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SIMULATION AND ANALYSIS OF POWER SYSTEM STABILIZER DESIGN BY DIFFERENT METHODS

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ABSTRACT: The major problem in power system operation is related to small signal instability caused by insufficient damping in the system. The most effective way of countering this instability is to use auxiliary controllers called power system stabilizers, to produce additional damping during low frequency oscillations in the system. The use of power system stabilizers (PSS) to damp power system swing mode oscillations is of practical importance. This paper discusses the experience in assigning PSS projects in an undergraduate control design course to provide students with a challenging design problem using three different techniques and to expose them to power system engineering. The details of the PSS design projects using root-locus, frequency domain, and state-space methods are provided.

I. INTRODUCTION

Power system stability has received a great deal of attention over the year. Stability is now a major concern in planning and operating electric power System. A large interconnected power system is exposed to many disturbances, which make the system unstable and thus are a threat to its security. In recent days, the effects of these disturbances are more serious considering the intensive use available electric power and its wide transmission. These disturbances result in electromechanical oscillations being set up in the interconnected system. The capability of the system to achieve an operating equilibrium after disturbances are caused in it depends on its inherent strength and on the nature and intensity of the disturbance .Increasing attention has been focused on the effect of excitation control on the damping of oscillations, which characterize the phenomena of stability. In particular it has been found useful and practical to incorporate transient stabilizing signal derived from speed, terminal frequency or accelerating power superimposed on the normal voltage error signal to provide for additional damping of this oscillation. Such device is known as Power System Stabilizer (PSS).

II. POWER SYSTEM STABILIZER (PSS)

Power System stabilizer (PSS) has board application throughout the world. Power system stabilizer (PSS) applied to generate exciter to limit the excitation system phase lag in the frequency range corresponding to the natural frequency of the interconnected system. With interconnection of large electric power system, low frequency oscillations have become the main problem for power system small single stability. They restrict the steady state power transfer limits, which therefore affects operational system economics and security. Considerable efforts has been placed on the application of PSS's to damp low frequency oscillation and thereby improve the small signal stability of power system. [8].The introduction of the supplementary controller for the power system not only improves the dynamic performance but also increase the stability margin. Power systems stabilizers have been developed, using liner control theory to damp the oscillation of synchronous machine following any disturbance. Power system stabilizer design and characteristics have been discussed and dynamic model of PSS with excitation control system and generator for small perturbation has been analyzed.

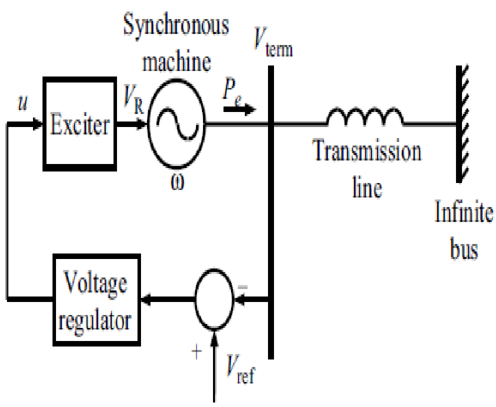


Fig. 1. Single-machine infinite-bus system.

Note that the conventional PSS path comes into the summing junction with a positive sign. Here, we use a negative sign, balanced by a sign inversion in the feedback path, because the MATLAB root-locus function assumes negative feedback. The open- and closed-loop transfer functions required in various designs tages are generated from the Simulink diagram by opening appropriate connections.

III. III.POWER SYSTEM STABILITY ENHANCEMENT

Flexible AC Transmission System (FACTS) devices are example of enhancing power systems stability by controlling power flow at transmission end. They are divided into series, shunt and series-shunt categories according to the manner of device connection with the system. The concept behind enhancing power system stability by series FACTS devices such as Static Series Synchronous Compensator (SSSC) is to increase active power flow during faulty condition consequently decreasing area A1 and increasing area A2 [21]. On the other hand, shunt devices as Static Synchronous Compensator (STATCOM) boost power system transient stability by injecting reactive power into system to support the system voltage during disturbance and ultimately leading to decrease of area A1 and increasing area A2 [22].

