



**Faculty of Electrical Engineering**

**DYNAMIC STABILITY STUDIES OF GENERATORS IN POWER  
SYSTEM USING FUZZY LOGIC CONTROLLER BASED POWER  
SYSTEM STABILIZER**

**Hayfaa Mohammed Hussein Hasan**

**Doctor of Philosophy**

**2018**

**DYNAMIC STABILITY STUDIES OF GENERATORS IN POWER SYSTEM  
USING FUZZY LOGIC CONTROLLER BASED POWER SYSTEM STABILIZER**

**HAYFAA MOHAMMED HUSSEINHASAN**

**A thesis submitted  
in fulfilment of the requirements for the degree of Doctor of Philosophy**

**Faculty of Electrical Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2018**

## DECLARATION

I declare that this thesis entitled “Dynamic Stability Studies of Generators in Power System Using Fuzzy Logic Controller Based Power System Stabilizer” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Hayfaa Mohammed Hussein Hasan

Date : .....

## **APPROVAL**

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : .....

Supervisor Name : Prof. Dr. Marizan Bin Sulaiman

Date : .....

## **DEDICATION**

I dedicate this project to God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge and understanding. He has been the source of my strength throughout this program and on His wings only have I soared. Tomy supervisor Prof. Dr. Marizan Bin Sulaiman.

## ABSTRACT

Excitation systems are affected by low frequency oscillation (LFO) when they are subjected to small perturbations. Damping during the LFO is enhanced via the addition of power system stabilizer (PSS) to the excitation system. This research entails a study on fuzzy logic controller power system stabilizer (FLCPSS) for the purpose of enhancing the stability of a single machine power system. In order to accomplish the stability enhancement, two approaches were used to design fuzzy logic controller (FLC). The first approach includes the use of genetic algorithm (GA) to design the PSS. The second approach entails the use of particle swarm optimization (PSO) to design the PSS. The performance of these two approaches is compared with the system and without PSS. The stabilizing signals were computed using the fuzzy membership functions depending on these variables. The simulations were tested under different operating conditions and also tested with different membership functions. The simulation is implemented using Matlab /Simulink and the results have been found to be quite good and satisfactory. Electro-mechanical oscillations were created in the event of trouble or when there was high power transfer through weak tie-line in the machines of an interrelated power network. This research presents an analysis on the change of speed ( $\Delta\omega$ ), change of angle position ( $\Delta\delta$ ) and tie-line power flow ( $\Delta p$ ). FLC which includes two areas of symmetrical systems are connected via tie-line to identify the performance of the controllers. Simulation results of the fuzzy logic based controller indicate dual inputs of rotor speed deviation and generator's accelerating power. Two generators have been used to control the arrangement in the tie-line system. The single fuzzy logic controller (S-FLC) has been used as a primary controller and the double fuzzy logic controller (D-FLC) has been used as a secondary controller. Additionally, the system shows a comparison between the two controllers, namely the S-FLC and D-FLC which have been used to achieve the best results. Notably, the double fuzzy controller has been found to have a greater effect on the multi-machine system and it is smoother than the single fuzzy controller as it increased the damping of the speed  $\Delta\omega$  and rotor angle (degree)  $\Delta\delta$ . Its simplicity has made it to be a good controller. In conclusion, much better response can be attained from the S-FLC if there is careful timing of the scaling factors.

