RECURRENT NEURO FUZZI CONTROLLER POWER SYSTEM STABILIZER

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To

my Beloved Mother, Father, Brothers, sisters and wife.

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In the name of Allah, Most Gracious, and Most Merciful

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ABSTRACT

Power system stabilizers (PSS) have been widely used to damp low frequency electromechanical oscillations which occur in power systems due to disturbances. If no adequate damping is available, the oscillation can increase and cause system separation. Power system stabilizers (PSS) are installed in power system generator to help the damping of power system oscillations. There are many approaches to enhance damping while extending the power stability limit .To improve power system stabilizer (PSS)design problem include optimal control ,adaptive and self-tuning control , PID control ,robust control, variable structure control and intelligent control. In this paper the power stabilizer is based on Recurrent Neuro-fuzzy Inference System (RNFIS) design controller. In order to test the robustness of the proposed design procedure of the (RNFIS), simulations will be carried out for the three-phase to ground fault and 1-phase fault at the middle of one of the transmission line. After these simulations, we will compare the result between a lead-lag and recurrent neuro-fuzzy controllers to see their difference in disturbances. The optimal solutions will be compared where the expected result will show that the oscillations in time response of the machine speed and the rotor angle is damped more effectively when the recurrent neuro-fuzzy controller and applied to the system.

ABSTRAK

Penstabil sistem kuasa (PSS) telah digunakan secara meluas untuk meredam ayunan elektromekanikal berfrekuensi rendah yang disebabkan oleh gangguan di dalam sistem kuasa. Sekiranya redaman tidak mencukupi, ayunan akan bertambah kuat dan boleh menyebabkan perpecahan sistem. Untuk mengatasi masalah ini, PSS dipasang di dalam penjana sistem kuasa. Terdapat banyak cara untuk meninggikan redaman ketika menambahkan had kestabilan kuasa. Dengan menggunakan kawalan optima, kawalan adaptif dan tuning-kendiri, kawalan PID, kawalan tegar dan kawalan berubah struktur, dan kawalan pintar, ia boleh mengatasi masalah rekabentuk PSS. PSS di dalam tesis ini adalah menggunakan rekabentuk kawalan *Recurrent Neuro-fuzzy Inference System* (RNFIS). Simulasi telah dilakukan terhadap sistem tiga fasa ke kesilapan pembumian dan kesilapan sistem satu fasa di pertengahan garisan transmisi untuk menguji ketegaran sistem yang dicadangkan. Perbandingan di antara kawalan mendulu-mengekor dan kawalan pengulangan *neuro-fuzzy* turut dinyatakan di dalam tesis ini. Perbandingan menunjukkan kawalan pengulangan *neuro-fuzzy* adalah lebih baik

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PSS	-	Power System Stabilizer
CPSS	-	Conventional lead-lag power system stabilizer
ANN	-	Artificial Neural Network
BP	-	Backpropagation
LSE	-	Least Square Error
ANFIS	-	Adaptive Neuro-fuzzy Inference System
NFIS	-	Neuro-Fuzzy Inference System
RANFIS	-	Recurrent Adaptive Neuro-fuzzy Inference System
FIS	-	Fuzzy Inference System
MLP	-	Multilayer Perceptron
MSE	-	Mean Square Error
SSE	-	Sum of Square Error
J	-	Total moment of inertia of the rotor masses in kgm
θ_M	-	Angular displacement of the rotor with respect to a stationary axis in mechanical radians (rad)
P_e	-	Electrical power(w)
p_m	-	Mechanical power(w)
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 acceleration or electromagnetic torque in Nm
M	-	Inertia constant of machine (MJ/rad)
δ	-	Potor angle perturbation
P	-	Active power(w)
ω	-	Rotor speed of synchronous machine (rad/s)
$\Delta\omega$	-	Rotor speed deviation(rad/s)

$\frac{\partial \omega}{\partial t}$	-	Derive of rotor speed
T_S	-	Synchronizing torque coefficient
T_D	-	Damping torque coefficient
μ	-	Membership function
y_{ji}	-	The output of the i th nod in the j th layer
w_i	-	Firing strength of Wight
k	-	Step size of learning rate
η	-	Learning rate of backpropagation
β	-	Momentum constant
x	-	Input of NFIS and RANFIS structure
y	-	Entry of training data set
y_d	-	Desired output of RANFIS structure
p	-	Entry of training data set
n	-	Number of node in layer j th
E	-	Error signal between target output and learning output
c_i	-	The center of membership function
σ_i	-	The widths of membership function
z^{-d}	-	Element of delay for d time step
AVR	-	Automatic voltage regulator
APSS	-	Adaptive power system stabilizer
E_q'	-	pu on machine base
E_d'	-	pu on machine base
ψ_{kd}	-	pu on machine base
ψ_{kq}	-	pu on machine base
i_d	-	d-axis current on system base
i_q	-	q-axis current on system base

