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Single Machine Infinite Bus System using GA and PSO

Garima Maheshwari
M. Tech. Scholar
garima.2802@gmail.com

Nandkishore Meena
Asst. Professor
nkmeena83@gmail.com

Abstract – **With the growth of interconnected power systems and particularly the deregulation of the industry, difficulties related to low frequency oscillation have been widely reported, together with major incidents. As the most economical damping controller, power system stabilizer (PSS) has been widely used to suppress the low frequency oscillation and enhance the system dynamic stability. Traditional methods for determining PSS placements are based on the analysis of the interconnected system. Though, the design of the PSS is based on a simplified single machine infinite bus (SMIB) model. Traditional methods for determining PSS placements are based on the analysis of the interconnected system. In this paper, the design of the PSS is based on a simplified single machine infinite bus (SMIB) model using Particle Swarm Optimization and Genetic Algorithm. MATLAB/SIMULINK model is used to implement proposed SMIB-PSS model.**

Keywords – **MATLAB, PSS, SIMULINK, SMIB.**

I. Introduction

The reliability of a power system has been an important topic of study in recent decades. Power system stability has been recognized as a factor for secure system operation. A secure system provides a constant frequency and constant voltage within limits to customers. To achieve this aim a highly reliable and cost effective long term investment technology is required. Stability limits can define transfer capability. Also in a complex interconnected system, stability has a great impact to increase the reliability and the profits. Although this interconnection gives the system a complicated dynamic. It has advantages such as reduced spinning reserves and a lower electricity price. To achieve these benefits, appropriate control is required to synchronize the machines after a disturbance occurs. This paper describe Power system stability of single machine infinite bus system using Genetic Algorithm and Particle Swarm Optimization

Power System Stability

Power system stability may be broadly defined as that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.

Power system stability can be divided into four different phenomena's: wave, electromagnetic, electromechanical and thermodynamic. Here we consider only electromechanical phenomenon, which takes place in the windings of a synchronous machine. A disturbance in the electrical network will create power fluctuations between the generating units and the electrical network. In addition the electromechanical phenomenon will also disturb the stability of the rotating parts in the power system [1]. Security of the power system relies on its ability to survive any disturbances which may occur without any interruption in the services. Figure 1 shows the functional block diagram of a typical excitation control system for a large synchronous generator [2].

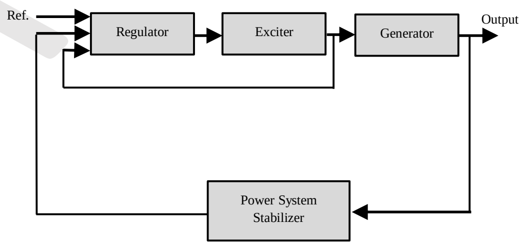

Figure 1: Functional block diagram of a synchronous generator excitation control system [2]

Power system stabilizers (PSS) are used on a synchronous generator to increase the damping of oscillations of the rotor/turbine shaft. The conventional PSS was first suggested in the 1960s and classical control theory, defined in transfer functions, was employed for its design. Later the revolutionary work of DeMello and Concordia [3] in 1969, control engineers, as well as power system engineers, have exhibited great interest and made significant assistances in PSS design and applications for both single and multi-machine power systems.

Optimal control theory for stabilizing SMIB power systems was developed by Anderson [4] as well as by Yu [5]. These optimal controllers were linear. Adaptive control techniques have also been proposed for SMIB, most of which involve linearization or model approximation.

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Klein et al. [2, 6] presented the simulation studies into the effects of stabilizers on inter-area and local modes of oscillations in interconnected power systems. It was shown that the PSS location and the voltage characteristics of the system loads are significant factor in the ability of a PSS to increase the damping of inter-area oscillations. Nowadays, the conventional lead-lag power system stabilizer is widely used by the power system utility [7]. Other types of PSS such as proportional-integral power system stabilizer (PI-PSS) and proportional-integral-derivative power system stabilizer (PID-PSS) have also been proposed [8-9].
Several approaches have been applied to PSS design problem. These include pole placement, H_∞, optimal control, adaptive control, variable structure control, and different optimization and artificial intelligence techniques [10].