## ABSTRAK

Sistem pengujian dipengaruhi oleh ayunan kekerapan yang rendah apabila mereka mengalami gangguan kecil. Mengurangkan semasa ayunan kekerapan rendah dipertingkatkan melalui penambahan sistem penstabil kuasa ke sistem pengujian. Kajian ini melibatkan kajian mengenai penstabil sistem kuasa pengawal logik fuzzy bagi tujuan meningkatkan kestabilan sistem kuasa mesin tunggal. Untuk mencapai peningkatan kestabilan, dua pendekatan digunakan untuk merancang pengawal logik fuzzy. Pendekatan pertama termasuk penggunaan algoritma genetik untuk mereka bentuk penstabil sistem kuasa. Pendekatan kedua melibatkan pengoptimuman swarm partikel untuk mereka bentuk penstabil sistem kuasa. Prestasi dua pendekatan ini dibandingkan dengan sistem dan tanpa penstabil sistem kuasa. Isyarat penstabil dikira menggunakan fungsi keahlian fuzzy bergantung pada pemboleh ubah ini. Simulasi telah diuji di bawah keadaan operasi yang berbeza dan juga diuji dengan fungsi keahlian yang berlainan. Simulasi dilaksanakan menggunakan Matlab / Simulink dan keputusannya didapati agak baik dan memuaskan. Ayunan elektro-mekanik telah dicipta dalam keadaan masalah atau apabila terdapat pemindahan kuasa tinggi melalui garis tali lemah dalam mesin rangkaian kuasa yang saling berkaitan. Kajian ini membentangkan analisis mengenai perubahan kelajuan ( $\Delta\omega$ ), perubahan kedudukan sudut ( $\Delta\delta$ ) dan aliran kuasa tali talian ( $\Delta p$ ). Pengawal logik fuzzy yang merangkumi dua bidang sistem simetri yang dihubungkan melalui talian ikat untuk mengenal pasti prestasi pengawal. Keputusan simulasi pengawal berasaskan logik fuzzy menunjukkan input dua sisihan kelajuan pemutar dan kuasa mempercepatkan penjana. Dua penjana telah digunakan untuk mengawal perkiraan dalam sistem talian ikat. Pengawal logik fuzzy tunggal telah digunakan sebagai pengawal utama dan telah digunakan sebagai pengawal menengah. Di samping itu, sistem menunjukkan perbandingan antara kedua-dua pengawal, iaitu dan yang telah digunakan untuk mencapai hasil yang terbaik. Terutamanya, pengawal kabus berganda telah didapati mempunyai kesan yang lebih besar pada sistem multi-mesin dan ia lebih lancar daripada pengawal fuzzy tunggal kerana ia meningkatkan redaman kelajuan  $\Delta\omega$  sudut rotor  $\Delta\delta$ . Kesederhanaannya menjadikannya pengawal yang baik. Sebagai kesimpulan, tindak balas yang lebih baik dapat diperolehi dari jika ada masa yang berhati-hati terhadap faktor skala.

## **ACKNOWLEDGEMENTS**

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Professor Dr. Marizan Bin Sulaiman from the Faculty of Electrical Engineering Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this thesis.

I would also like to express my greatest gratitude to Associate Professor Dr. Rosli Bin Omar from the Faculty of Electrical Engineering Universiti Teknikal Malaysia Melaka (UTeM), co-supervisor of this project.

Lastly thank you to everyone who had played a crucial role in the realization of this project.



## TABLE OF CONTENTS

	<b>PAGE</b>
<b>DECLARATION</b>	
<b>APPROVAL</b>	
<b>DEDICATION</b>	
<b>ABSTRACT</b>	<b>i</b>
<b>ABSTRAK</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>vii</b>
<b>LIST OF FIGURES</b>	<b>viii</b>
<b>LIST OF APPENDICES</b>	<b>xiv</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xv</b>
<b>LIST OF SYMBOLS</b>	<b>xvi</b>
<b>LIST OF PUBLICATIONS</b>	<b>xvii</b>
<b>CHAPTER 1</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Introduction	1
1.2 Background	2
1.2.1 Power System Stability	2
1.2.2 Stability Problem	2
1.2.3 Control of Dynamic Stability	4
1.2.4 Types of Power System Stabilizer (PSS)	5
1.3 Motivation for Research	6
1.4 Problem Statement	7
1.5 Objectives of the Research	8
1.6 Contributions of the Research	9
1.7 Scope of Research	10
1.8 Organization of Thesis	11
<b>CHAPTER 2</b>	<b>2.</b>
<b>LITERATURE REVIEW</b>	
2.1 Introduction	12
2.2 Transient Stability Analyses of Power System	13
2.3 Power System Stabilizer (PSS)	13
2.3.1 Types of Power System Stabilizer (PSS)	13
2.4 Genetic Algorithm Methods (GA) (Stabilizer Based on Shaft Speed Signal (Delta-Omega $\Delta\omega$ ) Type One	19
2.5 Particle Swarm Optimization (PSO)	25
2.6 PSS in Single Machine Connected to Infinite Bus	30
2.7 Expert System	37
2.7.1 Fuzzy Logic Controller (FLC) in Single Machine Infinite Bus (SMIB) (1-G)	37
2.7.2 Fuzzy Logic Controller (FLC) of A 2-Generators Connected via Tie-Line	45
2.8 Critical Review of Literature Studies	51
2.9 Summary	75

