POWER SYSTEM STABILIZERS OPTIMIZATION BASED ON NEURAL NETWORK USING LINEAR OPTIMAL CONTROL

J. AHMADIAN, M. JALALI, R. POUAGHABABA, M. NOUHI

[1] Islamic Azad University- Branh Khominishahr
[2] Isfahan Electrid Co.
Javad_Ahmadian@yahoo.com

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Abstract: *In this paper optimal design of power system stabilizers (PSS) based on artificial neural network (ANN) with using linear optimal control (LOC) method are introduced and analyzed. Benefits of conventional power system stabilizer (CPSS) such as simple structure, optimizing LOC strategy and the quick response of ANN are combined in this Stabilizer. The ANN was trained using data generated by the optimal control stabilizer (LOC-PSS). By this method, system damping will increase in a wide range of system operating points. Various stabilizers performances are compared and Results show that designed stabilizer improves dynamic response of power system under various contingences and operating conditions.*

1. INTRODUCTION

Power system always is treated by small and large disturbances. Power system stability is the "ability of a Power system stability is ability of power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact"[1]. Small signal stability depends on the damping characteristic of power system. To improve the damping characteristic of a synchronous generator under small disturbances like, load profile change or step changes of the system parameters, power system stabilizers (PSS) have been widely employed [2-3].

Conventional stabilizers with considering their structure (lag-lead) was proposed based on linear model of power system at some operating point to damp out the low frequency oscillations. The input signal of stabilizer may be rotor speed, electrical power or frequency or combination of them.

The advantage of this stabilizer is the simple construction, but its disadvantage is that it cannot cover wide range of operating conditions [4].

Stabilizing method based on liner optimal control, make a suitable damping at different loading condition, but also this method needs determination of all system states that seems to be very difficult. In recent years ANN methodology has widely used in power system engineering. Using of ANN to self tuning of stabilizers parameters are introduced [5]. Another work is based on the construction of neural network that can be used to design the stabilizer [6].

In the proposed PSS designed in this paper, the ANN is trained by LOC-PSS. It combines the good performance of the LOC-PSS, the single input of the CPSS and the quick response of ANN. The Block diagram of power system with power system stabilizer with various constructions is shown in fig. 1.

The linear model of single machine (Heffron-Filips) with its exciter and stabilizer is shown in fig. 2.

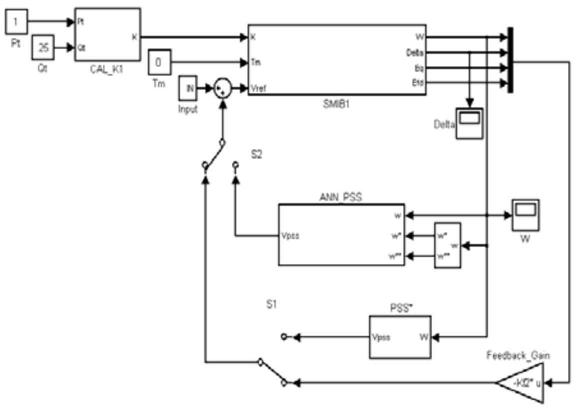

Fig. 1: Block diagram of power system with various construction stabilizers

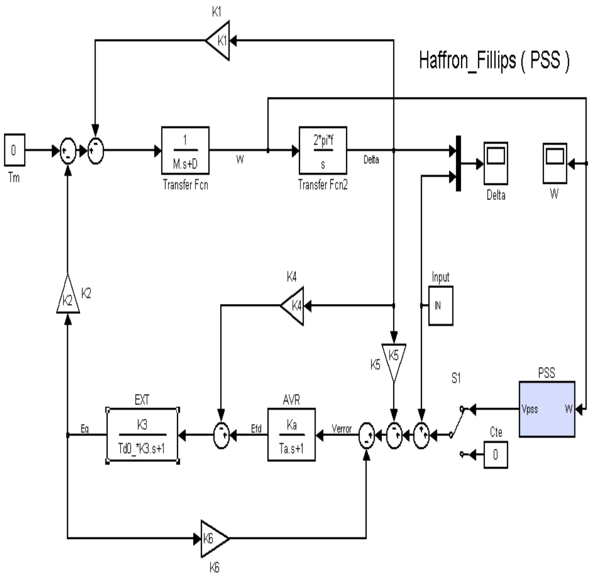

Fig. 2: Heffron-Filips model of a generator.

