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Multi Machine PSS Design by using Meta Heuristic Optimization Techniques

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ABSTRACT: Designing power system stabilizer (PSS) in multi machine power systems has always been reported as a critical issue; because, unsuitable adjusting of PSSs may lead to stability decreasing instead of stability improvement. Therefore, a coordinated PSS design should be carried out in multi machine power systems. In this paper, all PSSs are simultaneously tuned in a multi machine power system. A Meta heuristic optimization technique namely artificial bee colony (ABC) algorithm is used to adjust the PSSs parameters. Non linear simulations are carried out to validate of results. Simulation results clearly verify that the proposed technique enhances the dynamic stability of the system considering uncertainties.

Keywords: Artificial Bee Colony, Dynamic Stability, Multi Machine Power System, Non Linear Simulations, Power System Stabilizer.

INTRODUCTION

Practical electric power systems contain many synchronous generators which are connected to a large size transmission network. Many investigations in power systems are carried out based on the small test systems such as single machine power system or the other simplified systems, but it is necessary to model and simulate large power systems in order to obtain accurate results. In this regard, many power system investigations have been carried out based on the multi machine power systems. For example; paper (Yadaiah and Venkata Ramana, 2007) presents the survey of various techniques for linearization of multi-machine power system dynamics and designing of controllers for the transient stability problem. The simulation results are presented for a typical configuration of a WSCC multi-machine power system. Finally, it concludes with a comparison of their effectiveness in handling the transient stability problem of multi-machine power systems. A multi scale simulation of multi machine power system has been reported by (Gao and Strunz, 2009) This method enables the modeling and integration of synchronous machinery models in accurate and efficient simulation of power systems over diverse time scales that cover electromagnetic and electromechanical transients. It is shown how this shifting plays a critical role in integrating synchronous machine models that are represented using the Park transformation with the network model. In a further step, it is illustrated how the modeling approach is modified if the Park transformation is not applied. For illustrative purposes, the integration is first validated for a single-machine-infinite-bus system. In a following multi-machine test case involving four machines in two areas, the added value of the proposed methodology becomes clear as both electromagnetic transients and electromechanical transients are emulated accurately and efficiently within one simulation run. Paper (Bhattacharya et al., 1998) presents an approach based on integral of squared error (ISE) technique for tuning of the parameters of power system stabilizers (PSS) in a multi-machine power system. The PSS are tuned sequentially, depending on which machine needs stabilization most. However, later it has been establishes that if the tuning algorithm is iterated twice or more, no particular tuning sequence is necessary. Dynamic performance with PSS tuned by the proposed method is compared with a previously reported approach in which all the stabilizers are tuned simultaneously. The proposed approach provides satisfactory system dynamic performance and the method is computationally much simpler. paper (Yang, 1995) addresses an extended PSS design method for multi-machine systems. This is based on: pseudo global system models; frequency response based model order reduction technique; and the pole assignment algorithm. The new design method is applied to a practical ten-machine power system. A power system stabilizer design method for multi-machine power systems is given by (Yang, 1997). In this design method, the design problem is translated into an equivalent problem of decentralized controller design for Multi-Input Multi-Output (MIMO) control systems. Subject to a condition based on the structured singular values, each stabilizer can be designed independently. The robust stability condition for power systems with stabilizers on can be easily stated as to achieve a sufficient interaction margin, and a sufficient gain and phase margin defined in the classical feedback theory during each independent design. Within this general framework, the conventional stabilizer design methodology based on the concept of synchronous and damping torques is used to decide the design details of each stabilizer. The suggested design method is applied to a model of a practical 10 machine power system. In paper (Wang and Swift, 1998) the phase compensation method is used to design multiple FACTS-based stabilizers and PSSs in multi-machine power systems. A three-machine power system is demonstrated and TCSC-based stabilizer and PSS are designed by phase compensation method. An observer-based controller to improve stability in power systems, by using the excitation of synchronous generators, is introduced by (Leon et al., 2012). The strategy goal is to attain maximum damping injection and to increase the transient stability, while good voltage regulation performance is maintained. The proposed strategy presents two important features from the implementation point of view. First, the controller only needs sensing currents and rotor speed, and second, previous knowledge of network parameters and topology is not required. Several comparisons in multi-machine scenarios with current power system stabilizers are presented. These studies confirm the viability and the performance improvement when conventional solutions are replaced by the proposed approach.

This paper deals with power system stabilizer design in multi machine power system considering uncertainty. A new optimization algorithm namely artificial bee colony (ABC) algorithm is used for tuning power system stabilizers. A multi machine power system is considered as case study and installed with PSSs. Simulation results demonstrate the ability and effectiveness of the proposed method in stability improvement.