The most commonly used FACTS controller is Unified Power Flow Controller (UPFC). It consists of two branches; one is connected in series and the other is in shunt with the system. UPFC controller uses notion of both series and shunt FACTS controllers for increasing power system stability effectively than any other FACTS controllers [19,23].Controlled Islanding is a technique in which whole power system is divided into sections, without having any interconnection, to avert major blackouts [15].

Controlled islanding is the last line of defence in strategy to keep power system stable. Additionally, it is not proposed as the answer to all instability problems in the system [20]. High Voltage DC (HVDC) transmission system is potentially a shield against synchronism loss. Nonetheless, it poses problem of voltage instability following disturbance, if the system depletes reactive power reserves [24].The control actions at generator end to thwart the system instability are either in terms of excitation system or power system stabilizers or at mechanical end of power plants. The main cause of transient instability of generator is inability of mechanical torque to quickly balance out changes in electrical torque [15] and also generator rotor inertia plays major role.

IV. REVIEW OF DIFFERENT PSS TECHNIQUES

A. PID Control Approach

PID is used for stabilization in the system. The input is the change in speed from the generator. The aim is to control the angle between load and speed of generator. The PSS parameters are tuned from Open loop transfer function to close loop based on Fuzzy logic. Therefore, the open loop transfer function and maximum peak response parameter make the objective function which is used to adjust PID parameters.

B. LAG-LEAD Design

The washout block is used to reduce the over response of the damping during extreme events. Since the PSS produces a component of electrical torque in phase with speed deviation, phase lead blocks circuits can be used to compensate for the lag between the PSS output and the control action(hence lead-lag). It proves its value when the disturbance is multi natured.

C. Pole Placement Method

The pole placement method is applied to tune the decentralized output feedback of the PSS. The objective function is selected to ensure the location of real parts and damping ratios of all electro mechanical modes. At the end of the iterative process, all the electromechanical modes will be moved to the region if the objective function converges to zero [7][8].

D. Model predictive Control

It can handle non linarites and constraints in saturated way for any process model. In these techniques an explicit dynamic model of a plant is used to predict the effect of future actions of manipulated variables on the output.

E. Linear Matrix Inequalities:

The important feature is the possibility of combining design constraints into a single convex optimization problem. it is used in many engineering related problems. The condition that the pole of a system should lay within this region in the complex plane can be formulated as an LMI constraint.

F. Linear Quadratic Regulator

These are well known as compared to lag-lead stabilizers. This is used as a state feedback controller. A co-ordinated LQR design can be obtained with Heffron- Phillips Model and it can be implemented by using the information available within the power system. During the presence of faults even these methods prove to be stable [8].

G. Genetic Algorithm

Genetic algorithm is independent of complexity of performance parameters and to place the finite bounds on the optimized parameters [8]. As a result it is used to tune multiple controllers in different operating conditions or to enhance the power system stability via PSS and SVC based stabilizer when used independently and through different applications.

H. Fuzzy Logic Control

These are rule based controllers. The structure of this logic resembles that of a knowledge based controller; it uses principle of fuzzy set theory in its data interpretation and data logic. It has excellent response with small oscillations. The controller is robust and works effectively under all types of disturbance. It has very short computation time [9] [10].

I. Neural Network

Neural Network is used to approximate the complex non-linear dynamics of power system. Magnitude constraint of the activators is modelled as saturated non-linearity and is used in Lyapnov's stability analysis [9] [10]. The overshoot is nearly same as conventional PSS but settling time is drastically reduced.

J. Anfis PSS

The actual design method may be chosen based on real time application and dynamic performance characteristics. If the training data and algorithm are selected properly then good performance can be observed.