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CHAPTER 1

INTRODUCTION

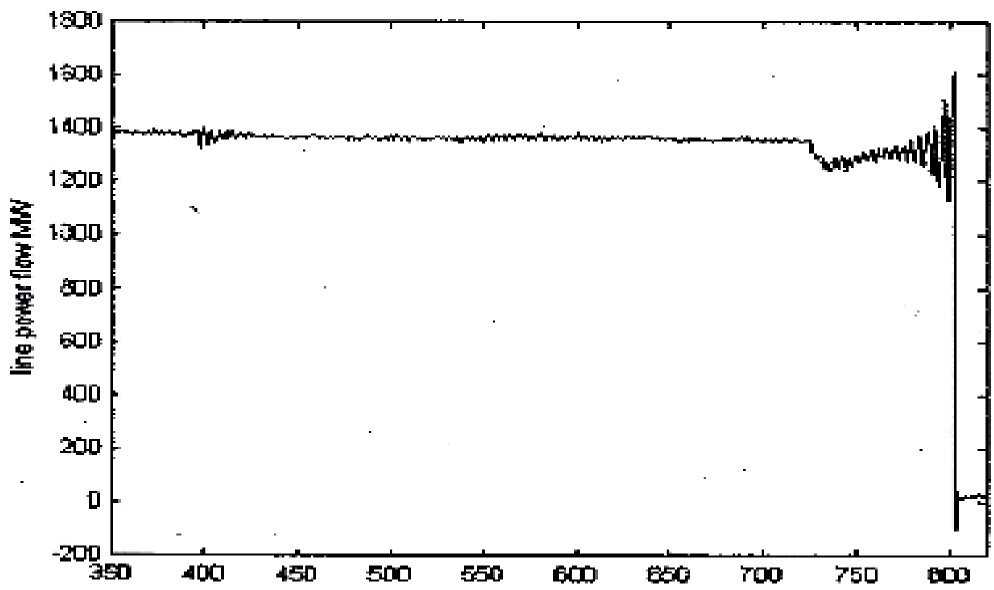
1.1 Background of power system Oscillation

In an interconnected power system, the synchronous generators should rotate at the same speed and power flows over tie-lines should remain constant under normal operating conditions. However, low frequency electromechanical oscillations may occur when a disturbance is applied to the power system. These oscillations can be observed in most power system variables like bus voltage, line current, generator rate and power. Power system oscillations were first observed as soon as synchronous generators were interconnected to provide more generation capacity and more reliability to a power system. Originally, the fairly closely connected generators were observed to swing against each other at frequencies of around 1-2 Hz. Damper windings on the generator's rotor were used to prevent the amplitude of oscillations from increasing. After fast excitation systems were introduced to prevent the generators from loosing synchronism following a system is fault, it was noticed that this kind of excitation system always tends to reduce the damping of the system oscillations [1]**.** Power System Stabilizers (PSSs), which are the excitation system based damping controllers, were then widely used to add damping torque and increase the damping of these oscillations.

Power system oscillations are generally associated with the dynamics of generators, turbine governors and excitation systems and can be represented by the linear zed swing equation of a synchronous generator around an operating condition as follows:

$$\frac{d}{dt}\Delta\omega_r = \frac{1}{2H}\left(\Delta T_m - \Delta T_e - D\Delta\omega_r\right) \tag{1-1}$$

$$\frac{d}{dt}\Delta\delta = \omega_0 \Delta\omega_r \tag{1-2}$$



Time s

Figure 1.1: Line flow transient –August 10, 1996 western USA/Canada system

Where

$\Delta\omega r$ is the per unit speed deviation of the generator (radians/sec)

$\Delta\delta$ is the rotor angle deviation (radians)

ω 0 is the base rotor electrical speed (radians/second)

Tm, *Te* are the mechanical torque and electrical torque, respectively

H is the inertia of the generator

D is the inherent damping coefficient

The electrical torque can be further represented as [2]

$$\Delta Te = KS\,(s) \quad \Delta\delta + KD\,(s)\Delta\omega r \tag{1-3}$$

Where *KS* and *KD* are synchronizing and damping torques, respectively. They are sensitive to generator operating conditions, power system network parameters, and excitation system parameters.