Power system stabilizer

A power system stabilizer (PSS) is a device which provides additional supplementary control loops to the automatic voltage regulator (AVR) system and/or the turbine-governing system of a generating unit.A PSS is also one of the most cost-effective methods of enhancing power system stability.Adding supplementary control loops to the generator AVR is one of the most common ways of enhancing both small-signal (steady-state) stability and large-signal (transient) stability.Adding such additional control loops must be done with great care; it is known that an AVR(without supplementary control loops) can weaken the damping provided by the damper and field windings. This reduction in the damping torque is primarily due to the voltage regulation effects inducing additional currents in the rotor circuits that oppose the currents induced by the rotor speed deviation $\Delta\omega$ (Machowski et al., 2011).

The main idea of power system stabilization is to recognize that in the steady state, that is when the speed deviation is zero or nearly zero, the voltage controller should be driven by the voltage error ΔV only. However, in the transient state the generator speed is not constant, the rotor swings and ΔV undergoes oscillations caused by the change in rotor angle. The task of the PSS is to add an additional signal which compensates for the ΔV oscillations and provides a damping component that is in phase with $\Delta\omega$. This is illustrated in Figure 1; where the signal V_{PSS} is added to the main voltage error signal ΔV. In the steady state V_{PSS} must be equal to zero so that it does not distort the voltage regulation process. The general structure of the PSS is shown in Figure 2; where the PSS signal V_{PSS} can be provided from a number of different input signals measured at the generator terminals. The measured quantity (or quantities) is passed through low- and high-pass filters. The filtered signal is then passed through a lead and/or lag element in order to obtain the required phase shift and, finally, the signal is amplified and passed to a limiter. When designing the phase compensation it is necessary to take into account the phase shift of the input signal itself and that introduced by the low- and high- pass filters. Typically the measured quantities used as input signals to the PSS are the rotor speed deviation, the generator active power or the frequency of the generator terminal voltage. There are a number of possible ways of constructing a PSS depending on the signal chosen (Machowski et al., 2011).

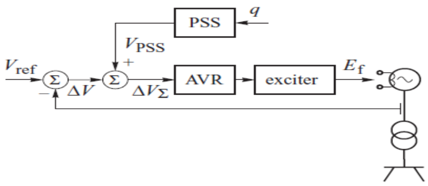

Figure 1. block diagram of supplementary control loop for the AVR system

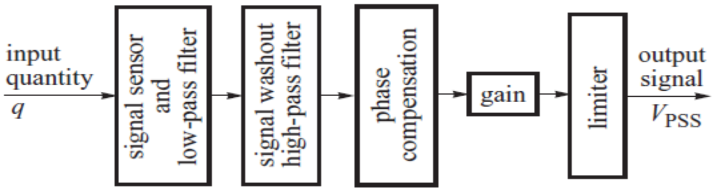

Figure 2. The major elements of a PSS

Artifital bee colony algorithm

The ABC algorithm was first proposed by Karaboga (Karaboga, 2005) in 2005. Similar to other intelligent swarm algorithms, it simulates the foraging behavior of honeybees. There are three groups of honeybees in the ABC algorithm, employed bees, onlooker bees, and scout bee. Employed bees take the responsibility of searching new food sources. After the process completed, they fly back to the hive and share the position and nectar amount information with onlooker bees in the dancing area. By observe the dance of employed bees, onlooker bees decide the food sources which they want. Scout bees carry out the random search while the food source is exhausted. In the original ABC algorithm (Karaboga and Basturk, 2007), the number of food sources is equal to the number of employed bees. The number of employed bees is equal to the number of onlooker bees simultaneously. In other words, a half of the colony size is employed bees. The process of the artificial bee colony algorithm is shown as below (Liao et al., 2013):

Step 1: Initialize the population.
Step 2: Send the employed bees to the food sources.
Step 3: Memory the best food source in employed bees by fitness evaluation.
Step 4: Employed bees come back to hive and share information of food sources with onlooker bees, then onlooker bees fly to the food sources which they have chosen.
Step 5: Memory the best food source in onlooker bees by fitness evaluation.
Step 6: The scout bees fly to the search area and look for new food sources.
Step 7: While the terminal condition is met or maximum cycle number is reached, Algorithm stop; otherwise, go back to step 2.

Simulated to other swarm evolution algorithms, the ABC algorithm has its own operators such as employed bee phase, onlooker bee phase and scout bee phase.