V. SIMULATION AND RESULTS

The Simulink model is given in the following figure :

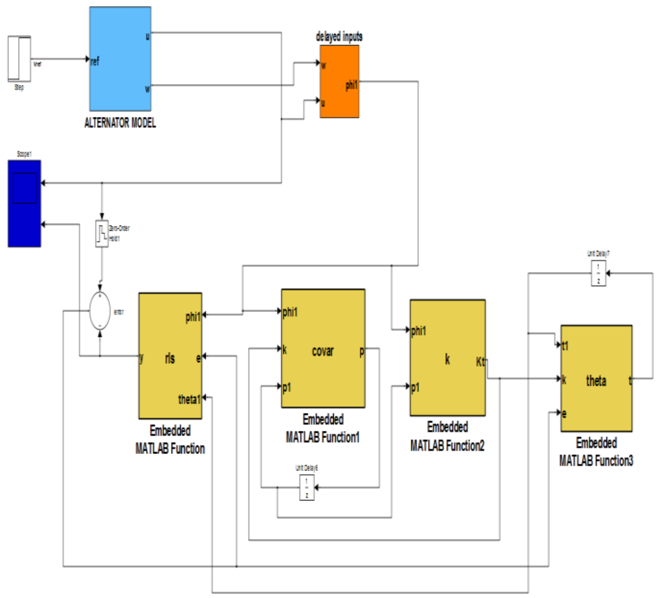


Fig.2. SIMULINK model of the ARMA implementation of the system identifier

The output RLS block is compared with the desired output signal obtained from the PSS as given in figure 2.

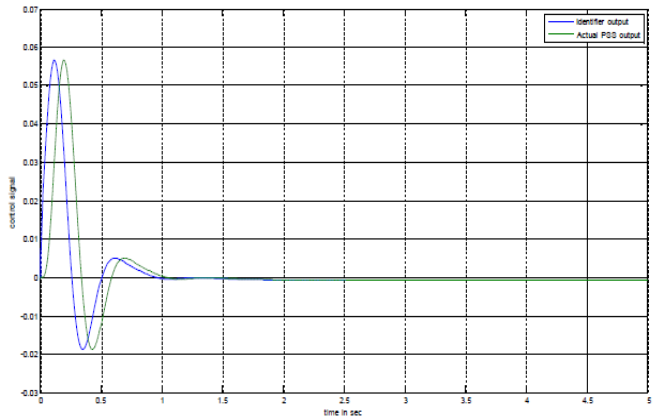


Fig.3. Comparison between ARMA output and actual output

The above figure shows that the identifier output follows the desired PSS output and the error signal reduced to zero subsequently.

A. PSS DESIGN USING ANFIS:

The ANFIS PSS uses a zero order Sugeno type fuzzy controller with 49 rules. The input to the PSS is the speed and electrical power which are obtained from the wash-out filter that is used to eliminate any existing dc offsets. The fuzzy inference system consists of the fuzzification block, rule table block and the suge node fuzzification block. Where is the jth input, represents the ith linguistic term related to the jth input and , are the centers and the spreads of the membership function related to which are adjustable by the neural network block of the ANFIS. Seven linguistic variables are used for each input for the fuzzifiacation. The fuzzy logic based controller is made adaptive by using feed forward neural network using a multilevel perception. The multilevel perception is implemented using the ANFIS-GUI block of MATLAB. The neural network can be trained using either OFFLINE method or ONLINE method. The details are as follows.

B. OFFLINE ADAPTATION USING ANFIS:

Here we first generate the input-output data pair of the system using the identifier or directly from the model. Then, we use the ANFIS module in MATLAB to generate a fuzzy inference system. Two inputs are used, namely $\Delta\omega$ and ΔP, and a single control output for the feedback. A Sugeno type FIS model is used.

