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 LFOis 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 ofgenetic 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 systemand 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 (Δp). 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 rotorangle (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 pengujaan dipengaruhi oleh ayunan kekerapan yang rendah apabila mereka mengalami gangguan kecil. Mengurangkan semasa ayunan kekerapan rendah dipertingkatkan melalui penambahan sistem penstabil kuasa ke sistem pengujaan. 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 bentukpenstabil sistem kuasa. Pendekatan kedua melibatkan pengoptimuman swarm partikel untuk merekabentuk penstabil sistem kuasa. Prestasi dua pendekatan ini dibandingkan dengan sistemdan tanpapenstabil sistem kuasa. Isyarat penstabil dikira menggunakan fungsi keahlian fuzzy bergantung pada pembolehubah 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 (Δp). 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 rolein the realization of this project.

TABLE OF CONTENTS

LIST OF TABLES

TABLETITLE PAGE

LIST OF FIGURES

FIGURE **TITLE** **PAGE**

LIST OF APPENDICS

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 DFLC

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 - OutputVoltage 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

ω_0- Rotor Electrical Speed

ω_r- Angular Speed of the Rotor

ψ_{fd}- Field Circuit Flux Linkage

E_{fd}-Field Voltage

K_E- Excitation Gain

T_E- Time Constant

δ 0- Initial Rotor Angle

ΔP_m- Change in Mechanical Power Input

ΔP_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 Studiesof 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 ARPN Journal of Engineering and Applied Sciences ©2006-2017 Asian Research Publishing Network (ARPN). 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.*ARPN Journal of Engineering and Applied Sciences ©2006-2017 Asian Research Publishing Network (ARPN). 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 systemsdue 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 foranalysis. 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 includesrotor oscillations with increased amplitude as a result ofinsufficient 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 kindof generator excitation control that isdeployed. As for generatorsconnected 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 planningnewfacilities 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 machineis 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 lackofstudies 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).