COMPARATIVE STUDY ON CONVENTIONAL CONTROLLER AND PID CONTROLLER OF POWER SYSTEM DYNAMIC STABILITY

by

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TABLE OF CONTENTS

		PAGE
TABLE OF CONTENT		iii
LIST OF TABLES		vi
LIST OF FIGURES		vii
LIST OF ABBREVIATIONS		ix
LIST OF SYMBOLS		x
ABSTRAK		xii
ABSTRACT		xiii
CHAPTER 1 INTRODUCTION		
1.1	Research Background	1
1.2	Problem Statement	2
1.3	Objectives	3
1.4	Research Scope	3
1.5	Thesis Outline	4
CHAPTER 2 LITERATURE REVIEW		
2.1	Introduction	6
2.2	Power System Stability	7
2.3	Previous Research on Power System Stability	9
2.3.1	Coordination of PSS and PID Controller for Power System Stability Enhancement	9
2.3.2	Design of PID Controller Based Power System Stabilizer Using Modified Philip Heffron's Model: An Artificial Bee Colony Approach	11
2.3.3	Effect of PID Power System Stabilizer for Synchronous Machine in Simulink Environment	12
2.3.4	Designing Power System Stabilizer with PID Controller	13
2.3.5	Summary of The Previous Work on Power System Stability	13
2.4	Low Frequency Oscillation	15

2.5 Basic Model for Power System Dynamic Studies 16

2.6 Philip Heffron Constant 18

2.7 Conventional Power System Stabilizer Controller 20

2.8 PID Controller 22

CHAPTER 3 METHODOLOGY

3.1 Introduction 24

3.2 Project Flowchart 24

3.3 Mathematical Modelling of SMIB Power System 26

3.3.1 Equation for Parameter K_1 To K_6 27

3.3.2 State Space Model of SMIB 33

3.3.3 Block Diagram Representation 39

3.4 Obtaining The Initial Parameter for Power System 45

3.5 MATLAB Simulink Model of Uncontrolled System 46

3.6 SMIB Power System Model With Conventional Controller. 47

3.7 SMIB Power System Model With PID Controller. 49

3.8 Stability Evaluation Techniques 51

3.8.1 Time Domain Evaluation 51

3.8.2 Eigenvalue Evaluation 52

CHAPTER 4 RESULT AND DISCUSSION

4.1 Introduction 54

4.2 K_1 To K_6 Parameter 55

4.3 Stability Evaluation Using Time Domain Technique 56

4.3.1 Electrical Power Oscillation With Increasing of 0.1 p.u Electrical Power 56

4.3.2 Rotor Angle Oscillation With Increasing of 0.1 p.u Electrical Power 59

4.3.3 Rotor Speed Oscillation With Increasing of 0.1 p.u Electrical Power 62

4.3.4 Electrical Power Oscillation With Decreasing of 0.1 p.u Electrical Power 64

4.3.5 Rotor Angle Oscillation With Decreasing of 0.1 p.u Electrical Power 67

4.3.6 Rotor Speed Oscillation With Decreasing of 0.1 p.u Electrical Power 70

4.4 Stability Evaluation Using Eigenvalue Technique 75

CHAPTER 5 CONCLUSION

5.1 Summary 78

5.2 Future Work 79

REFERENCES 80

APPENDIX A 83

LIST OF TABLES

NO.		PAGE
Table 2.1	The summary of the previous research study	13
Table 3.1	Initial parameter of SMIB	46
Table 3.2	The value of K_P , K_I , and K_D	50
Table 4.1	K_1 to K_6 parameter	55
Table 4.2	Tabulated data from the oscillation of increasing of 0.1 p.u electrical power	74
Table 4.3	Tabulated data from the oscillation of decreasing of 0.1 p.u electrical power	75
Table 4.4	Eigenvalue data for the system	76
Table 4.5	Damping ratio data for the system	77

