NEURO-FUZZY BASED POWER SYSTEM STABILIZER OF A MULTI-MACHINE SYSTEM

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Specially dedicated to my beloved parents
for their endless support and encouragements.

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ABSTRACT

This thesis presents a study of neuro-fuzzy power system stabilizer (PSS) for stability enhancement of a multi-machine power system. In order to accomplish a stability enhancement, speed deviation ($\Delta\omega$) and acceleration ($\Delta\bar{\omega}$) of the rotor synchronous generator were taken as the input to the neuro-fuzzy controller. These variables take significant effects on damping the generator shaft mechanical oscillations. The stabilizing signals were computed using the neuro-fuzzy membership function depending on these variables. Simulink Block Design and Matlab 7.6 were utilized in implementing the study. The simulations were tested under different types of conditions; the steady state operation, the three phases to ground fault, with load connected to the system, mechanical input power changes and reference voltage (V_{ref}) step changes. The performance of the neuro-fuzzy power system stabilizer was compared with the conventional power system stabilizer and without power system stabilizer.

ABSTRAK

Tesis ini membentangkan kajian Penstabil Sistem Kuasa *neuro-fuzzy* untuk meningkatkan tahap kestabilan suatu sistem penjana segerak. Untuk meningkatkan tahap kestabilan sistem ini, perbezaan kelajuan ($\Delta\omega$) dan pecutan ($\Delta\bar{\omega}$) rotor pada penjana segerak digunakan sebagai isyarat masukan pengawal *neuro-fuzzy*. Isyarat masukan ini memberi kesan secara langsung bagi mengurangkan ayunan mekanikal terhadap aci penjana. Isyarat ini ditukarkan ke bentuk fungsi keanggotaan berdasarkan kelakuan penjana tersebut. Semua model dan analisis menggunakan perisian Simulink (MATLAB 7.6). Simulasi dijalankan berdasarkan beberapa keadaan iaitu keadaan mantap, kerosakan tiga fasa ke bumi, penjana berbeban, perubahan kuasa masukan mekanikal dan perubahan voltan rujukan (V_{ref}). Perbandingan dilakukan antara Penstabil Sistem Kuasa *neuro-fuzzy* dengan Penstabil Sistem Kuasa Konvensional dan sistem tanpa Penstabil Sistem Kuasa untuk mencari teknik kawalan yang terbaik.

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LIST OF SYMBOLS

PSS	-	Power System Stabilizer
CPSS	-	Conventional Power System Stabilizer
ANFIS	-	Adaptive Neuro-Fuzzy Inference System
FIS	-	Fuzzy Inference System
MSE	-	Means Square Error
SSE	-	Sum of Square Error
J	-	Total moment of inertia of the rotor masses in kgm^2
θ_m	-	Angular displacement of the rotor with respect to a stationary axis in mechanical radians (rad)
P_e	-	Electrical power
P_m	-	Mechanical power
T_a	-	Net accelerating torque in Nm
T_m	-	Mechanical or shaft torque supplied by the prime mover less retarding torque due to rotational losses in Nm
T_e	-	Net accelerating and electromagnetic torque in Nm
M	-	Inertia constant of machine (MJ/rad)
δ	-	Rotor angle perturbation
P	-	Active power (W)
ω	-	Rotor speed of synchronous machine (rad/s)
$\Delta\omega$	-	Rotor speed deviation (rad/s)
T_S	-	Synchronizing torque coefficient
T_D	-	Damping torque coefficient
$\Delta\delta$	-	Delta rotor angle
ΔV_T	-	Delta terminal voltage
f	-	Output frequency
N	-	Rotor speed in rpm
P	-	Number of poles

P_{REF}	-	Mechanical power references
P_{SV}	-	Feedback through governor
T_M	-	Turbine output torque
V_{inf}	-	Infinite bus voltage
V_{TREF}	-	Terminal voltage reference
V_T	-	Terminal voltage
V_A	-	Voltage regulator output
V_F	-	Field voltage
V_E	-	Excitation system stabilizing signal
$\Delta\omega$	-	Speed deviation
$\Delta\bar{\omega}$	-	Acceleration
V_{PSS}	-	PSS output signal
Q	-	Reactive power (VAR)
μ	-	Membership function
c_i	-	The center of membership function
σ_i	-	The widths of membership function

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CHAPTER 1

INTRODUCTION

1.0 Introduction

An interconnected power system basically consists of several essential components. They are namely the generating units, the transmission lines, the loads, the transformer, static VAR compensators and lastly HVDC lines [1]. During the operation of the generators, there may be some disturbances such as sustained oscillations in the speed or periodic variations in the torque that is applied to the generator. These disturbances may result in voltage or frequency fluctuation that may affect the other parts of the interconnected power system [1].

