Design of Fuzzy Logic Controller Based Power System Stabilizer and Compare With Conventional Power System Stabilizer

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Abstract— This paper presents the application of a fuzzy logic controller to improve the stability of electric power system. The stabilizing signal is computed using the standard fuzzy membership function depending on the speed acceleration state of the generator in the phase plane. Studies have been carried out considering FLPSS based on 3, 5 and 7 MFs of Gaussian shape. Investigations reveal that the performance of the proposed FLPSS is quite robust to wide variations in loading condition both for small and large perturbations. The performance of the fuzzy PSS is compared with the conventional power system stabilizer (CPSS). The simulations were tested under different operating conditions and change in reference voltage also tested with different membership functions.

Key Words: - Power system stabilizer, SMIB, WPSS, CPSS, and FLPSS

I. INTRODUCTION

Power system is highly non-linear system. A high gain fast acting AVR is used to enhance large scale stability to hold generator in synchronism with the power system during the large transient fault condition. But it produces negative damping especially at high values of external system reactance and high generator output.

To compensate unwanted effect of these voltage regulators (or to provide damping) additional signals are introduced in feedback loop of voltage regulators. These additional signals are mostly derived from speed deviation, excitation deviation or accelerating power. The device set up to provide the signal is called “power system stabilizer.”

The most widely used PSS is conventional PSS or lead –lag PSS. In lead-lag PSS the gain setting are fixed under certain values which are determine under particular operating condition. CPSS parameters are determined based on linearized model of power system around the normal operating condition where they can provide good performance.

Since power system is highly non-linear system with configuration and parameters changes with time. The CPSS is designed based on the linearized model of the power system cannot guarantee its performance in practical environment. They give poor performance under different synchronous generator loading condition.

To improve the performance of CPSS, numerous techniques have been proposed for their design, such as using intelligence optimization methods (simulated annealing, genetic algorithm, fuzzy, neural networks and many other nonlinear techniques).

Recently, Fuzzy logic power system stabilizers (FLPSS) have been proposed to overcome this problem. Fuzzy logic makes complex and non-linear problems much easier to solve by allowing a more natural representation of the situation being dealt with. Fuzzy logic control appears to possess many advantages like lesser computational time and robustness. It has been shown that fuzzy logic is one of the best approaches for non-linear, time varying and well-defined system. However, optimum tuning of the parameters of the FLPSS further required for better performance under wide variation of system operating conditions.

Investigations reveal that the performance of the proposed FLPSS is quite robust to wide variations in loading condition both for small and large perturbations. The performance of the fuzzy PSS is compared with the conventional power system stabilizer (CPSS). The simulations were tested under different operating conditions and change in reference voltage also tested with different membership functions.

II. POWER SYSTEM STABILIZER

The power system is a dynamic system. It is constantly being subjected to disturbances, which cause the generator voltage angle to change. When these disturbances die out, a new acceptable steady state operating condition is reached. It is very important that these disturbances do not drive the power system to unstable condition because it is so harmful. The disturbances may be of local mode having frequency range of 0.7 to 2 Hz or of inter area modes having frequency range in 01 to 0.8 Hz, these swings are due to the poor damping characteristics caused by modern voltage regulators with high gain. A high gain regulator through excitation control has an important effect of eliminating synchronizing torque but it affects the damping torque negatively. To compensate the unwanted effect of these voltage regulators, additional signals are introduced in feedback loop of voltage regulators. The additional signals are mostly derived from speed deviation, excitation deviation or accelerating power. This is achieved by injecting a stabilizing signal into the excitation system voltage reference summing point junction. The device setup to provide this signal is called “power system stabilizer.”

![Fig. 1: Block diagram of a synchronous generator excitation control system with FLPSS.](image-url)
III. CONVENTIONAL POWER SYSTEM STABILIZER
The basic function of a PSS is to add damping to the generator rotor oscillations by controlling its excitation using auxiliary stabilizing signal and also improve stability of the system. To provide damping, the stabilizer must give a component which gives electrical torque in phase with the rotor speed deviation. For the simplicity a conventional PSS is modeled by two stage (identical), lead/lag network which is represented by a gain $K_{STAB}$ and two time constants $T_1$ and $T_2$. This network is connected with a washout circuit of a time constant $T_w$ as shown in Figure 6.1.