The employed bee phase

In the employed bee-phase, artificial bees update the new food sources by following expression(Liao et al., 2013):

$$m_i^j = x_i^j + \varphi_i^j \left(x_i^j - x_k^j \right) \tag{1}$$

where m^i_j and x^j_i represents the new and old solution (food source) in *j*th dimension of the *i*th individual, respectively; φ^i_j is a random real number between {-1, 1} corresponding to x^j_i, it controls the effectiveness of distance between x^j_i and x^j_k, *k* is an index number selected randomly in food sources. Obviously, a new food source is affected by the status of the bee colony distribution. After the new food source updated, original ABC chose the food source by the fitness value of each corresponding employed bee. Greedy selection has been applied in the ABC algorithm in order to determine which food source is better and would be remembered after the employed bee phase.

The onlooker bee phase

In the onlooker bee phase, employed bees go to a dance area share the nectar amount information of a food source, and onlooker bees waiting in the hive chose the employed bees randomly, but probability is related to the nectar amount. In the ABC algorithm, the nectar amount represents the fitness value of food source. Therefore, the food sources which have higher nectar amount information are more likely to be chosen after onlooker bee phase completed (Liao et al., 2013).

Scout bee phase

After onlooker bee phase, a modified bee colony distribution is determined. If one of these food sources cannot be improved in predetermined cycle ‘‘limit’’, it will be replaced by a new one according to following equation(Liao et al., 2013):

$$x_i^j = x_{\min}^j + rand[0,1]\left(x_{\max}^j - x_{\min}^j\right) \tag{1}$$

where x^j_{min} and x^j_{max} represent the lower and upper boundary in dimension j, respectively; *rand* {0, 1} is the random number between {0, 1}; Scout bee phase in ABC is applied to abandon the solution which cannot be improved (Liao et al., 2013).

Power suystem stabilizer design

A multi machine power system comprising four synchronous generators is considered as case study. The proposed test system is depicted in Figure 3 and the system data are given in (Anderson and Farmer, 1996). Three generators G_1, G_2 and G_3 are equipped with PSSs and their parameters are tuned by using ABC method. The PSS configuration is as follows; it comprises two compensators with time constants, T_1–T_4 with an additional gain K.

$$\text{Stabilizer output} = \text{K}\frac{\text{ST}_\text{W}}{1+\text{ST}_\text{W}}\frac{1+\text{ST}_1}{1+\text{ST}_2}\frac{1+\text{ST}_3}{1+\text{ST}_4}\Delta\omega \tag{2}$$

The optimum values of K and T_1–T_4 are accurately computed using ABC Algorithms. Objective function is also considered as following which is the Integral of the Time multiplied Absolute value of the Error (*ITAE*). The optimum values of the parameters are obtained and summarized in the Table 1.

$$\text{ITAE} = \sum_{i=1}^{n}\int_{0}^{t} t\left|\Delta\omega_i\right|dt \tag{3}$$

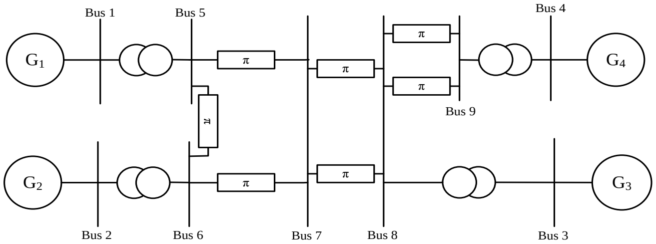

Figure 3. Two areas power system

Table 1. optimal values of PSS parameters

Parameter	K	T_1	T_2	T_3	T_4
G_1	52.11	0.61	0.01	0.88	0.01
G_2	98.44	0.65	0.01	0.85	0.01
G_3	54.7	0.51	0.01	0.73	0.01

RESULTS AND DISCUSSION

Simulation results

The proposed power system installed with PSSs is simulated following a 6 cycles three phase short circuit at bus 6. Figures 4-10 show the result following the proposed fault. Figure 4-7 show the speed of generators and each figure comprises two diagrams which are system installed with PSS (solid line) and system without PSS (dashed line). The results show that PSS can mitigate the oscillations and increase power system damping; where the oscillations are damped out faster than system without PSS. The injected signal by PSSs is also shown in Figure 8-10. It is seen that PSS signal is limited from up and down sides and also it becomes stable after oscillations.