LIST OF FIGURES

NO.		PAGE
Figure 2.1	The classification of power system stability	8
Figure 2.2	The basic structure of power system	17
Figure 2.3	The category of voltage levels	18
Figure 2.4	Philip Heffron model	20
Figure 2.5	PSS block diagram	21
Figure 2.6	Type of PSS	21
Figure 2.7	A PID controller	22
Figure 3.1	The thesis flowchart	25
Figure 3.2	The single machine infinite bus (SMIB) system	39
Figure 3.3	The vector diagram of the SMIB	40
Figure 3.4	The torque angle loop of synchronous machine	42
Figure 3.5	Flux decay model	43
Figure 3.6	The excitation system	44
Figure 3.7	The overall block diagram of SMIB system	44
Figure 3.8	MATLAB Simulink model of the uncontrolled power system	47
Figure 3.9	A supplementary excitation control	48
Figure 3.10	The conventional controller design	48
Figure 3.11	The PID controller design in series connection with the reset block	49
Figure 3.12	The PID controller design in parallel connection with the reset block	49
Figure 3.13	The output oscillation of PID controller system	50
Figure 3.14	The output waveform of the system	52
Figure 4.1	Oscillation of electrical power in uncontrolled system	57
Figure 4.2	Oscillation of electrical power in conventional system	57
Figure 4.3	Oscillation of electrical power in PID system in series connection with the reset block	58

Figure 4.4	Oscillation of electrical power in PID system in parallel connection with the reset block	59
Figure 4.5	Oscillation of rotor speed in uncontrolled system	59
Figure 4.6	Oscillation of rotor speed in conventional system	60
Figure 4.7	Oscillation of rotor speed in PID system in series connection with the reset block	61
Figure 4.8	Oscillation of rotor speed in PID system in parallel connection with the reset block	61
Figure 4.9	Oscillation of rotor angle in uncontrolled system	62
Figure 4.10	Oscillation of rotor angle in conventional system	63
Figure 4.11	Oscillation of rotor angle in PID system in series connection with the reset block	63
Figure 4.12	Oscillation of rotor angle in PID system in parallel connection with the reset block	64
Figure 4.13	Oscillation of electrical power in uncontrolled system	65
Figure 4.14	Oscillation of electrical power in conventional system	66
Figure 4.15	Oscillation of electrical power in PID system in series connection with the reset block	66
Figure 4.16	Oscillation of electrical power in PID system in parallel connection with the reset block	67
Figure 4.17	Oscillation of rotor speed in uncontrolled system	68
Figure 4.18	Oscillation of rotor speed in conventional system	68
Figure 4.19	Oscillation of rotor speed in PID system in series connection with the reset block	69
Figure 4.20	Oscillation of rotor speed in PID system in parallel connection with the reset block	70
Figure 4.21	Oscillation of rotor angle in uncontrolled system	70
Figure 4.22	Oscillation of rotor angle in conventional system	71
Figure 4.23	Oscillation of rotor angle in PID system in series connection with the reset block	72
Figure 4.24	Oscillation of rotor angle in PID system in parallel connection with the reset block	72

LIST OF ABBREVIATIONS

ABC	Artificial Bee Colony
DE	Differential Evolution
EMF	Electromagnetic Force
EP	Evolutionary Programming
GA	Genetic Algorithm
LFO	Low Frequency Oscillation
p.u	Per Unit
PID	Proportional Integral Derivative
PSS	Power System Stabilizer
rms	Root Mean Square
SI	Swarm Intelligence
SMIB	Single Machine Infinite Bus
MATLAB	Mathematic Laboratory

LIST OF SYMBOLS

δ	Rotor Angle
f	Frequency Oscillations in Hz
λ	System Eigenvalue
σ	Real Part Eigenvalue
ς	Damping Ratio
ω	Rotor Speed
ω_b	Rotor Speed Deviation (Base Speed)
ω_s	Rotor Speed of Synchronous Generator
D	Damping Coefficient
E_{fd}	Excitation System Voltage in p.u
E'_q	Voltage Proportional to Field Flux Linkage
H	Inertia Constant
I_q, I_d	d-axis And q-axis Generator Current
K_A	Exciter Gain
K_D	Damping Torque Coefficient
R_E	Transmission Line Resistance
T_A	Exciter Time Constant
T'_{do}	Open Circuit d-axis Time Constant in Sec
T_e	Electric Torque
T_M	Mechanical Power Input in p.u
T_p	Peak Time
T_s	Settling Time