![Fig. 2: Conventional lead-lag PSS](image)

**A. Phase Compensation:**
The phase compensation block provides the appropriate phase lead characteristics to compensate for the phase lag between exciter input and generator electrical torque by this we can improve stability of the system. The phase compensation may be a single first order block as shown in Fig. 6.1 or having two or more first order blocks or second order blocks with complex roots.

**B. Signal Washout:**
The signal washout block serves as high pass filter, with time constant $T_w$ high enough to allow signals associated with oscillations in $\omega_r$ to pass unchanged, which removes d.c. signals. Without it, steady changes in speed would modify the terminal voltage. It allows PSS to respond only to changes in speed.

**C. Stabilizer Gain:**
The stabilizer gain $K_{STAB}$ determines the amount of damping introduced by PSS. The gain should be set at a value corresponding to maximum damping however, it is limited by other consideration which is use in CLPSS.

![Fig. 3: Block diagram representation with AVR and PSS](image)

IV. FUZZY LOGIC CONTROLLER BASED POWER SYSTEM STABILIZER
The fuzzy control systems are rule-based systems therefore it uses fuzzy rules which a set of fuzzy rules represent a control decision mechanism to adjust the effects of certain system stimuli. With an effective rule base, the fuzzy control systems can replace a skilled human operator. The fuzzy logic controller has an algorithm which can convert the linguistic control strategy based on expert knowledge into an automatic control strategy which is very useful. The Fig. 2.2 shows the schematic design of a fuzzy logic controller which consists of a four members which are fuzzification interface, a knowledge base, decision making logic, and a defuzzification interface.

- **Fuzzification:** define as a process in which the value of input variables are measured, scale mapping that transfers the range of values of input variables into corresponding universe of discourse is performed; it performs the function of fuzzification that converts input data into suitable linguistic values they may be viewed as label fuzzy sets this is first function. The knowledge base comprises knowledge of application domain and attendant control goals. It consists of a database and linguistic control rule base. The second function is rule base which characterizes the control goals and control policy of domain experts from the set of linguistic control rules. The decision making logic has the capability of simulating human decision making based on fuzzy concepts by this we can solved out the problem which is difficult in conventional system therefore we use FLPSS rather than CLPSS. The last function is defuzzification which performs scale mapping, which converts the range of values of output variables into corresponding universe of discourse; it converts a non-fuzzy control action from an inferred control action. The different methods of defuzzification are max criterion method, mean of maxima method and centroid method etc.

![Fig.4: Simulink model of FLPSS](image)
A. Controller Design Procedure

The fuzzy logic controller (FLC) design consists of the following steps.
1) First of all identification of input and output variables.
2) Construction of control rules.
3) Establishing the approach for describing system state in terms of fuzzy sets, i.e. establishing fuzzification method and fuzzy membership functions.
4) Selection of the compositional rule of inference.
5) Defuzzification method, i.e., transformation of the fuzzy control statement into specific control actions.

B. Selection of Input signals of FLPSS

The first step in designing a fuzzy logic power system stabilizer (FLPSS) is to decide which state variables representing system dynamic performance must be taken as the input signal to FLPSS. However, selection of proper linguistic variables formulating the fuzzy control rules is very important factor in the performance of fuzzy controllers. For the present investigations generator speed deviation $\Delta \omega$ and acceleration are chosen as input signals to FLPSS. In practice, only shaft speed deviation $\Delta \omega$ is readily available. The acceleration signal can be derived from speed signals measured at two sampling instant by the following expression:

$$\Delta \omega(KT) = \frac{\Delta \omega(KT) - \Delta \omega(K-1)T}{T}$$  \hspace{1cm} (10)

C. Membership Functions

After choosing proper variables for input and output of fuzzy controllers, it is important to decide on the linguistic variables. The linguistic variables transform the numerical values of the input of the fuzzy controllers to fuzzy values. The number of these linguistic variables specifies the quality of control, which can be achieved using fuzzy controller. As the number of linguistic variables increases, the quality of control increases at the cost of increased computer memory and computational time. Therefore, a compromise between the quality of control and computational time is needed to choose the number of variables. For the power system under study, five linguistic variables for each of the input and output variables are used. The linguistic variables are labeled as shown in Table 1. Membership Function

