, there are four variables required to be determine. All the variables required to determine at each bus bar, which is voltage magnitude, voltage angle, reactive power and real power. Basic charts of bus data and bus types are shown in figure 3.1. There are four types of bus data, which are voltage magnitude, voltage phase angle, real power and reactive power. While for bus types, there are three types of bus; slack bus, load bus and voltage controlled bus. Further explanation on bus types has been done in previous subchapter.

At each bus, there are only two bus data will be determining using calculation or computation methods. While another two bus data has been given. However, the power flow equation can be formulated symmetrically in variety of form. In power flow solution, there are many methods can be used to solve the problems. In this case, the most suitable methods required to choose to perform the calculation. The formulations of the network equation in the nodal admittance, form result in complex linear algebraic equation in term of nodes current. The suitable methods of calculation is important in order to make it simples and easier. Besides that, the most suitable methods is important to ensure that the methods suitable to used in large power system network.

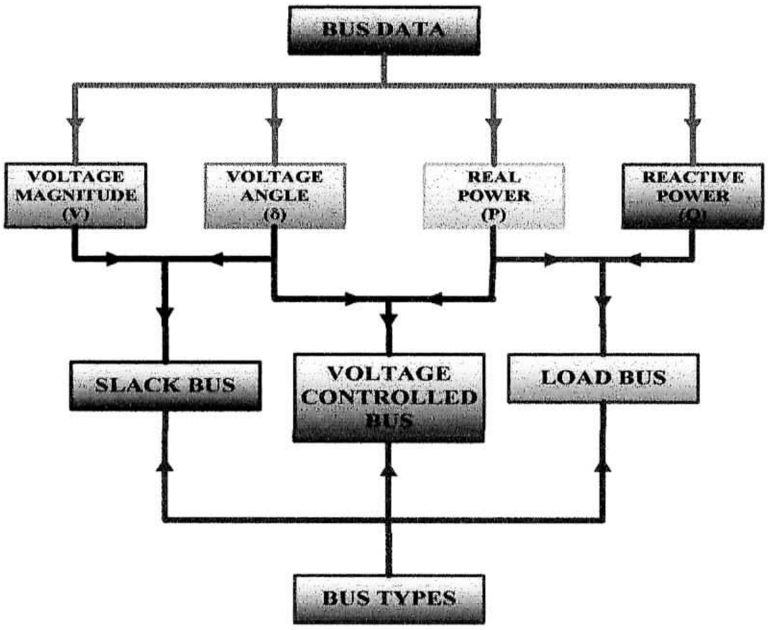

Figure 3.1: Basic chart of bus types and bus data.

There are four steps in solving power flow analysis, which is preparing single line diagram of the network system, convert all the parameters in per unit system, admittance bus and determine the unknown bus data to complete the analysis. Basic diagram of power flow solution method are shown in figure 3.2. To convert the parameters in per unit system, base MVA and base KV required choosing for each section at the system. After all the parameters converted in per unit, impedance value of each component in network system required to calculate in order to preparing the admittance matrixes of the system. After that, value of each bus data will be calculated.

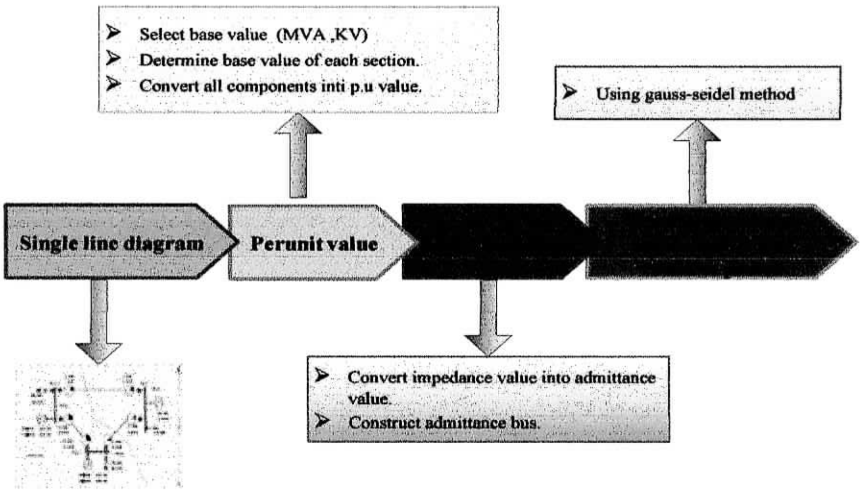

Figure 3.2: Basic diagram of power flow solution methods