V_d , V_q	d-axis and q-axis
V_{ref}	Exciter Reference Input
V_t	Terminal Voltage
V_∞	Infinite Bus Voltage
X_d	d-axis Synchronous Reactance in p.u
X'_d	d-axis Transient Reactance in p.u
X_e	Transmission Line Reactance
X_q	q-axis Synchronous Reactance in p.u
X'_q	q-axis Transient Reactance in p.u

Kajian Perbandingan diantara Pengawal Konvensional dan Pengawal PID Keatas Sistem Kuasa Kestabilan Dinamik

ABSTRAK

Disertasi ini membentangkan kajian perbandingan diantara pengawal konvensional dan pengawal PID dalam bas tanpa had mesin tunggal (SMIB). Pengawal digunakan untuk menghasilkan isyarat kawalan redaman tambahan untuk sistem pengujaan bagi mengurangkan Ayunan Frekuensi Rendah (LFO). Sistem ini bermula dengan mewujudkan pemodelan matematik bas tunggal tanpa had (SMIB) untuk mensimulasi sistem selepas mengalami kekerapan frekuensi rendah (LFO). Gambarajah blok untuk sistem ini direka bentuk dalam perisian MATLAB untuk menganalisis prestasi mesin segerak selepas diaplikasikan dengan pelbagai gangguan tertentu. Pengawal konvensional dan pengawal PID dijana dan simulasi dijalankan pada nilai gangguan yang berbeza untuk melihat prestasi sistem kuasa. Gangguan ini ditetapkan dengan peningkatan dan penurunan kuasa elektrik sebanyak 0.1 pu. Gelombang keluaran dianalisis pada lajakan, masa puncak dan masa penyelesaian. Selain itu, nisbah eigen dan redaman juga dianalisis untuk melihat kestabilan sistem. Berdasarkan hasil analisis, pengawal PID memberikan prestasi yang lebih baik berbanding dengan pengawal konvensional kerana simulasi keluaran menghasilkan nilai lajakan, masa puncak dan masa penyelesaian yang paling rendah. Di samping itu, pengawal PID mempunyai nilai nisbah yang negative dan nilai redaman yang tertinggi.

Comparative Study on Conventional Controller and PID Controller of Power System Dynamic Stability

ABSTRACT

This report presents the comparative study on conventional controller and PID controller in a single machine infinite bus (SMIB). The controller is used to generate the supplementary damping control signals for an excitation system in order to damp out the Low Frequency Oscillations (LFO). The system starts with formulating the mathematical modelling of a single machine infinite bus (SMIB) for simulating the system after experiencing a low frequency oscillation (LFO). The block diagram of the system has been designed in MATLAB software to analyze the performance of a synchronous machine after facing a specific range of disturbance. The conventional controller and PID controller are generated and the simulation is conducted on different value of disturbance to observe the performance of the power system. The disturbance is set by increasing and decreasing the electrical power by 0.1 pu. Output waveform is being analyzed on the overshoot, peak time and settling time. Besides, the eigenvalue and damping ratio are also being analyzed to observe the stability of the system. Based on the analysis result, the PID controller gives a better performance as compared to conventional controller because the output produces lowest overshoot, peak time and settling time. Besides, the PID controller provides negative eigenvalue and highest value of damping ratio.

CHAPTER 1 : INTRODUCTION

1.1 Research Background

Nowadays, the demand of the electricity is increasing due to the increment of the global population that is highly related to the building and transportation. This phenomenon had caused the limitation in the power system operation and a variety of problems such as power quality and unstable power system. The power system engineers are working hard to solve such problem in power system stability area as to ensure a balancing electrical power generation and load demand to provide a stable condition for the system to operate smoothly.