External factors, such as lightning, can also cause disturbances to the power system. All these disturbances are termed as faults. When a fault occurs, it causes the motor to lose synchronism if the natural frequency of oscillation coincides with the frequency of oscillation on the generators. With these factors in mind, the basic condition for a power system with stability is synchronism. Besides this condition, there are other important condition such as steady-state stability, transient stability, harmonics and disturbance, collapse of voltage and the loss of reactive power [2].

The stability of a system is defined as the tendency and ability of the power system to develop restoring forces equal to or greater than the disturbing forces to maintain the state of equilibrium [1].the system is also considered as a stable if it converges to another equilibrium position in the proximity of initial equilibrium point. If the physical state of the system differs such that certain physical variable increases with respect to time, the system is considered to be unstable. Therefore, the system is said to remain stable when the forces tending to hold the machines in synchronism with one another are enough to overcome the disturbances [2]. The system stability that is of most concern is the characteristic and the behaviours of the power system after a disturbance.

Stability studies are generally categorized into two major areas: steady-state stability and transient stability [1]. Steady-state stability is the ability of the power system to regain synchronism after encountering small and slow disturbances. Example of small and slow disturbances is gradual power changes. Dynamic stability is the ability to regain synchronism after encountering small disturbances within a long time frame. The effects of large and sudden disturbances are known as transient stability. Examples of such faults are sudden outrage of a transmission line or the sudden addition of removal of the loads. The transient stability occurs when the power system is able to withstand the transient conditions following a major disturbance [2].

Power system stabilizers are used to generate supplementary control signals for the excitation system in order to damp the low frequency inter-area and intra-area oscillations [3]. The most widely used in existing power system is conventional power system stabilizer and has made a contribution in enhancing power system dynamic stability.

A supplementary excitation controllers referred to as power system stabilizer (PSS) have been added to synchronous generators to counteract the effect of high gain automatic voltage regulator (AVR) and other sources of negative damping [4]. The stabilizer should produce a component of electrical torque in order to provide a damping on the rotor which is in phase with speed variations.

1.1 Problem Statement

Power systems are complex nonlinear systems and often result in low-frequency power oscillations due to insufficient damping. Unfortunately, AVR provide negative damping that can make the system unstable, especially in large system. Power system stabilizers provide this supplementary stabilizing signal and are widely used to suppress the generator electromechanical oscillations and enhance the overall stability of power systems [5].

Conventional PSS are based on linearized machine model and thus tuned at a certain operating point. Since, power systems are highly nonlinear complex systems, with configurations and parameters that change time, the conventional PSS design cannot guarantee its performance in a practical operating environment [5].

1.2 Objectives

The objectives of the project are:

i. To simulate and design a power system stabilizer (PSS) based on neuro-fuzzy
ii. To examine/ analyse the effect of a fault in a multi-machine power systems with PSS using MATLAB
iii. To make a performance comparison between without PSS, conventional PSS and with the neuro-fuzzy PSS

1.3 Scopes

The scope of this project will be undertaken in the following five development stages which are:

i. Study the power system stability phenomenon for multi-machine synchronous generator and control system using fuzzy logic and neural network techniques.
ii. Design a power system stabilizer based on neuro-fuzzy in MATLAB.
iii. Simulate the controller design in MATLAB power system toolbox and compare both controllers performance in an interconnected power system.

1.4 Thesis Organization

The rest of the thesis is organized as follow:

Chapter 2 describes the power system stability phenomena and power system stabilizers are used on generator. This chapter also discusses the basic theory of synchronous generator such as the model and related equations of the relationship between generator and load.

Chapter 3 discusses the basic of intelligent control techniques by neuro-fuzzy and some approaches of neuro-fuzzy system also will be explained. This chapter also briefly explains the structure and type of model used in neuro-fuzzy controller.

Chapter 4 discusses the parameter of power system modelling and proposed neuro-fuzzy PSS design. The power system modelling is illustrated by Simulink block diagram which presents highly interactive surroundings for simulation.

Chapter 5 presents the simulation results of the neuro-fuzzy design and discussion on the result from simulation using MATLAB. The structures of neuro-fuzzy are tested in several disturbances such as a three phases to ground fault, generator loading, mechanical input (P_m) increase and voltage reference step changes in interconnected power system. The dynamic responses of synchronous machine during test conditions are performed and performances between without neuro-fuzzy and with neuro-fuzzy are discussed.

Chapter 6 gives the conclusion for the thesis and provide relevant recommendation to improve the stability and negative damping which include further research in this work.

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