Problem Identification
Power system stability is a very important aspect to supply continuous power. It is defined as that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance. Instability of power system can occur in many different situations depending on the system configuration and operating mode. One of the stability problems is maintaining synchronous operation or synchronism especially that power system rely on synchronous machines. This feature is influenced by the dynamic of generator rotor angles and power-angle relationships. Other uncertainty problem that may be encountered is voltage collapse that is mostly related to load behaviour and not synchronous speed of generators.

II. Proposed Methodology

The power system is a high order complex nonlinear system. In order to simplify the analysis and focus on one machine, the multi-machine power system is reduced to the single machine infinite bus (SMIB) system. In the SMIB system, the machine of interest is modelled in detail while the rest of the power system is equated with a transmission line connected to an infinite bus.

As shown in figure 2, Single machine is connected to infinite bus system through a transmission line having resistance r_e and inductance x_e .

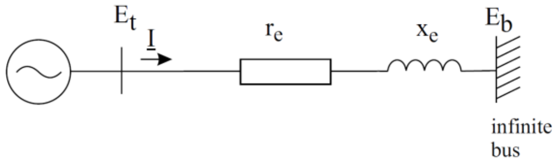

Figure 2: Single machine infinite bus system

The generator is modelled by transient model, according to the following equations. All system data can be found.

Stator winding equations:

$$v_q = -r_s i_q - x'_d i_d + E'_q \qquad (1)$$

$$v_d = -r_s i_d - x'_q i_q + E'_d \qquad (2)$$

Where
r_s is the stator winding resistance
x'_d is the d-axis transient resistance
x'_q is the q-axis transient resistance
E'_q is the q-axis transient voltage
E'_d is the d-axis transient voltage.

Rotor winding equations:

$$T'_{do}\frac{dE'_q}{dt} + E'_q = E_f - (x_d - x'_d)i_d \qquad (3)$$

$$T'_{qo}\frac{dE'_d}{dt} + E'_d = E_f - (x_q - x'_q)i_q \qquad (4)$$

Where,
T'_{do} is the d-axis open circuit transient time constant,
T'_{qo} is the q-axis open circuit transient time constant
E_f is the field voltage.

Torque equation:

$$T_{el} = E'_q i_q + E'_d i_d + (x'_q - x'_d) i_d i_q \qquad (5)$$

Rotor equation:

$$2H\frac{d\omega}{dt} = T_{mech} - T_{el} - T_{damp} \qquad (6)$$

Then

$$T_{damp} = D\Delta\omega \qquad (7)$$

Where
T_{mech} is the mechanical torque, which is constant in this model.
T_{el} is the electrical torque.
T_{damp} is the damping torque and
D is the damping coefficient.
For the study of single machine infinite bus system a Heffron-Phillips model can be obtained by linearizing the system equations around an operating condition. The obtained Heffron model is as in figure 3 and the parameters are:
$K_1 = 0.5320$, $K_2 = 0.7858$, $K_3 = 0.4494$, $K_4 = 1.0184$, $K_5 = -0.0597$, $K_6 = 0.5746$, $K_A = 20$, $M = 7$.

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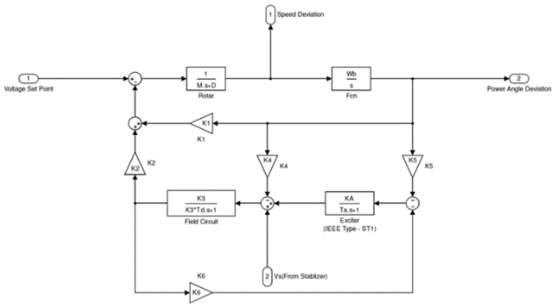

Figure 3: Heffron-Phillips model – SMIB

Figure 4 showing the SIMULINK Implementation of Phillip-Heffron model stated above.