Power system stability is the capability of the power system to maintain at the steady state after subjected to any disturbance. The disturbance can be large or small and the impact depends on the stability of control effectiveness. There are a few examples of disturbances such as load changes, switching operations and random fluctuations. Therefore, transient stability is the results for the large disturbance whereas steady state stability was shown for the small disturbance

Dynamic stability is the stability of a power system to withstand to small unexpected disturbance. The linear differential equation can be used to model the system and the system can be stabilised by using a linear and continuous supplementary stability control. Typical examples are the low frequency oscillation of the interconnected large electric power systems.

This thesis conducts the comparison analysis of the conventional controller and PID controller in the power system dynamic stability. MATLAB software is used to simulate the dynamic power system stability. The oscillation of rotor angle, rotor speed and electrical power for both controllers are compared based on the settling time and overshoot which indicates the better controller.

1.2 Problem Statement

In the past few decades, the stabilizer is widely applied in the power system to stabilize the system after subjected to any disturbance. The disturbance can occur continuously in daily normal operations resulted from the minimum variations in generation and load. Besides, the disturbance will cause a low frequency oscillation to the system and affected the system torque. Hence, the stabilizer need to be applied to maintain the operation of the power system and to reduce the time of damped oscillation.

There are numerous number of techniques that have been proposed to solve the stability problem such as nonlinear system, adaptive controlling techniques and artificial intelligence techniques. However, there are only some techniques that could meet the specifications of the stability which gives the positives damping in short time efficiently.

1.3 Objectives

The aim of this project is to compare the performance of conventional controller and PID controller in power system dynamic stability in single machine infinite bus (SMIB). There are three objectives that are needed to be fulfilled based on the analysis of the problem statement:

1. To formulate a mathematical modelling of single machine infinite bus (SMIB) for simulating the oscillations after low frequency oscillation (LFO) occurs in the system.

2. To analyse the oscillation of the rotor speed and rotor angle in conventional and PID controller by using MATLAB simulation.

3. To compare the performance of the system in uncontrolled system, conventional controller system and PID controller system.

1.4 Project Scope

The main idea of this project is to study the comparison between the conventional controller and PID controller based on the power system dynamic stability. The stabilizer that had been used for this system have gains optimum value which will be calculated and put-into the SMIB in MATLAB Simulink. Then, the simulation of the system can be done when the system is already developed. The simulation will produce a real damping oscillation with the speed and angle that will be used to improve the damping system that will give positive effect to the power system.

This study will focus on the implementing the conventional controller and PID controller on the improvement of power system dynamic stability and the power system model based on the analysis made on the single machine infinite bus (SMIB). The analysis are based on the overshoot and the settling time of the output oscillation from the electrical power, rotor speed and rotor angle scope.

1.5 Report Outline

This report begins with Chapter 1 which explains briefly about the project and power system dynamic stability. In addition, this chapter also explains about the dynamic stability through the problem statement, objectives and scope of this project.

Next, Chapter 2 is the theory review of this project based on the power system dynamic stability and discussion about the previous research paper that are related to this project.

Then, Chapter 3 describes the methodology that has been used from the beginning until the end of this project. After the mathematical modelling was created, the blocks diagram of the SMIB is designed and being implemented in MATLAB Simulink to be analysed further.

Chapter 4 discusses the result from the MATLAB Simulink simulation in Chapter 3 based on the oscillation of both controllers. The overshoot and settling time of the oscillation will be discussed.

Lastly, Chapter 5 is the summary of the project. This chapter will conclude the overall result from the simulation based on the improvement in power system dynamic stability by implementing both controller in the original SMIB power system.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

In the previous chapter, a brief introduction including objective and the scope of project about this thesis have been discussed. This chapter will discuss in details about the related topic such as the stability in power system, low frequency oscillation and Philip Heffron constant which is includes in designing the block diagram of the power system.