<b>3.</b>	<b>SYSTEM DESIGN AND METHODOLOGY</b>	<b>CHAPTER 3</b>	<b>76</b>
3.1	Introduction		76
3.2	Research Methodology		76
3.3	Flow Chart of System Design and Methodology		77
3.3.1	Inertia Constant and Swing Equation		78
3.3.2	Generator Represented by the Classical Model		84
3.3.3	Effect of Synchronous Machine Field Circuit Dynamics		87
3.3.4	Excitation System		94
3.3.5	Types of Excitation System		95
3.3.6	Modelling of Excitation System in Power System		95
3.3.7	Dynamic Performance Measures		96
3.3.8	Effect of Excitation System		97
3.3.9	Effect of AVR on Synchronizing and Damping Torque Components		100
3.3.10	Effect of $K_5$ on the Operating Power System		101
3.3.11	Stabilizing Signal		102
3.3.12	Power System Stabilizer Design		103
3.3.13	Power System Stabilizer		105
3.4	Design of Controllers		106
3.4.1	Genetic Algorithm (GA)		107
3.4.2	Design of Fuzzy Logic Control (FLC)		108
3.4.3	Particle Swarm Optimization (PSO)		111
3.4.4	Fuzzy Logic Controller (FLC)		115
3.4.5	Reasons for Choosing Fuzzy Logic		116
3.4.6	Fuzzy Inference System (FIS)		117
3.4.7	Scaling Factors (SFs)		120
3.4.8	Reduce Rule of Membership Function		121
3.5	Simulation of System		126
3.5.1	Infinite Bus to Single Machine Connection		126
3.5.2	Fuzzy Logic Controller Based Power System Stabilizer		127
3.6	A Two Generators System Connected Via Tie-Line		130
3.6.1	Single Fuzzy Logic Controller (S-FLC) Based Power System Stabilizer (PSS)		130
3.6.2	Double Fuzzy Logic Controller (D-FLC) Based Power System Stabilizer (PSS)		132
3.7	Summary		134
<b>4.</b>	<b>RESULTS AND DISCUSSION</b>	<b>CHAPTER 4</b>	<b>136</b>
4.1	Introduction		136
4.1.1	Single Machine Connected to Infinite Bus without Power System Stabilizer (PSS)		137
4.1.2	Single Machine Connected to Infinite Bus with PSS, GA and PSO		137
4.1.3	Single Machine Connected to Infinite Bus with 16 Rules Fuzzy Logic Controller (FLC) Based Power System Stabilizer (PSS)		140
4.1.4	Single Fuzzy Logic Controller (S-FLC) Based Power System Stabilizer of A Two Generators Connected Via Tie-Line System		147
4.1.5	Double Fuzzy Logic Controller (D-FLC) Based Power System Stabilizer of A Two Generators Connected Via Tie-Line System		154

4.1.6	Reduce Reduction for Double Fuzzy Logic Controller (D-FLC) Based Power System Stabilizer of A Two Generators Connected Via Tie-Line System 167	
4.2	Interpretation of Results	178
4.3	Summary	180
<b>5.</b>	<b>CONCLUSION AND RECOMMENDATION CHAPTER 5</b>	<b>181</b>
5.1	Introduction	181
5.2	Conclusion	181
5.3	Recommendations for Future Research	184
	<b>REFERENCES</b>	<b>185</b>
	<b>APPENDICES</b>	

## LIST OF TABLES

<b>TABLETITLE</b>	<b>PAGE</b>
2.1 Critical Review of Literature Studies	52
3.1 Truth tables	109
3.2 16 Rules base for fuzzy logic controller	118
3.3 Rule base for fuzzy logic controller 16 to 8 rules	123
3.4 Rule base for fuzzy logic controller 8 to 7 rules	124
3.5 Machine data	126
3.6 Machine data	130
3.7 Machine data	132
3.8 Change of input torque ( $\Delta T_{\text{mech}}$ )	132
3.9 Change of input torque ( $\Delta T_{\text{mech}}$ )	134
4.1 Change of input torque ( $\Delta T_{\text{mech}}$ )	168
4.2 Change of input torque ( $\Delta T_{\text{mech}}$ )	168
4.3 Properties of PSS and FLC	179

## LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Angular speed variation	4
1.2	Block diagram representation AVR and PSS	5
2.1	Block diagram realization of delta -P- omega ( $\Delta$ -P- $\omega$ ) stabilizer	17
3.1	Flow chart of system design and methodology	78
3.2	Mechanical and electrical torques in a generating unit	79
3.3	Block diagram representation of swing equations	83
3.4	Synchronous machine connected to infinite bus bar	84
3.5	Block diagram of a single-machine infinite bus system with classical generator model	87
3.6	d-q axis vector diagram	87
3.7	Equivalent circuit relating flux linkage in d-q axis	89
3.8	Block diagram representation with constant $E_{fd}$ , i.e. $E_{fd} = 0$	94
3.9	Functional block diagram of a synchronous generator excitation control system	95
3.10	Block diagram of an exciter model	96
3.11	Excitation control system in the classical feedback control form	97
3.12	Block diagram representation with exciter and AVR	99
3.13	Speed input PSS	103
3.14	Block diagram representation with AVR and PSS	106
3.15	Three functions, fuzzy sets and fuzzy logical operation AND, OR and NOT	110

3.16 Main components of a FIS	111
3.17 Implementation of PSO to select $K_1$ , $K_2$ and $K_3$ for fuzzy logic controller (FLC)	113
3.18 Relationship between speed and position for $K_1$ , $K_2$ and $K_3$	114
3.19 Principle design of fuzzy logic controller	116
3.20 Fuzzy logic controller based PSS	116
3.21 Fuzzy inference system	118
3.22 (a) Membership functions for speed deviation (b) membership functions for acceleration (c) membership functions for voltage	119
3.23 Rule viewer of fuzzy logic controller	120
3.24 Zones in a rule table	121
3.25 Output variable	123
3.26 Rule viewer of fuzzy logic controller	123
3.27 Output variable	124
3.28 Rule viewer of fuzzy logic controller	125
3.29 Firing rules shifting rout	125
3.30 Implementation of PSS in simulink	127
3.31 Block diagram representation with AVR, FLC and PSS designed by PSO	128
3.32 Block diagram representation with AVR, PSS and FLC	129
3.33 Block diagram representation of a 2- generators single fuzzy logic controller (S-FLC) connected via tie-line	131
3.34 Block diagram representation of a 2- generators double fuzzy logic controller (D-FLC) connected via tie-line	133

4.1 Simulation result of angular speed, angular position (rotor angle (degree)) and variation of electrical torque for the system without PSS for 10% change in step input ( $\Delta T_{mech}$ )	137
4.2 Simulation result angular speed for 10% change in step input ( $\Delta T_{mech}$ )	138
4.3 Simulation result angular position (rotor angle (degree)) for 10 % change in step input ( $\Delta T_{mech}$ )	138
4.4 Simulation result variation of electrical torque for 10% change in input ( $\Delta T_{mech}$ )	139
4.5 Simulation result variation of voltage for 10% change in step input ( $\Delta T_{mech}$ )	140
4.6 Angular speed in three cases (1) with AVR (2) FLC based PSS and (3) with PSS designed by PSO with $K_5 = - 0.1103$	141
4.7 Angular position (rotor angle (degree)) in three cases (1) with AVR (2) FLC based PSS and (3) with PSS designed by PSO with $K_5 = - 0.1103$	141
4.8 Variation of electrical torque in three cases (1) with AVR (2) FLC based PSS and (3) with PSS designed by PSO with $K_5 = - 0.1103$	142
4.9 Variation of voltage in three cases (1) with AVR (2) FLC based PSS and (3) with PSS designed by PSO with $K_5 = - 0.1103$	142
4.10 Angular speed in three cases (1) with AVR (2) PSS and (3) FLC with $K_5 = 0.1462143$	
4.11 Angular position (rotor angle (degree)) in three cases (1) with AVR (2) PSS and (3) FLC with $K_5 = 0.1462$	144
4.12 Variation of electrical torque in three cases (1) with AVR PSS and (3) FLC with $K_5 = 0.1462$	144
4.13 Variation of voltage in three cases (1) with AVR (2) PSS and (3) FLC with $K_5 = 0.1462$	145