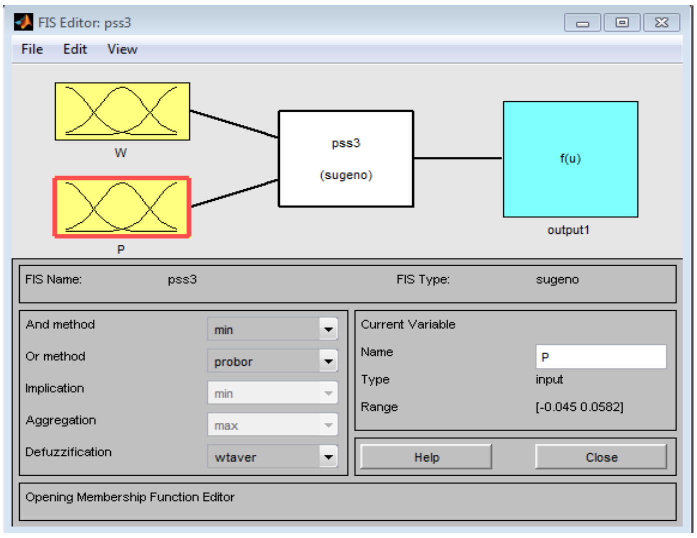


Fig.4. FIS model of the PSS

The membership functions of the inputs are of Gaussian distribution type. We use 7membership functions for each input to cover the full range of the respective inputs. Thus, we get 49 rules for the output function which is linear relation of the inputs. The initial input parameters are arbitrarily chosen and output parameters are given in table5 (appendix-1). The output is governed by the AND function and thus the rules are generated.

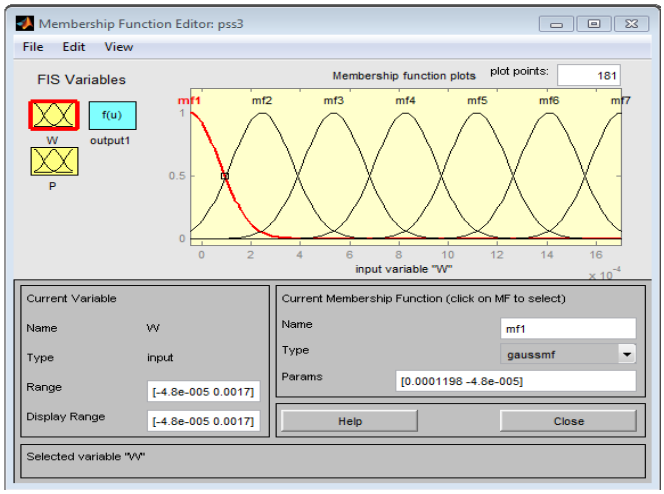


Fig.5. Gaussian membership functions of the inputs

The above generated fis file is opened in the ANFIS GUI for training. We also import the training data which was previously generated to the GUI. The neural network thus has four layers as given below:

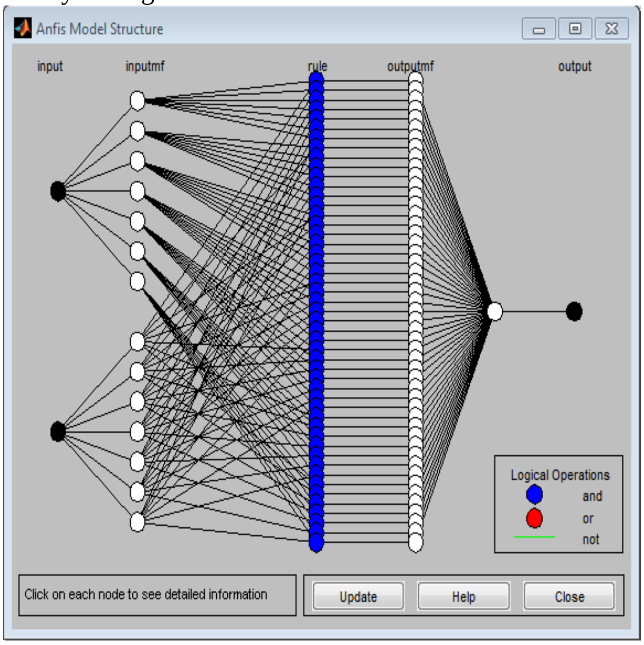


Fig.6. Structure of the Neural Network

The first layer represents the input membership functions (MFs) which is Gaussian. The second layer represents the AND function. The third layer represents the normalized firing35strength as given in the sugeno model and, the fourth layer represents the combination of the rules and their weighted average to find the final output using sugenode fuzzification technique. Now, the training is started using the back-propagation method and the model is trained for 100 epochs for greater reliability. The error is given as below:

