ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)
Volume 2, Issue 1, January 2013

A Comparative Study of Fuzzy & Genetic Power System Stabilizers and Role of Static Voltage Compensation on Power System stability

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Abstract— **This paper describes the application of genetic and fuzzy logic Power System Stabilizer (PSS), for single line to ground and three phase faults, with/without static voltage compensator. The genetic and fuzzy PSSs are presented for multi area power systems. The controller provides auxiliary reference signals for the automatic voltage regulator of the generator as well as the line voltage controller of the static voltage regulator in such a way that it improves the damping of the rotor speed deviations of the synchronous machines. Simulation results are provided for Line to Ground and three phase faults to indicate the comparative impact on power swing, change in angle, and change in voltage for equivalent two machine systems.**

Index Terms-**Automatic voltage regulator, fuzzy logic controller, genetic controller, stability, static voltage compensation.**

I. INTRODUCTION

The electrical energy has become the major form of energy for end use consumption in today's world. There is always a need of making electric energy generation more economic and reliable. For proper operation, this large integrated system requires a stable operating condition. The power system is a dynamic system. It is constantly being subjected to small disturbances, which cause the generators relative angles to change. For the interconnected system to be able to supply the load power demand when the transient caused by disturbance die out, a new acceptable steady state operating condition is reached [1]-[27].

The electric power system in generally consists of components such transmission line, synchronous machine, transformers, static/rotating loads, active/reactive power compensators, switch gear and protective devices etc. The compensators are synchronous condensers, shunt or series elements such as capacitors and inductors or FACT devices.

Typically the voltage at the terminals of synchronous generator are controlled by Automatic Voltage Regulator in order to maintain a proper voltage throughout the network, until now, designs of the internal controller of a generator (Automatic Voltage Regulator and Governor) have traditionally considered only the single generator and ignored other devices in the electrical power system. Now, extra stabilizing capabilities are provided for generators by using Power System Stabilizer (PSS), which are mostly designed to increase the damping of local low frequency oscillation mode of the generators [1]-[27].

Although, the various PSSs are used, and each PSS performs primarily task based on its own interest of power system therefore care should be taken that no PSS's action should violate its own limits.

The paper is organized in five sections. In section II, description of FLPSS is presented. The overview of Genetic Algorithm is given in section III. In section IV, simulation results are presented. Finally, the paper is concluded in section V.

II. DESCRIPTION OF FLPSS [7]

A. FUZZY LOGIC CONTROLLER

The design process of the fuzzy logic controller may be split into five steps: the selection of control variables, the membership function definition, the rule creation, the fuzzy inference and the defuzzification strategy.

The fuzzy inference method is min-max type such as mamdani. The defuzzification strategy in the fuzzy inference used is the fuzzy centroid method.

The two variable membership functions have been chosen identical because of the normalization achieved on the physical variables. The normalization is important because it allows the controller to associate an equitable weight to each of the rules and, therefore, to calculate the stability signal correctly.

Each of the input variables is classified by seven "trapezoidal" fuzzy membership functions. The following fuzzy sets were chosen: BN, MN, LN, Z, LP, MP, and BP.

Where:
BN=big negative
MN=medium negative
LN= low negative
Z= zero
LP=low positive
MP= medium positive
BP=big positive

The output variable is also classified by seven but "triangular" fuzzy membership functions.

The output signal was obtained using the following principles:

- If the speed deviation is weak, but tends to increase, then the control must be significant. In this case, it

Manuscript received: January 2013

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means that, if the machine accelerates, the control must permit to reverse the situation.

- 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.

The Inference mechanism of the FLC is represented by a seven to seven decision table. The entire set of rules (49 if-then rules) is presented in Table I.

TABLE-I
DECISION TABLE [7]

dw/ dp	BP	MP	LP	Z	LN	MP	BN
BN	BZ	LN	MN	MN	BN	BN	BN
MN	LP	BZ	LN	MN	MN	BN	BN
LN	MP	LP	BZ	LN	LN	MN	BN
Z	BP	MP	LP	LZ	LN	MN	BN
LP	BP	MP	LP	LP	BZ	LN	MN
MP	BP	BP	MP	MP	LP	BZ	LN
BP	BP	BP	BP	MP	MP	LP	BZ

III. OVERVIEW OF GENETIC ALGORITHM (GA)

Genetic Algorithm has been used for optimizing the parameters of the control system that are complex and difficult to solve by conventional optimization methods. GA maintains a set of candidate solutions called population and repeatedly modifies them. At each step, it selects individuals from the current population to be parents and uses them to produce the children for the next generation. Candidate solutions are usually represented as strings of fixed length, called chromosomes. A fitness or objective function is used to reflect the goodness of each member of the population. Given a random initial population, the GA operates in cycles called generations, as follows:

- Each member of the population is evaluated using a fitness function.
- The population undergoes reproduction in a number of iterations. One or more parents are chosen stochastically, but strings with higher fitness values have higher probability of contributing an offspring.
- Genetic operators, such as crossover and mutation, are applied to parents to produce offspring.