Power system stability is the capability of the power system to be maintained at the steady state or remained stable after facing any disturbance either there is small or large disturbance. Normally, the power system frequency, voltage and angle of rotor are the parameters used to indicate the system is recover to the steady state after being disturbed. There were various techniques that can increase the performance of the power system after being disturbed. This thesis is using conventional controller and PID controller as a technique to reduce the oscillation of the output after being disturbed. The performance of these two controller will be compared and analysed.

2.2 Power System Stability

Power system stability is the capability of the power system to maintain at the steady state after facing any disturbance, to determine whether the disturbance is larger or small it is depending on the stability control of its effectiveness. The disturbance can be removal of loads, load changes, voltages collapse and switching operations. While, the stability is classified into three main groups which are steady state stability for small and gradual changes in the system, transient stability for the major and large disturbance and dynamic stability for the continuous small disturbance such as fault due to a random fluctuation (Sohail Ansari, 2014).

Since 1920, the power system stability has been considered as the main problem for the operation of the power system (Kundur et al., 2002). There are many problems occurs such as major blackout due to the instability of the power system and the transient stability is considered as the dominant stability problem. From time to time, a new form of system instability is arising when the new technologies and controls are developed. Normally, there are three things needed to be concerned which are the stability of frequency, voltage and angle of rotor compared to before. Hence, to determine the smooth operation of the power system depends on how the instability of the system is being solved based on the classified problem stated.

Power system stability normally can be categorised based on the physical nature of the resulting mode on instability as indicated by the main system variable in which instability can be observed. Besides, the size of disturbances is considered as influencing the method of calculations and prediction of stability. Lastly, the devices, processes and the time span are the items that must be taken into consideration in order to assess stability. Based on Figure 2.1, the categorized and sub categorized of power system stability have been shown (Kundur, 2004).

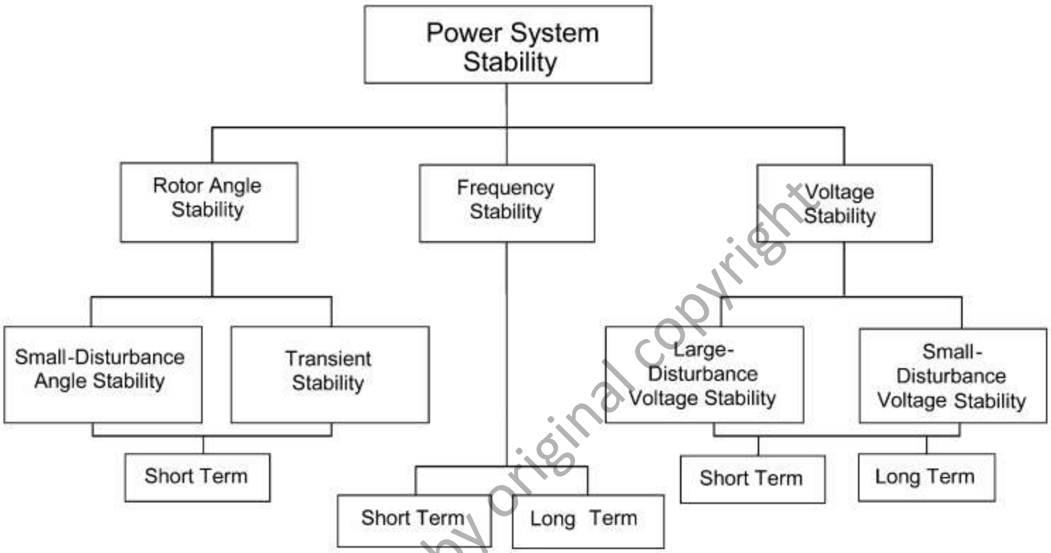

Figure 2.1: The classification of power system stability (Kundur, 2004)

Hence, to analyses the power system stability problem, the stability conditions have been categorized into three main groups which are steady state stability, dynamic stability and transient stability. The steady state stability is the analysis of the system stability to return to steady state after experiencing a small and gradual changes at load. The system can be stabilized by using governor controls and conventional excitation.