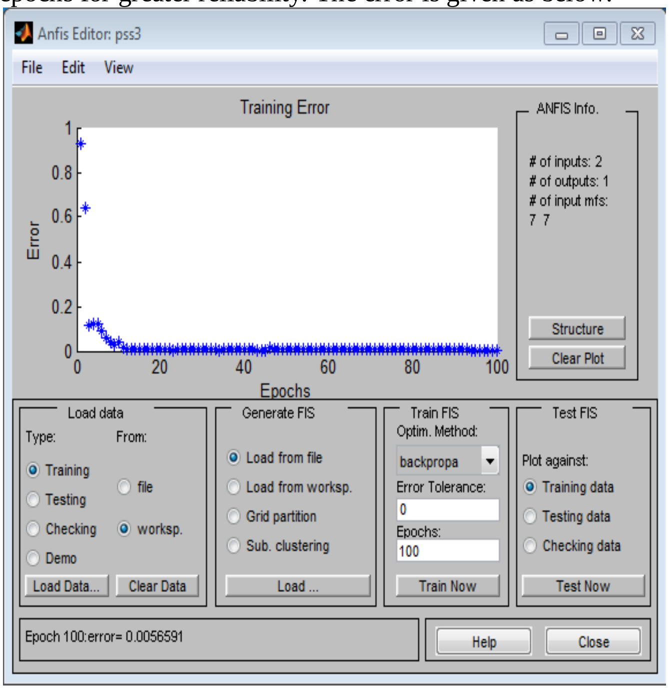


Fig.7. The training of ANFIS showing the training error

Finally the trained model is tested against the output data as below:

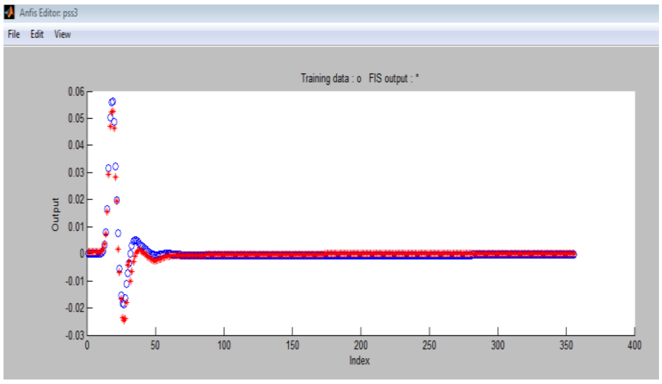


Fig.8. Comparison between trained and test data

As seen in the figure above, the trained data (red stars) almost faithfully follows the output (Blue circles). This trained FIS model is exported for use in our fuzzy logic controller block (PSS). Thus, the offline-trained fis was used in the fuzzy controller to simulate the PSS.

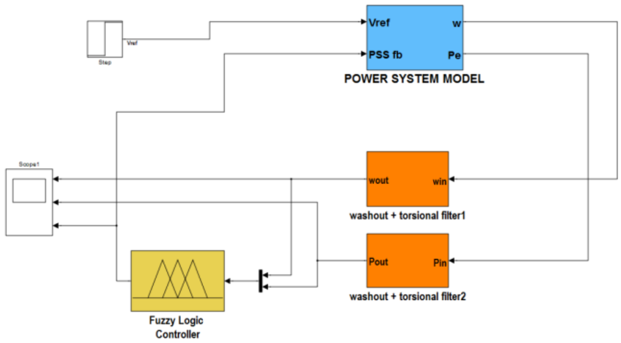


Fig.9. SIMULINK implementation of the fuzzy controller

The output responses as seen from the simulation results are crisp and have good design specifications such as rise time, overshoot and settling time.