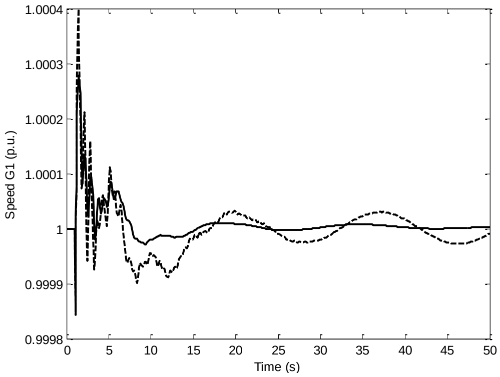

Figure 4. Speed G_1 following disturbance

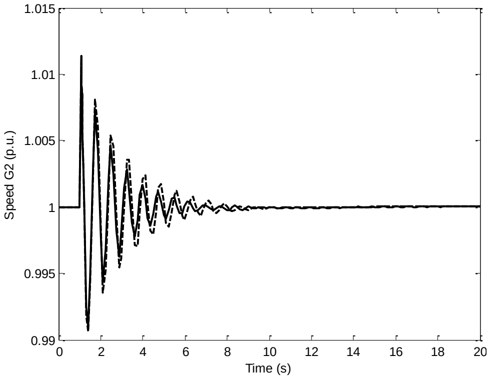

Figure 5. Speed G_2 following disturbance solid: with PSS; dashed: without PSS

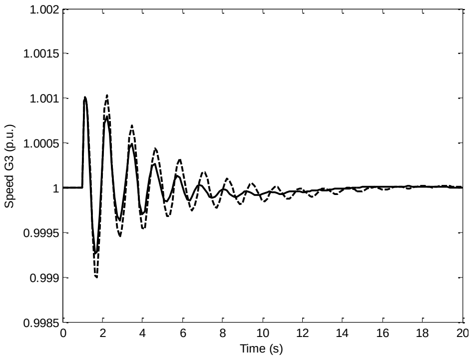

Figure 6. Speed G_3 following disturbance solid: with PSS; dashed: without PSS

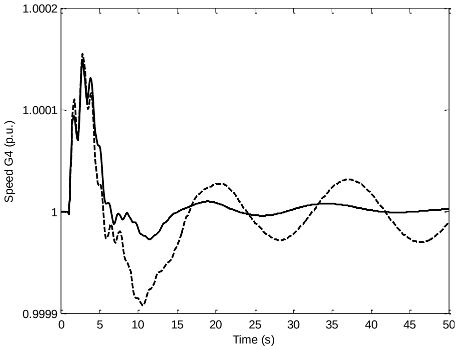

Figure 7. Speed G_4 following disturbance solid: with PSS; dashed: without PSS

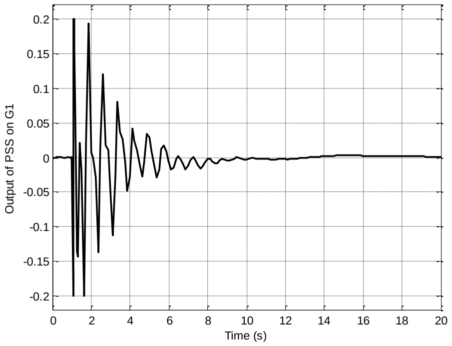

Figure 8. output signal of installed PSS on G_1 following disturbance

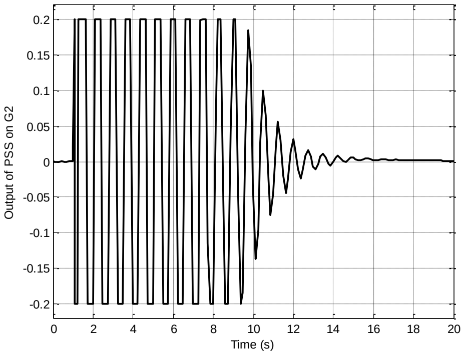

Figure 9. output signal of installed PSS on G_2 following disturbance

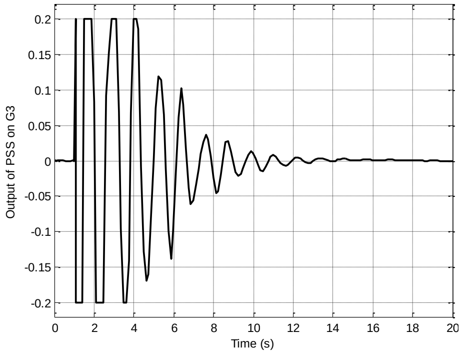

Figure 10. output signal of installed PSS on G_3 following disturbance

CONCULSION

A multi machine power system stabilizer design by using BAC algorithm was presented by this paper. Three PSSs were simultaneously tuned and simulated on the given test system. The simulation results were carried out to validate the proposed technique in damping oscillations. The ability of PSSs in damping low frequency oscillations was successfully shown.

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