The offspring are inserted into population and the process is repeated.

IV. SIMULATION CASES AND RESULTS

A 1000 MW hydraulic generation plant (plant-1) is connected to a load center through a long 400 kV, 700 km transmission line. The load center is modeled by a 5000 MW resistive load. The load is fed by the remote 1000 MW plant and a local generation of 5000 MW (plant-2). The system has been initialized so that the line carries 950 MW which is close to its surge impedance loading (SIL = 970 MW).

In order to maintain system stability after faults, the transmission line is shunt compensated at its mid point by a 250-Mvar Static Var Compensator (SVC). The SVC does not have a Power Oscillation Damping (POD) unit. The two machines are equipped with a Hydraulic Turbine and Governor (HTG), Excitation system and PSS. Two types of stabilizers are selected: a genetic model using the acceleration power dp (P_a= difference between mechanical power P_m and output electrical power P_{eo}) and a Fuzzy stabilizer using the speed deviation (dw) and acceleration power dp. During this simulation line to ground and three-phase faults are applied on the 400 kV systems and observed the impact of the PSS and SVC on system stability.

The plant-1 ‘Bus type’ is initialized as ‘PV generator’, indicating that the load flow will be performed with the machine controlling its active power and its terminal voltage. Plant-2 will be used as a swing bus for balancing the power. Check that the following parameters are specified for plants one and two:

Plant-1:
Type = PV
Terminal voltage (kVrms) = 13.8
Active Power = 950 X 10^6
Plant-2:
Type = Swing bus
Terminal voltage (kVrms) = 13.8
Active power guess = 4000 X 10^6

A. An Impact of PSS with no SVC on occurrence of one line to ground fault

Single-phase line to ground fault at any phase of the three phase system is applied and simulation is carried out without SVC. Important thing is to be noticed that for this type of fault the system is stable without SVC. After fault clearing, the 0.75 Hz oscillation is quickly damped. This oscillation mode is typical of inter area oscillations in a large power system.

Power transfer is maximum, when this angle reaches 90 degrees. This signal is a good indication of system stability. If angle difference between two plants is increasing for a too long period of time, the machines will lose synchronism and the system goes unstable. By simulating over a long period of time (60 seconds) it may also be noticed that the machine speeds oscillate together at a low frequency (0.026 Hz) after fault clearing. The two PSS (P_a type) succeed to damp the 0.75 Hz mode. If the fuzzy logic PSS is taken then it is noticed that this stabilizer type succeeds to damp both the 0.75 Hz mode and the 0.026 Hz mode.

This system is naturally unstable without PSS, even for small disturbances.

B. An Impact of PSS with no SVC on occurrence of three phase fault

A 3-phase fault is applied on the power system for observing the impact. The two PSS are applying in service one after one. By looking at the angle signal, it should be observed that system is unstable, which can be observed in Fig. 1.

For example, if the fault is removed and applying a P_{ref} step of 0.065 pu on plant-1, it is seen the instability slowly building up after a few seconds.

The system voltage and line power responses are shown in Fig. 2 and Fig. 3, respectively.

C. An Impact of PSS with SVC on occurrence of three phase fault

Now the SVC is brought in operation in above mentioned case. The SVC will now try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage (1.007 pu). The chosen SVC reference voltage corresponds to the bus voltage with the SVC out of service. In steady state the SVC will, therefore, be 'floating' and waiting for voltage compensation when voltage departs from its reference set point. Restarting simulation and observing that the system is now stable with a 3-phase fault. For example, if the fault is removed and applying a P_{ref} step of 0.05 pu on plant 1, it is seen the instability slowly building up after a few seconds. If the test with the two PSSs without SVC, it is notice that the system is unstable, whereas, it is stable with PSS (s) and SVC.

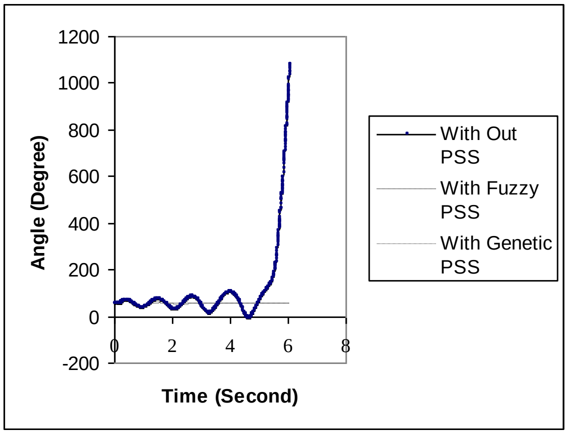

Fig.1 Rotor angle difference angle between the two plants
Note: Responses with Fuzzy and Genetic PSS are almost overlapping.