Dynamic stability is the ability of the power system to remain constant after subjects to a small scale and unusual disturbances. For this case, the system can be represented by linear differential equations. Besides that, the linear and continuous supplementary stability control act as a system stabilizer. Small disturbances can occur due to some random fluctuations in generations and loads levels. One of common example for the small disturbances are low frequency oscillations of the interconnected large electric power systems and the torsional oscillations of a steam electric power plant.

While, transient stability is the analysis of a power system refers to an unexpected and drastic disturbance that exceeding the ability of the control system such as linear and continuous supplementary stability control. The analysis of the system can be described by using nonlinear differential equation. The system may lose the stability during the first swing if there is no effective prevention action is taken. The prevention actions usually are conducted in discrete type such as dynamic resistance braking in the electric energy surplus area and load shedding in the electric energy deficient area.

Lastly, nonlinear stability is classified as a general class of stability in mathematical term. The stability problem is not focused only on power system stability but for all types of engineering system and the system can be described by using nonlinear equation. The study of nonlinear stability had used the analysis of steady state stability using the equal area criterion and the analysis of transient stability using Lyapunov's direct method as an example.

2.3 Previous Research on Power System Stability

2.3.1 Coordination of PSS and PID Controller for Power System Stability Enhancement

The paper from (Gowrishankar Kasilingam, 2015) is studying about Coordination of PSS and PID Controller for Power System Stability Enhancement. The purposes of this research is to solve the low frequency oscillation (LFO) that ranges from 0.1 Hz to

2.5 Hz by using power system stabilizer (PSS) and shows the PID controller is the simplest and effective solution to most of control engineering nowadays. The stability of power system is extracted from PID and PSS. The parameter of the PID and PSS is tuned manually and fix for certain condition and the non-linear conventional method of power system has a lack of robustness. Besides, it is necessary to take advantages in simplifying the problems and implemented by utilizing the most efficient optimization methods.

There are many optimization methods and algorithm that have been employed to tune the PID gains and PSS parameter. Examples of the optimization methods and algorithm are conventional methods, soft computing, genetic algorithm (GA), evolutionary programming (EP), differential evolution (DE) and swarm intelligence (SE). The conclusion of the research is the conventional optimization method, and two algorithms which are soft computing and GA have limitation while swarm intelligence had been proved to be able to solve the limitation. Swarm intelligence is the based coordinate for PIS and PSS controller to enhance the small signal and transient stability. The objectives that have been achieved from this research are to tune the PID gains and PSS parameter.

This paper focuses on the study of the analysis of literature review and did not show the actual design of the system of the controller. Besides, the simulation result of the waveform is also required to prove either the system is stable or not and the difference shown is from the waveform during before and after the implementation of the controller. The value in the waveform is required to determine the stability of the system which are overshoot and settling time.

2.3.2 Design of PID Controller Based Power System Stabilizer Using Modified Philip Heffron's Model: An Artificial Bee Colony Approach

The second research paper is from (Bagepalli Sreenivas Theja, 2013) with paper Design of PID Controller Based Power System Stabilizer Using Modified Philip Heffron's Model: An Artificial Bee Colony Approach. The purpose of this study is to design a PID controller equipped with PSS for a SMIB system using linearized modified Philip Heffron's model. The method used is by designing the PSS based on the model that utilizes signals shown within the generation station. The method does not require the knowledge about external system parameters such as the line impedance and infinite bus voltage. The PSS and PID parameters used a new swarm intelligent Artificial Bee Colony (ABC) algorithm for tuning. Besides that, in order to enhance the small signal stability due to small signal stability due to small variations in generation and load. Thus, various simulation results and comparison are shown over different loading conditions on SMIB using ABC tuned PID and PSS. The superiority in ABC algorithm in designing the PSS model is being considered.

The further research of this paper will include the implementation of fractional order controllers for single machine. On the other hand, also includes the fractional order for three machine power system.