4.14 Angular speed in three cases (1) with AVR (2) PSS and (3) FLCwith $K_5 = - 0.1462145$	
4.15 Angular position (rotor angle (degree)) in three cases (1) with AVR PSS and (3) FLC with $K_5 = - 0.1462$	(2) 146
4.16 Variation of electrical torque in three cases (1) with AVR (2)PSS and FLC with $K_5 = - 0.1462$	(3) 146
4.17 Variation of voltage in three cases (1) with AVR (2) PSS and FLCwith $K_5 = - 0.1462$	(3) 147
4.18 Angular speed variation	148
4.19 Angular position (rotor angle (degree)) variation	148
4.20 Tie - line power flow variation	149
4.21 Angular speed variation	149
4.22 Angular position (rotor angle (degree)) variation	150
4.23 Tie - line power flow variation	150
4.24 Angular speed variation	151
4.25 Angular position (rotor angle (degree)) variation	151
4.26Tie - line power flow variation	152
4.27 Angular speed variation	153
4.28 Angular position ( rotor angle (degree)) variation	153
4.29 Tie - line power flow variation	154
4.30 Angular speed variation	155
4.31 Angular position (rotor angle (degree)) variation	155
4.32 Tie - line power flow variation	156
4.33 Angular speed variation	157



4.34 Angular position (rotor angle (degree)) variation	157
4.35 Tie - line power flow variation	158
4.36 Angular speed variation	158
4.37 Angular position (rotor angle (degree)) variation	159
4.38 Tie - line power flow variation	159
4.39 Angular speed variation	160
4.40 Angular position (rotor angle (degree)) variation	161
4.41 Tie - line power flow variation	161
4.42 Angular speed variation	162
4.43 Angular position (rotor angle (degree)) variation	162
4.44 Tie - line power flow variation	163
4.45 Angular speed variation	164
4.46 Angular position (rotor angle (degree)) variation	164
4.47 Tie - line power flow variation	165
4.48 Angular speed variation	166
4.49 Angular position (rotor angle (degree)) variation	166
4.50 Tie - line power flow variation	167
4.51 Angular speed variation	169
4.52 Angular position (rotor angle (degree)) variation	169
4.53 Tie - line power flow variation	170
4.54 Angular speed variation	170
4.55 Angular position (rotor angle (degree)) variation	171
4.56 Tie - line power flow variation	171
4.57 Angular speed variation	172

4.58 Angular position(rotorangle (degree)) variation	172
4.59 Tie - line power flow variation	173
4.60 Angular speed variation	174
4.61 Angular position (rotor angle (degree)) variation	174
4.62 Tie - line power flow variation	175
4.63 Angular speed variation	175
4.64 Angular position (rotor angle (degree)) variation	176
4.65 Tie - line power flow variation	176
4.66Angular speed variation	177
4.67Angular position (rotor angle (degree)) variation	177
4.68Tie - line power flow variation	178

## LIST OF APPENDICS

APPENDIX TITLE		PAGE
A	Time Response	215
B.1	Parameters FLC	217
B.2	Simulation of Systems	217

## LIST OF ABBREVIATIONS

PSS	-	Power System Stabilizer
AVR	-	Automatic Voltage Regulator
GA	-	Genetic Algorithm
PSO	-	Particle Swarm Optimization
LFOs	-	Low Frequency Oscillations
FLCPSS	-	Fuzzy Logic Controller Power System Stabilizer
SFLC	-	Single Fuzzy Logic Controller
DFLC	-	Double Fuzzy Logic Controller DFCLC
FIS	-	Fuzzy Inference System
SMIB	-	Single Machine Infinite Bus
SF	-	Scaling Factor
M F	-	Membership Function
E	-	Generator Voltage
$K_D$	-	Damping Torque Coefficient Deviation
$K_S$	-	Synchronizing Torque Coefficient
H	-	Inertia Constant
$V_R$	-	Output Voltage of the Regulator
M	-	Inertia Coefficient = 2H
FLS	-	Fuzzy Logic System

## LIST OF SYMBOLS

$T_a$	Accelerating Torque
$T_m$	Mechanical Torque
$T_e$	Electromagnetic Torque
$P_a$	Accelerating Power
$P_m$	Mechanical power
$P_e$	Electromagnetic Power
$E_B$	Infinite Bus Voltage
$\omega_0$	Rotor Electrical Speed
$\omega_r$	Angular Speed of the Rotor
$\psi_{fd}$	Field Circuit Flux Linkage
$E_{fd}$	Field Voltage
$K_E$	Excitation Gain
$T_E$	Time Constant
$\delta_0$	Initial Rotor Angle
$\Delta P_m$	Change in Mechanical Power Input
$\Delta P_e$	Change in Electric Power Output
$\Delta\omega_{eq}$	Derived or Equivalent Speed Deviation
$\Delta\omega$	Speed Deviation
$G_{ex}(s)$	Transfer Function of the AVR and Exciter