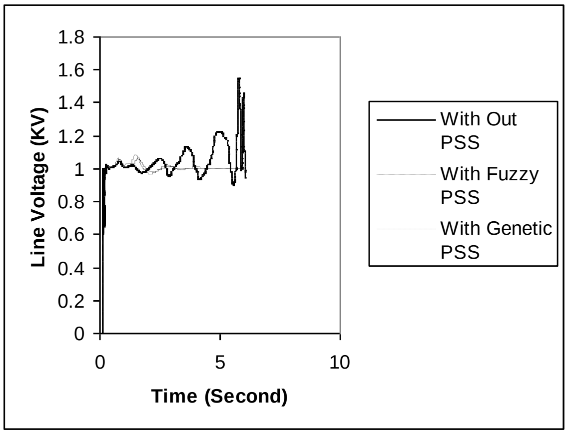

Fig.2. Variation in line voltage (kV)

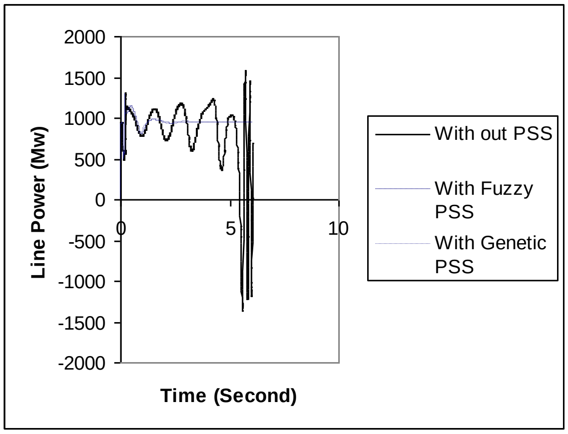

Fig.3. Variation in line power (MW)

Variation in rotor angle difference between two plants, line power and line voltage at three phase fault are observed with application of Without PSS, FPSS, Genetic PSS and SVC are shown in Fig.4-6, respectively.

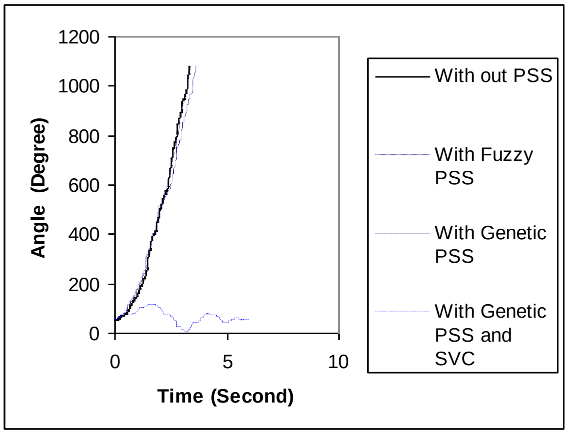

Fig.4. Rotor angle difference between the two plants

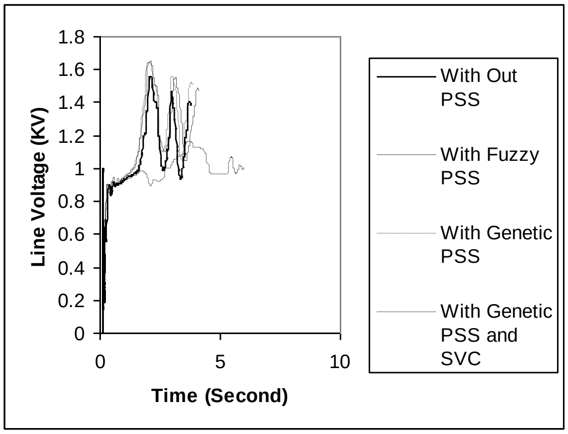

Fig.5. Variation in line voltage (kV)

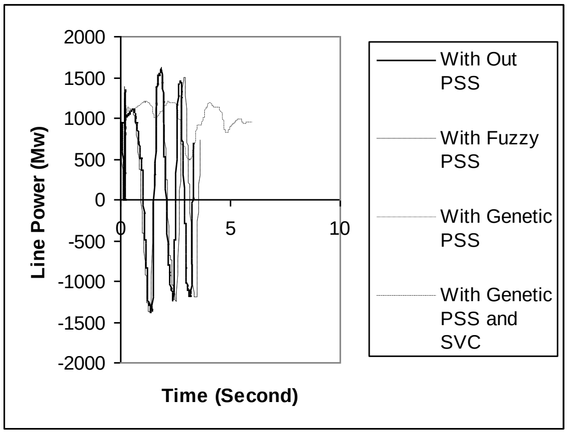

Fig.6. Variation in line power (MW)

V. CONCLUSIONS

In this paper, simulation of a power system installed with PSS and Static Voltage Compensator (SVC) has been presented. It has incorporated a comparative analysis for genetic and fuzzy power system stabilizers. Moreover, the role of SVC on power system stability has also been presented. The simulated system has been presented in MATLAB/SIMULINK for carrying out power system stability analysis and explaining the generator dynamic behavior as affected by PSS and SVC under faults.

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