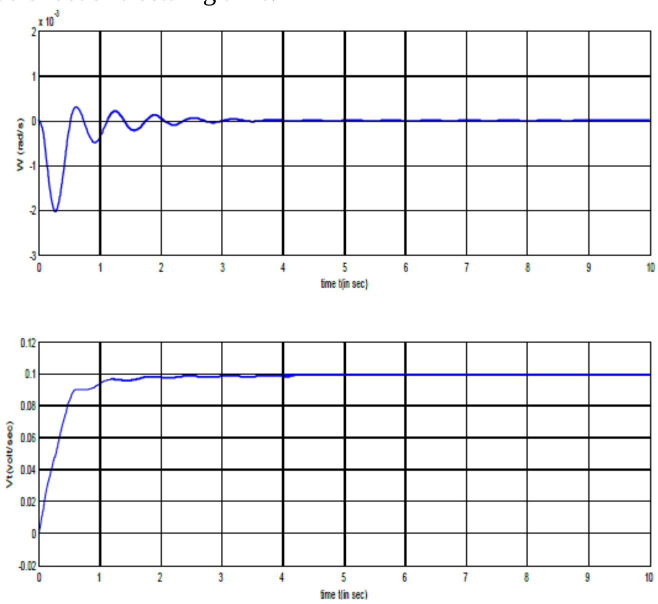
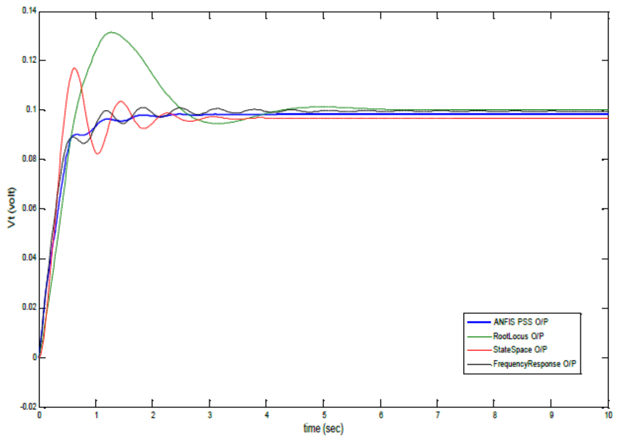


Fig.10. w and Vt outputs using the fuzzy controller

C. COMPARISON OF THE ANFIS PSS CONTROLLER WITH CPSS:

Finally, we are in a position to compare the conventional PSS or CPSS with the PSS developed using Fuzzy inference system. As seen in Figure 28, the fuzzy PSS has the best output response (Vt), the least overshoot and settling time. Also, it produces the best damping which is manifested in the plot showing the rotor speed perturbation (w). Thus, by proper training algorithms, the fuzzy PSS can surpass the performance of the CPSS.



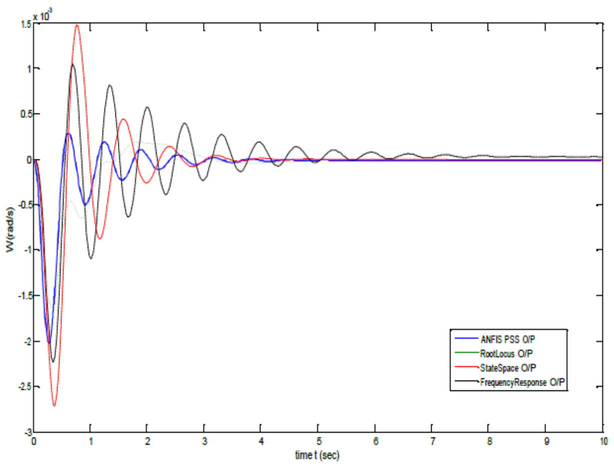


Fig.11. Comparison of Vt and w between CPSS and ANFIS PSS

VI. CONCLUSION

From this paper we can study different types of design method of power system stabilizers and also study the concept of power system stability importance. This stabilizer is synthesized using information available at the local buses and makes no assumptions about the rest of the system connected beyond the secondary bus of the step up transformer. As system information is generally not accurately known or measurable in practice, the proposed method of PSS design is well suited for designing effective stabilizers at different system operating conditions. The performance of the proposed stabilizer is comparable to that of a linear quadratic stabilizer and genetic algorithm stabilizer which has been Designed assuming that all system parameters are known accurately.

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