By substituting (1-2) and (1-3) into (1-1), with $\Delta Tm = 0$, we obtain

$$\frac{2H}{\omega_0}\Delta\ddot{\delta} + (D + K_D).\Delta\dot{\delta} + K_S.\Delta\delta = 0 \tag{1-4}$$

The characteristic equation for (1-4) is given by

$$S^2 + \frac{K_{D+}D}{2H}S + \frac{K_S\omega_0}{2H} = 0 \tag{1-5}$$

For the system to be stable, KD+*D* and *KS* have to be positive. If *KS* is negative, the system will have at least one positive real root and the generator will slip out of synchronism without any oscillation. If *KD*+*D* is negative, the system will have at least one root with positive real part. Normally, the effect of AVR in an excitation system with moderate or high response is to introduce a positive synchronizing torque component and a negative damping torque component. Therefore, *KS* is positive and *KD*+*D* could be negative. In the case of *KD*+*D* being negative, the system will have complex roots with positive real parts and exhibits oscillations with increasing magnitude. This dissertation explores the controller designs for enhancing the damping of low frequency power oscillations.

1.2 Problems of Conventional Power Control

Today, PSS are widely used on synchronous generators. The most commonly used PSS, referred to as the Conventional PSS (CPSS), is fixed parameter analog –type device. The CPSS first proposed in 1950, is based on the use of a transfer function designed using the classical control theory [2].It contains a phase compensation network for the phase different from the excitation controller input to the damping torque output. By appropriately tuning the phase and gain characteristic of the compensation network, it is possible to set the desired damping ratio. CPSSs are widely used in power systems these days to improve power system dynamic stability. The conventional lead-lag power system stabilizer (CPSS) is widely used by power system utilities. Other types of PSS such as proportional integral power system stabilizer (PI PSS) and proportional integral derivation power system stabilizer (PID PSS) have also been proposed.

The CPSS designed for a particular operation condition around which a linear zed transfer function model is obtained. The high non-linearity, very wide operating condition and unpredictability of perturbations of power system exhibit the following problems to the CPSS:

- The accuracy of linear model for the power system.
- The accuracy of the parameter for that model.
- The effective tuning of the CPSS parameters.
- The interaction between various machines.

However, the CPSS is a linear controller which generally cannot maintain the quality of performance at other operating condition.

1.3 Computational Intelligence Techniques

Recently, many intelligent system techniques have been developed and introduced, such as neural network and fuzzy logic. Artificial neural networks and fuzzy logic system have recently emerged as attractive tools for engineering applications. Fuzzy logic provides a convenient method for constructing nonlinear controllers via the use of expert knowledge [3] .Therefore, the recent direction is to integrate the use of neural network and fuzzy logic system in order to combine their different strengths and overcome each others weaknesses to generate a hybrid solution.

1.4 Thesis Objective and Scope of Work

The objective of this study is listed as follows:

- **i.** To present an approach for designing intelligent power system stabilizer.
- **ii.** To study and understand the nature of power system stabilizer and the structure of power system generating.
- **iii.** To design and simulate a power system stabilizer based on recurrent neuro-fuzzy algorithm.
- **iv.** To make a comparison in the performance between controller responses signals of conventional power system and recurrent neuro-fuzzy system.

In this project, the scope of work will be undertaken in the following stages:

i. Study the power system stability phenomena for a signal generator and interconnected synchronous generators.

ii. Design and analyze the effectiveness of intelligent PSS using Recurrent Neuro-fuzzy structure (RANFIS) in MATLAB m-file and evaluate it into the proposed power system stabilizer.

iii. Propose intelligent power system stabilizer that damp the low frequency oscillation.

1.5 Thesis Outline

The thesis is organized as follows:

Chapter 2 describes the basic theory of synchronous generator such as the model and related equations of the relationship between generator and load. it also briefly discusses power system stability and presents some cases of interconnected synchronous generator.

Chapter 3 discuses the basics of intelligent control techniques by Fuzzy logic and neural network. Some mathematical formulations of the control system are also explained in this chapter. Brief explanations about the behavior of Fuzzy logic and Neural Network are also given.

Chapter 4 explains the proposed artificial neural network and fuzzy logic in dynamic system Identification and control. The structure of the adaptive PSS based on recurrent neuro-fuzzy is proposed. The control algorithm of the new PSS is also discussed in this chapter.

Chapter 5 presents the simulation results of the recurrent neuro fuzzy design and discussion on the result produced from the simulation using MATLAB. The structures of recurrent neuro fuzzy are tested in online learning mode. using dynamic plant.

Chapter 6 gives a conclusion of the thesis and recommendations to further improve this research.