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative big</td>
<td>NB</td>
</tr>
<tr>
<td>Negative Small</td>
<td>NS</td>
</tr>
<tr>
<td>Zero</td>
<td>ZO</td>
</tr>
<tr>
<td>Positive Small</td>
<td>PS</td>
</tr>
<tr>
<td>Positive big</td>
<td>PB</td>
</tr>
</tbody>
</table>

Table 2 Decision Table (Rule Base) with Five Membership Functions for each of the two input signals
V. RESULTS AND DISCUSSION

The performance of single machine infinite bus system with Conventional (lead-lag) PSS and fuzzy PSS has been studied in SIMULINK model. Shown in fig.7. Corresponding to the system data specified in Appendix, the K-coefficients are calculated as K1=0.7636, K2=0.8644, K3=0.3231, K4=1.4189, K5 =-0.1463, K6=0.4167. Kin1=1.8, Kin2=29.58, Kout=1.05. The constant K5 has important bearing on system performance. The K5 can have positive value for low reactance and low power output and have negative value for high reactance and high power out-put.

VI. COMPARISON RESULTS

A. Angular Position

![Fig. 8: Comparison of WPSS, CPSS and FLPSS angular position](image)

The response shows that the angular position reach its steady state position much faster with Fuzzy logic PSS Compared to Conventional & Without PSS.

As shown in plots with fuzzy logic angular position reach to steady state condition in about 2.9 seconds, while Conventional PSS takes about 6.82 seconds to reach its final steady state value.

B. Angular Speed:

![Fig. 9: Comparison of WPSS, CPSS and FLPSS angular speed](image)

The response shows that the oscillations in angular speed reduce much faster with Fuzzy logic PSS Compared to Conventional and Without PSS.

As shown in plots with fuzzy logic the variation in angular speed reduces to zero in about 2.86 seconds, while Conventional PSS takes about 5.82 seconds to reach its final steady state value.

VII. COMPARISON RESULTS OF CPSS WITH DIFFERENT OPERATING CONDITION

A. Angular speed

![Fig. 10: Angular speed of CPSS with 10%, 20% & 40% step change in mech. Input](image)

B. Angular position

![Fig. 11: Angular Position with 10%, 20% & 40% step change in mech. Input](image)

Fig. 11: Angular Position with 10%, 20% & 40% step change in mech. Input

Shown the response of angular speed & angular position with different operating conditions 10%, 20% and 40% step change in mechanical input with Conventional PSS.

It depicts that angular speed & angular position stabilizes after few seconds with very few oscillations.

VIII. COMPARISON RESULTS OF FLPSS WITH DIFFERENT OPERATING CONDITION

A. angular speed

![Fig. 12: Angular Speed of FLPSS with 10%, 20% & 40% step change in mech. Input](image)

Fig. 12: Angular Speed of FLPSS with 10%, 20% & 40% step change in mech. Input
B. Angular position (FLPSS):

As shown in fig. 16 the performance of FLPSS with Triangular Membership function is superior compared to trapezoidal & Gaussian membership function. The system becomes stable in nearly 3 seconds with triangular membership function.

IX. CONCLUSIONS

The Simulation Results Shows that the FLPSS provide better damping of oscillation as compared to Conventional PSS (lead-lag). We considered the Triangular, Gaussian and Trapezoidal Membership functions. Investigation Reveal that the dynamic performance of FLPSS with Triangular membership function is Superior Compared to other Membership functions. There is no merit in increasing & decreasing number of Membership Functions from 5 to 7 & 5 to 3.

X. FUTURE ENHANCEMENT

Having gone through the study of FLPSS for single machine infinite bus system, the further scope of the work may be identified as – (a) Extend the FLPSS to actual multi-machine interconnected system. (b) The work done in this thesis is focused on rotor speed as an input variable. For further work frequency can be taken as input parameter.

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