## LIST OF PUBLICATIONS

1. Sulaiman, M., Hussein, H.M., Omar, R. and Salleh, Z., 2016. Dynamic Stability Analysis of Generator with Power System Stabilizers Using Matlab Simulink. *Indonesian Journal of Electrical Engineering and Computer Science*, 2(3), pp.501–509.
2. Mohammed, H. et al., 2016. Comparative Studies of Fuzzy Logic Base Power System Stabilizers in Enhancing Dynamic Stability of a Generator Connected to Infinite Bus. *World Applied Sciences Journal 34 (10): 1370-1379, 2016 ISSN 1818-4952 © IDOSI Publications, 2016 DOI: 10.5829/idosi.wasj.2016.*, 34(10), pp.1370–1379.
3. Mohammed, H. et al., 2017. Stability Studies of Fuzzy Logic Based Power System Stabilizer in Enhancing Dynamic Stability of A Two Generators Tie-Line system. *VOL. 12, NO. 5, MARCH 2017 ISSN 1819-6608 ARPJ Journal of Engineering and Applied Sciences ©2006-2017 Asian Research Publishing Network (ARPJ). All rights reserved.*, 12(5), pp.1–8.
4. Hussein, H.M. et al., 2017. Effect of Double Fuzzy Logic Controller (DFLC) Based on Power System Stabilizer (PSS) on A Tie – Line Two Generators System. *ARPJ Journal of Engineering and Applied Sciences ©2006-2017 Asian Research Publishing Network (ARPJ). All rights reserved.*, 12(21), pp.1–10.

## CHAPTER 1

### INTRODUCTION

#### 1.1 Introduction

Power systems have the potentials to remain synchronized when small disturbances occur and its ability to remain synchronized is known as dynamic stability. Disturbances occur continuously on power systems due to small differences that occur in loads and generation. These disturbances are small enough to allow the linearization of system equations when it is intended for analysis. When there is loss of synchronism, instability occurs. There are two types of instability. The first type of instability involves rotor angle increase as a result of insufficient synchronizing torque, and the second type includes rotor oscillations with increased amplitude as a result of insufficient damping torque. Simultaneously, several factors influence the nature of how the system responds to small disturbances. These factors include the initial operating, the strength of the transmission system as well as the kind of generator excitation control that is deployed. As for generators connected to large power systems that are not controlled by “automatic voltage regulators” but with constant field voltage, instability results due to insufficient synchronizing torque. A power system stability is ultimately concerned with the quality of electricity supply, it is one of the main research topics in power system studies (P. Kundur, 1994). Stability refers to the ability of the power system to develop restoring forces that are either similar or greater than the disturbing forces for the purpose of keeping the state of equilibrium intact. The system maintains its stability or synchronism when the forces that

control the machines are able to handle the disturbing forces besides being able to be in synchrony with each other. Studies on power system stability are often administered while planning new facilities to generate and transmit power. The aforesaid studies are contributive towards determining several aspects such as the type of relaying system required, critical time needed to clear circuit breakers, voltage level as well as the transfer capability of one system with another (Sadat, 1999).

## **1.2 Background**

### **1.2.1 Power System Stability**

Power system stability is the ability of the power system to operate with stable equilibrium in normal conditions besides ensuring that the state of equilibrium is acceptable even when it is affected by disturbances. (P.Kundur, 1994).

### **1.2.2 Stability Problem**

All synchronous machines that are interconnected should maintain synchronism and operate concurrently at the same speed and time (Anderson *et al.*, 2003). Conversely, problems in its stability arises when the behavior of the machine is perturbed. If the perturbation does not cause any total change in power, the synchronous machine is supposed to return to its original state. In the event of an unbalance between the supply and demand as a result of difference in load, generation or network conditions, a new operating state would be essential. A lack of studies have been conducted to overcome problems related to the stability of power systems. In analytical studies, power system stability has been classified into three categories (P.Kundur, 1994).