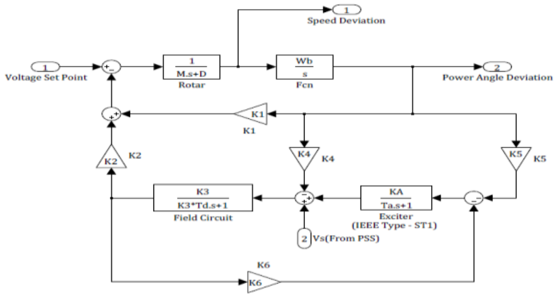

Figure 4: Simulink Implementation of SMIB

The parameters of Heffron-Phillips model are optimized using Particle Swarm Optimization and Genetic Algorithm which are explained in following sub-section.

Particle Swarm Optimization

PSO is a technique used to explore the search space of a given problem to find the settings or parameters required to maximize or minimize a particular objective.

The original PSO algorithm was inspired by the social behaviour of biological organisms, specifically the ability of groups of some species of animals to work as a whole in locating desirable positions in a given area, e.g. birds flocking to a food source. This seeking behaviour was associated with that of an optimization search for solutions to non-linear equations in a real-valued search space.

Particle Swarm Algorithm

1. Begin
2. Factor settings and swarm initialization
3. Evaluation
4. g = 1
5. While (the stopping criterion is not met) do
6. for each particle
7. Update velocity
8. revise place and localized best place
9. Evaluation
10. End For
11. Update leader (global best particle)
12. g + +
13. End While
14. End

The PSO procedure has various phases consist of Initialization, Evaluation, Update Velocity and Update Position.

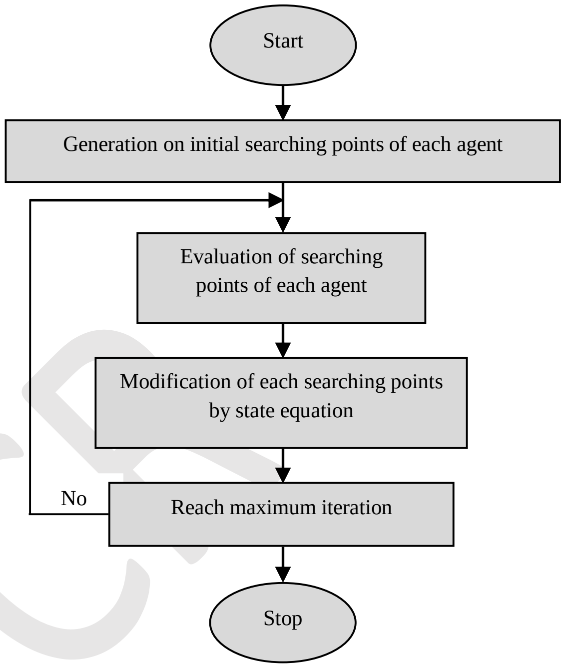

Figure 5: Flow chart of PSO

Genetic Algorithm

Genetic algorithms (GA) were first introduced by John Holland in the 1970s (Holland 1975) as a result of investigations into the possibility of computer programs undergoing evolution in the Darwinian sense.

GA are part of a broader soft computing paradigm known as evolutionary computation. They attempt to arrive at optimal solutions through a process similar to biological evolution. This involves following the principles of survival of the fittest, and crossbreeding and mutation to generate better solutions from a pool of existing solutions.

Genetic algorithms have been found to be capable of finding solutions for a wide variety of problems for which no acceptable algorithmic solutions exist. The GA methodology is particularly suited for optimization, a problem solving technique in which one or more very good solutions are searched for in a solution space consisting of a large number of possible solutions. GA reduce the search space by continually evaluating the current generation of candidate solutions, discarding the ones ranked as poor, and producing a new generation through

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crossbreeding and mutating those ranked as good. The ranking of candidate solutions is done using some pre-determined measure of goodness or fitness.

