Dynamic Stability Improvement of Power System using Fuzzy Controlled Power System Stabilizer

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Abstract— One of the most important stability problems arising in large scale electric power system interconnections is the low-frequency oscillations of interconnected systems. Many dominant methods are available to address this issue. In this paper, Dynamic Stability Improvement of Power System using a Fuzzy Controlled Power System Stabilizer is addressed. A conventional power system stabilizer is first tested which is extended to a fuzzy application which provides an improvement in small signal performance and greater flexibility for different operating conditions, which has speed deviation and acceleration as its inputs. The comparison between models and analysis has been done in MATLAB/SIMULINK. An approximate linear model of Single Machine Infinite Bus system is considered as a test case.


I. INTRODUCTION

One of the most important stability problems arising from large scale electric power system interconnections is the low-frequency oscillations of interconnected systems. The oscillations may be sustained for minutes and grow to cause system separation if no adequate damping at the system oscillating frequency is available. The supplementary control signal is normally generated through analog circuits, commonly known as Power System Stabilizer (PSS). The conventional Power System Stabilizer (CPSS), a fixed parameters lead-lag compensator, is widely used by power system utilities. The gain settings of these stabilizers are determined based on the linearised model of the power system around a nominal operating point to provide optimal performance at this point. CPSS performance is degraded whenever the operating point changes from one to another because of fixed parameters of the stabilizer. Fuzzy control appears to be the most suitable one, due to its robustness and lower computation burden. The fuzzy logic controllers can be easily constructed. Control signal is given to sum point of AVR unit and will provide sufficient damping torque for synchronous generator unit with enhancement in settling time and maximum overshoot. FPSS makes use of Fuzzification, knowledge base, Defuzzification combined with a decision making logic to achieve Robustness, making it much suitable for interconnected nonlinear synchronous generators.

II. POWER SYSTEM MODELLING

The study is done considering an approximate linear model of Single Machine Infinite Bus (SMIB) system which is shown below:

Figure 1: (a) Single Line Diagram of Single Machine Infinite Bus System
(b) SMIB including AVR/Exciter

Figure 2: SMIB Block Diagram including AVR/Exciter
III. CONVENTIONAL POWER SYSTEM STABILIZER (CPSS)

Basic function of CPSS is to damp generator oscillations by providing auxiliary stabilizing signals to control excitation, using speed deviation as input signal. Criteria to be satisfied for proper design of CPSS:

1. Should not interfere with primary function of AVR.
2. CPSS output should be zero in steady state.

The CPSS is generally designed to exactly compensate for the negative damping of AVR for satisfactory performance of the overall system.

IV. FUZZY CONTROLLED POWER SYSTEM STABILIZER (FPSS)

The crisp inputs (speed deviation and acceleration) are fuzzified into linguistic variables and after applying the fuzzy rules based on knowledge based decision making skills of the interface system; the fuzzy output is defuzzified and is given as the crisp output to the AVR. The speed deviation and acceleration applied as inputs give a required proportionate fuzzy control output and modifies generator excitation to reduce the small signal instability in the power system.

V. PERFORMANCE ANALYSIS OF SMIB WITH AVR / EXCITER, SMIB WITH AVR AND CPSS

Small signal oscillations are primarily caused due to AVR (having high gain, low time constant). The oscillations are constantly increasing with time due to poor damping and may drive the system into instability. The oscillations die out with time and are of relatively lesser magnitude when PSS is employed in the system. The operating point is fixed in both the responses and hence, the PSS has no effect under steady state.
VI. DESIGN AND PERFORMANCE OF SMIB WITH FUZZY CONTROLLED POWER SYSTEM STABILIZER (FPSS)

Fuzzy rule base is designed based on the following basic rules:

1. If the speed deviation is important, but tends to decrease, then the control must be moderated. In other words, when the machine decelerates, even though the speed is important, the system is capable, by itself, to return to steady state.

2. If the speed deviation is weak, but tends to increase, the control must be significant. In this case, it means that, if the machine accelerates, the control must permit to reverse the situation.

VII. DESIGN PARAMETERS (GAIN VALUES, SCALING PARAMETERS)

Gain parameters $K_1$, $K_2$, $K_3$, $K_4$, and $K_6$ are always positive (for all operating conditions). Gain parameter $K_5$ can take either positive or negative values. $K_5$ is negative for low values of reactive power and high generator outputs. In practice, negative values of $K_5$ are observed.

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Figure 10: Fuzzy Rule base

Figure 11: SIMULINK Model of SMIB with FPSS

Figure 12: Gain value at different operating Conditions (a) Gain value $K_3$ (b) Gain value $K_5$ (c) Gain value $K_1$ (d) Gain value $K_2$ (e) Gain value $K_4$ (f) Gain value $K_6$ (For $\omega=10$ rad/s (1.6 Hz).)
Considering the worst case of damping for AVR (at gain=200), CPSS is designed to exactly compensate the negative damping for CPSS gain=3.

As gain is increased further (beyond 3), damping increases but slight under compensation is preferred due to positive Ks.

The scaling factor is chosen such that both the inputs (speed deviation and acceleration) fall in the same range [-1, 1]. We can observe that, as the scaling factor of speed deviation is increased, the response becomes better. For all practical purposes and operating conditions, the value of Kin2 is chosen to be 30.

VIII. CONCLUSION & FUTURE SCOPE

The power system tends to be dynamically unstable due to observed large deviations in speed, which necessitates the need of a control action. The improvement of dynamic stability realized through the use of a conventional power system stabilizer (CPSS) and a fuzzy controlled power system stabilizer (FPSS), the performance of the latter being better than the former in terms of settling time and magnitude of deviation. The gain settings in a CPSS need to be accurately chosen for different operating conditions and thus, is not robust, but is otherwise in case of a FPSS. Also, the calculations are simplified in case of FPSS as no complexities of parameter tuning etc. are not involved. The fuzzy logic based PSS (FLPSS) can be extended to multi machine interconnected system. The study can be extended to include non linear loads and compare the functioning of PSS and FLPSS. The fuzzy logic based PSS with frequency, rotor angle deviations as input parameters can be investigated. Testing using more complex network models can be carried out.

REFERENCES


APPENDIX

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19