2. CONVENTIONAL STABILIZER DESIGN

Electromechanical oscillations of generator are damped by compensator that one type of it is shown in fig 3.

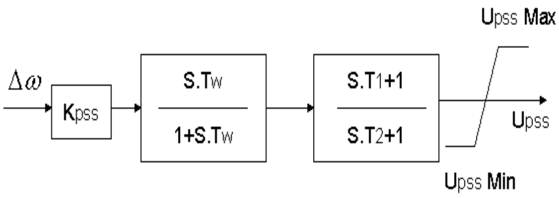

Fig. 3: Block diagram of a CPSS

The main disadvantage of this method is improper operation for electromechanical oscillation when system parameters varied.

3. NEURAL NETWORK STRUCTURE

Simple three layer structure, fig 4, in this study used for neural network. This network is contains an input layer, an output layer and a hidden layer.

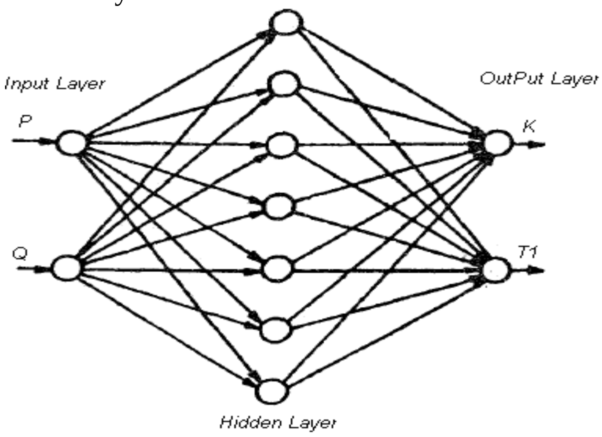

Fig. 4: Neural network construction

Input layer nodes are active power (P), reactive power (Q) of generator. Active power and power factor (PF) is next option for input layer nodes. For neural network training considered back propagation algorithm that used reduction gradient method for minimize square mean error between real output and reference in each training set path [8].

4. STUDIED NETWORK

A single bus system connected to infinite bus via two lines is considered for studied network, fig. 5. Generator with three degree model is used for stability study [3].

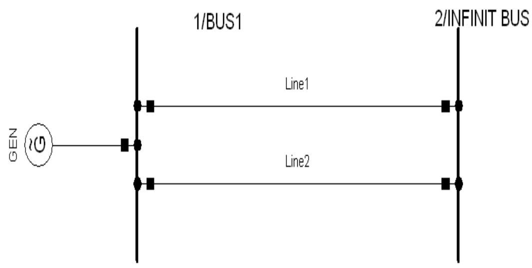

Fig. 5: Single machine connected to a large power system through double circuit.

5. NEURAL NETWORK TRAINING

Training of neural network has important role in stabilizer design based on neural network. Training must contain extend area of generator operating point. In this paper area of generators operating point are considered between 0.4 Pu to 1 Pu and PF between 0.5 to 0.9 lag. Used disturbance for neural network training is 5% step variation in reference voltage. Fig. 6 and fig. 7 show T1 and Kc coefficient computed for (lag-lead stabilizer parameters) for different generator loading conditions.

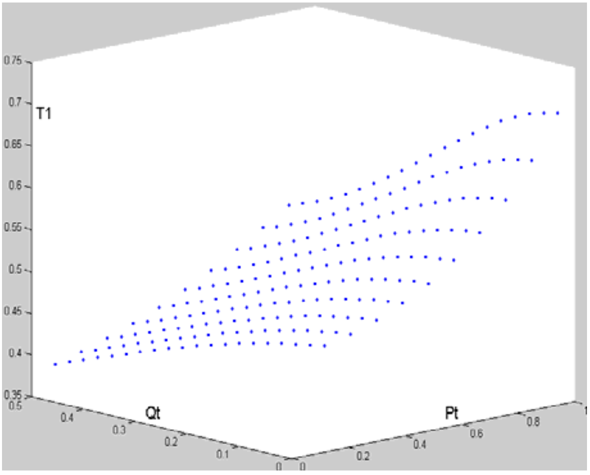

Fig. 6: The computed parameter T1 for different generator loading condition (P&Q)