A genetic algorithm is a probabilistic search technique that computationally simulates the process of biological evolution. It mimics evolution in nature by repeatedly altering a population of candidate solutions until an optimal solution is found.

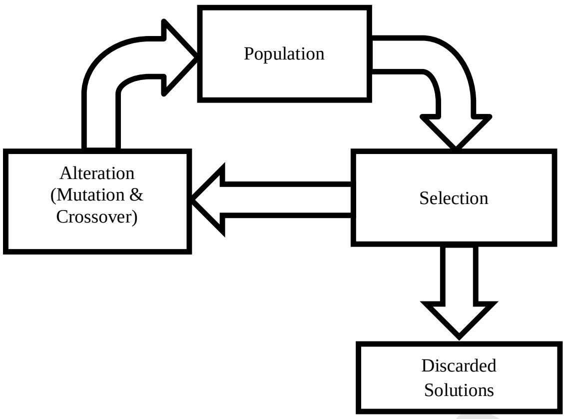

Figure 6: Genetic algorithm evolutionary cycle

The steps in the typical genetic algorithm for finding a solution to a problem are listed below:

1. Create an initial solution population of a certain size randomly
2. Evaluate each solution in the current generation and assign it a fitness value.
3. Select "good" solutions based on fitness value and discard the rest.
4. If acceptable solution(s) found in the current generation or maximum number of generations is exceeded then stop.
5. Alter the solution population using crossover and mutation to create a new generation of solutions.
6. Go to step 2.

III. Simulation And Results

The performance of proposed approach has been studied by means of MATLAB simulation.

Figure 7: Simulink model of PSS

The figure above shows the Simulink model for PSS consists two lead-leg compensator preceded by washout controller. The five time constants are optimized Particle Swarm Optimization and Genetic Algorithm for performance improvement.

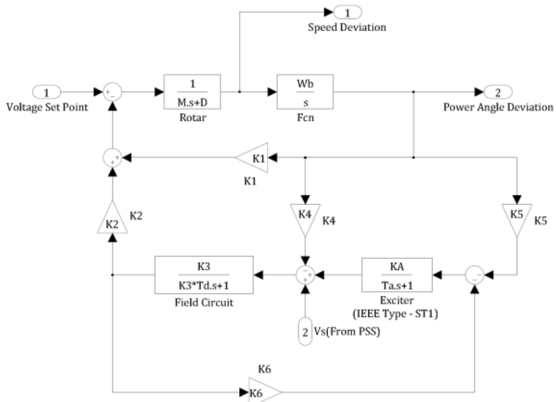

Figure 8: Simulink model of SMIB

The model above is the Philip Heffron model of single machine infinite bus system. All electrical and mechanical parts are modelled here as standard transfer functions.

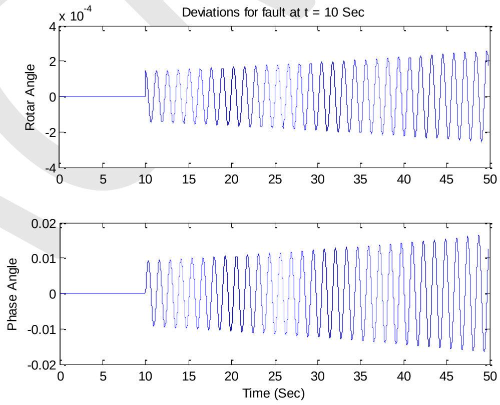

Figure 9: Speed deviation in SMIB for rotor angle and phase angle

When a fault occurs in the SMIB system at t = 10 Sec, Rotor start deviation and if no control is there than oscillation become higher as shown above. Following are the graphs for the rotor angle and phase angle deviations.

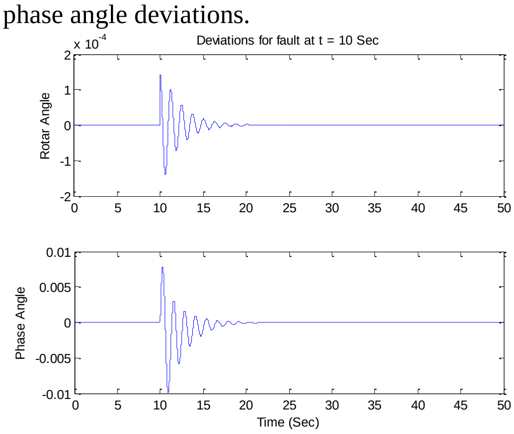

Figure 10: Speed deviation in SMIB for rotor angle and phase angle

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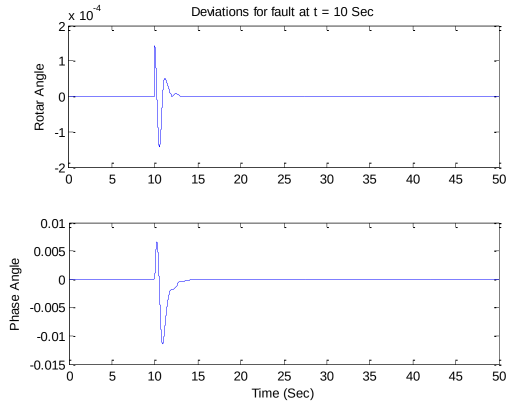

Figure 11: Speed deviation in SMIB for rotor angle and phase angle

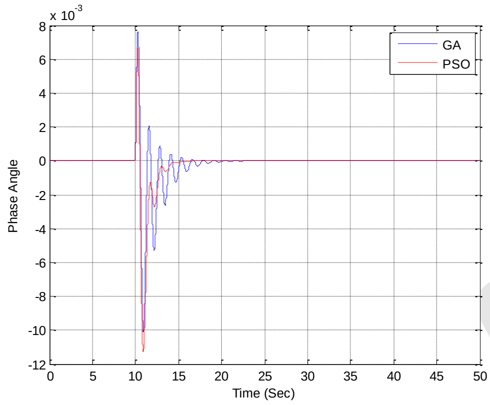

Figure 12: Comparison of phase angle in SMIB for GA and PSO

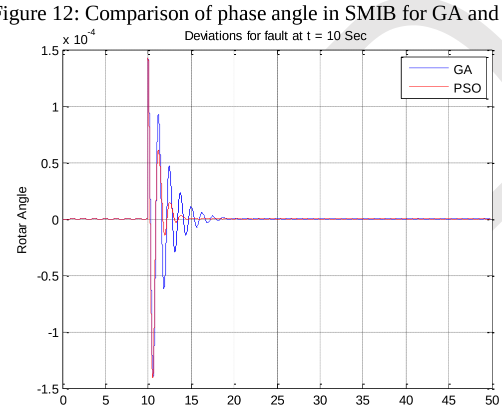

Figure 13: Comparison of rotor angle in SMIB for GA and PSO

IV. CONCLUSION

In this paper, ensuring system stability, in order to provide faster responses over a wide range of power system operation a power system stability (PSS) of single machine infinite bus system (SMIB) was developed and its parameters was tuned by a robust evolutionary algorithm that offers flexibility to designers for achieve a compromise between conflicting design objectives, the power angle and speed deviation in SMIB.

The design problem of robustly tuning PSS parameters is formulated as an optimization problem according to the time domain based objective function which is solved by the Particle Swarm Optimization and Genetic Algorithm techniques. The effectiveness of the proposed PSO and GA based PSS is demonstrated on a SMIB power system. It was found that the PSO based PSS outperforms than the GA based PSS. The design was done off-line, which also can be performed on-line for a time varying or time dependent systems so that the computational time and global optimization on a single-run process is of prime importance. Application of the developed method to a typical problem, especially in comparison with such traditional implementations illustrated the performance and effectiveness in achieving the stated design objectives.

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