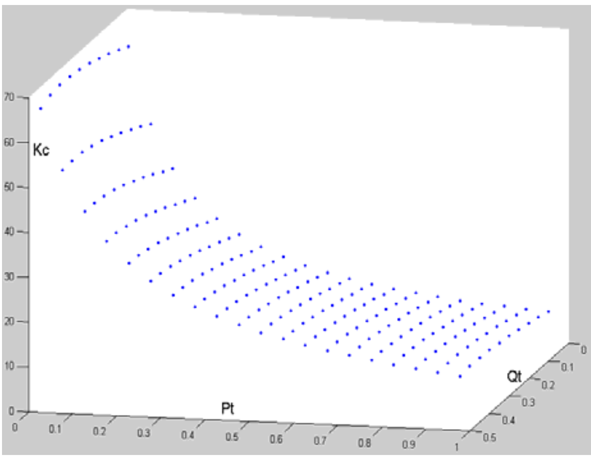

Fig. 7: The computed parameter Kc for different generator loading condition (P&Q)

Self tuning neural network operation results compared with CPSS are shown in fig. 8 and fig. 9.

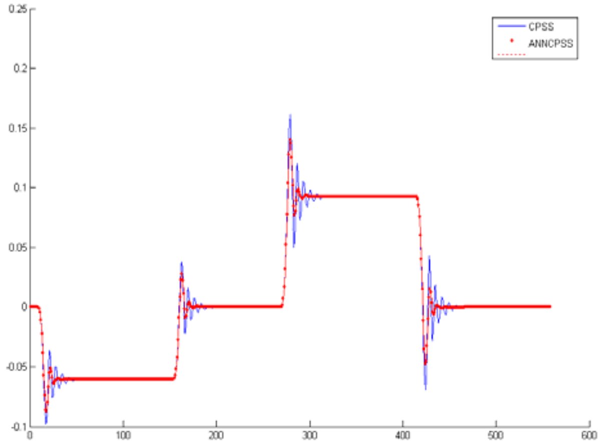

Fig. 8: Generator rotor angle variation comparison between CPSS and ANN-CPSS

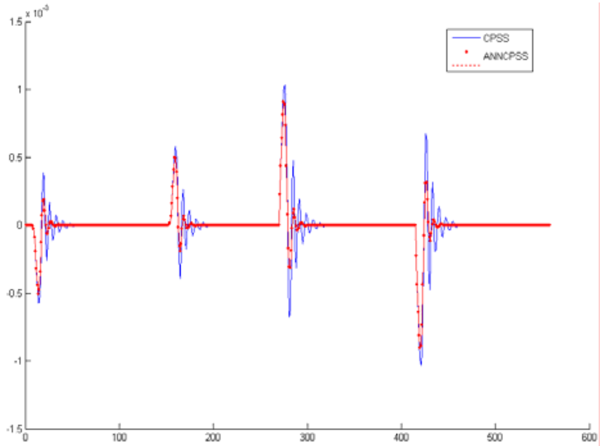

Fig. 9: Generator speed variation comparison in CPSS and ANN-CPSS

Important notice to design the stabilizer is the selection suitable and optimal neural network training method to obtain maximum system damping. Therefore operation analysis and comparison of two stabilizers, CPSS and LOC-PSS are done and according to their results suitable training method are selected. Fig. 10 and fig. 11 show rotor angle and speed variation to a 5% step variation in exciter system reference voltage for CPSS and LOC-PSS.

According to results, LOC-PSS method makes better damping characteristic in system. Therefore for stabilizer optimal design, LOC outputs use for neural network training. Generator operating point is equal to P=1pu and Q=0.15pu in PF=0.9 lag. Neural network is trained by LOC output that considered as a single input – single output controller.

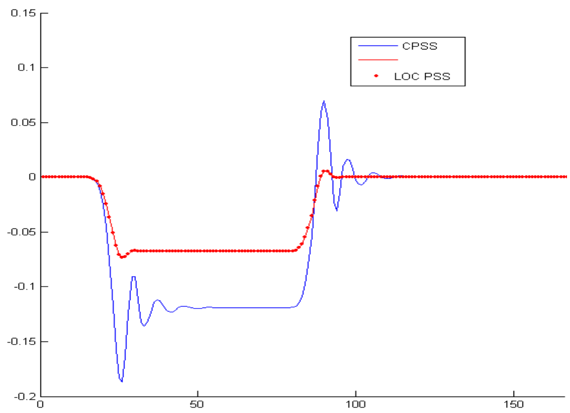

Fig. 10: Generator rotor angle variation comparison in CPSS and LOC-PSS

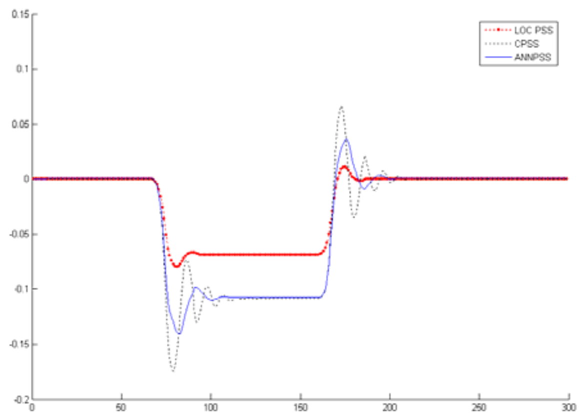

Fig. 12: Generator rotor angle variation comparison in different stabilizer to a step change in reference voltage

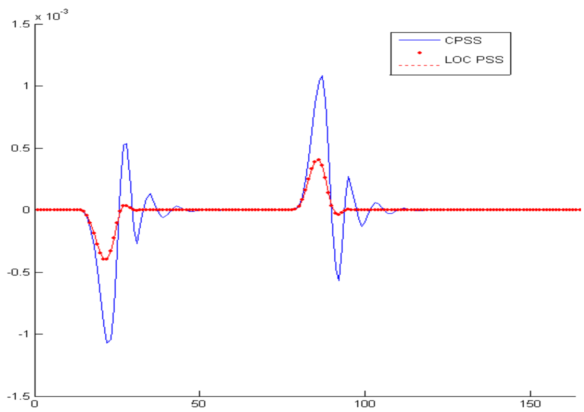

Fig. 11: Generator speed variation comparison in CPSS and LOC-PSS

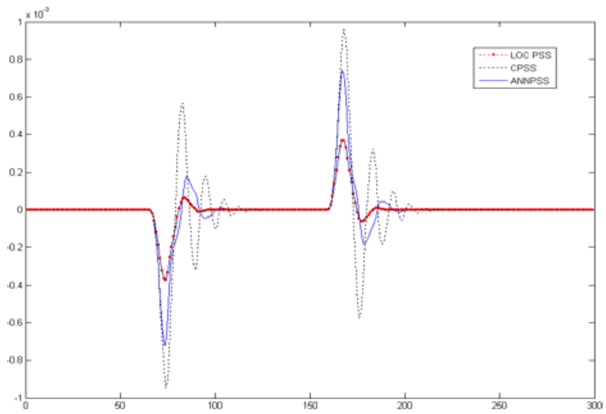

Fig. 13: Generator speed variation comparison in different stabilizer to a step change in reference torque

6. STABILIZER OPERATION COMPARISON

For evaluate of trained stabilizer operation, a different disturbance like a 5% step change in mechanical torque are considered. Operating area is between 0.9pu to 1.2pu with equal PF. The best input for designed stabilizer is speed [7].

Fig. 12 and fig. 13 show comparison of different stabilizer operation include CPSS, LOC-PSS and ANN-LOC-PSS. Fig. 12 shows generator rotor angle variation to a ±5% step change in reference voltage and fig. 13 shows speed variation to a ±5% step change in reference torque.

According to figures, designed stabilizer has suitable response to a disturbance different with disturbance that used for training.

Also neural network that trained by LOC parameters has same response with LOC method. In fact ANN-PSS that trained by LOC outputs, has LOC-PSS specification with fast response and don't need to determine all system equation.

7. CONCLUSION

In this paper optimal design of power system stabilizers based on neural network with using LOC are introduced and analyzed. This work is done in two separate sections, first analyze and selection of suitable and optimal method for neural network training and next analyze operation and system dynamic response to disturbances. Results show that trained neural network by LOC has a very similar response to LOC-PSS with fast response and without need to determine all system states.

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