IJDACR
ISSN: 2319-4863

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 8, March 2017)

Artificial Bee Colony based FOPID for SMIB System

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Abstract –**The designing of power transmission network is a difficult task due to the complexity of power system. This complex nature always causes a loss of the stability due to the fault. Whenever a fault occurs in the system, the whole system goes to severe transients. These transients cause oscillation in rotor angle which leads poor power quality. The nature of oscillation is increasing instead of being sustained, which leads system failure in the form of generator damage. To reduce and eliminate the unstable oscillations one needs to use a stabilizer which can generate a perfect compensatory signal to minimize the harmonics generated due to instability. This paper presents a FOPID stabilizer connected to the SMIB to reduce oscillations due to small signal disturbance. Artificial Bee Colony (ABC) is used for the parameter tuning of the stabilizer.**

Keywords –**ABC, FOPID, PID, PSS, SMIB.**

I. Introduction

A power plant contains several synchronous machines (turbo-generators) which are designed to transform the mechanical power of turbines into power (Production Phase), the latter will be transmitted usingTransport distributed to potential consumers (Domestic or Industrial). These consumers of electrical energy always require continuity of service with system stability to satisfy electro-technicians are always looking for methods and to ensure a stable, high-quality, continuous production of electricity, and without any interruption [1].

The problem of robustness of stability is posed in a serious way to guarantee a good operation of the Electro-Energetic Systems, and to overcome the problem of oscillations electromechanical systems by improving the damping of the system (stability), for these purposes signals stabilizers are introduced into the excitation system via its voltage [2]. These stabilizing signals will produce torques in phase with the speed variation of the generator for compensating for the phase delay introduced by the excitation system. The stabilizers[3] (Power System Stabilizers, PSSs), thanks to their advantages regarding cost economic efficiency and efficiency, are the usual means, not only to eliminate the negative effects voltage regulators but also for damping electromechanical oscillations and Stability of the system. These conventional stabilizers (often made in PI or PID) have the main disadvantage [4] poor adaptation to changes in system parameters and variations of the operating conditions of the system to be controlled (uncertainties).

To ensure the stability of the electro-energy system in the presence of various variations, use advanced control techniques such as optimal, adaptive and robust rather than the conventional ones. One of the main characteristics currently required of regulators is the robustness of stability that is the ability to maintain stability in the presence of variations (Or also nonparametric) parameters, thus called uncertainties or problems uncertain. The investigation of adaptive control algorithms (Fuzzy logic, Neurons) has been widely carried out [2]. Recently, optimal and robust control algorithms assume knowledge of a system model or intervals on uncertainties. For the continuous power supply, the stability of power system is a desirable key factor. Power system stability describes the attribute of a system that helps the system to maintain equilibrium under normal conditions and also retrieve the equilibrium condition under the condition of disturbance also. Various circumstances could lead to the conditions of instability in power system relying upon the mode of operation and system's configuration.

Maintenance of synchronization is the major issue of concern particularly for those power systems that depend upon synchronous machines. The relationship between power and angle and the dynamics of generator angles affects the above mentioned synchronous attribute. Apart from the synchronization problem, the other issues that may

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encounter are loading problems such as voltage collapse, etc.

The reliability of a power system has been an important topic of study in recent decades. Power system stability recognizes 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-effectivelong-term investment technology is required. Stability limits can define transfer capability. Also in a complex interconnected system, stability has a great impact on increasing the reliability and the profits. Although, this interconnection gives the system a complicated dynamics. It has advantages such as reduced spinning reserves and a lower electricity price. An appropriate control is required to achieve these benefits for the synchronization of the machines after a disturbance occurs. This research work describes power system stability of single machine infinite bus system using Artificial Bee Colony algorithm.

II. Power System Stabilizer (PSS)

Power system stability is that property of a power system which enables it to remain in a state of operating equilibrium under normal operating conditions and regaining an acceptable state of equilibrium after being subjected to a disturbance.

Power system stability has 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. Also, the electromechanical phenomenon will also disturb the stability of the rotating parts in the power system [5]. 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 [6].

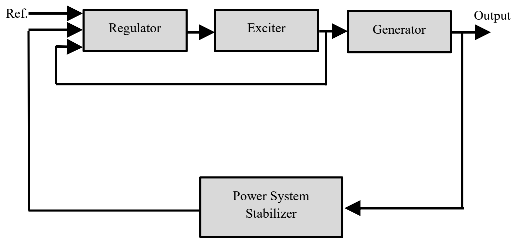

Figure 1: Functional block diagram of a synchronous generator excitation control system [6]

Power system stabilizers (PSS) are used on a synchronous generator to increase the damping of oscillations of the rotor/turbine shaft. The conventional PSS 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 [7] 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 [8] as well as by Yu [9]. These optimal controllers were linear. Adaptive control techniques are also proposed for SMIB, most of which involve linearization or model approximation.

Klein et al. [6, 10] presented the simulation studies into the effects of stabilizers on inter-area and local modes of oscillations in interconnected power systems. It is given that the PSS location and the voltage characteristics of the system loads are significant factors 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 [11]. 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 [12-13].

Several approaches are applied to PSS design problem. These include pole placement, H_∞, optimal control, adaptive control, variable structure control, and different optimization and artificial intelligence techniques [14].

III. Proposed Method

SMIB with FOPID

The PID controllers are described and named according to their nature of gains and proportional parameters. The controller output is the function of these parameters:

$$u(t) = K_P e(t) + K_I \int_0^t e(\tau)d\tau + K_D \frac{d}{dt} e(t) \quad (1)$$

Equation (1) shows the transfer function of PID controller.

Where, K_P: Proportional gain, a tuning parameter

K_I: Integral gain, a tuning parameter

K_D: Derivative gain, a tuning parameter

e: Error

t: Time or instantaneous time

τ: Variable of integration; takes on values from time 0 to t.

The FOPID controller has three parameters similar to PID controller along with the two

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additional parameters namely; the integral order λ, and the differential order μ. The transfer function of $PI^{\lambda}D^{\mu}$ controller is given by [15]:

$$G_c(s) = K_P + K_I s^{-\lambda} + K_D s^{\mu}, \quad \lambda, \mu > 0 \qquad (2)$$

The differential equation for the $PI^{\lambda}D^{\mu}$ controller in the time domain is given by [16]:

$$u(t) = K_P e(t) + K_I D^{-\lambda} e(t) + K_D D^{\mu} e(t) \qquad (3)$$

The FOPID parameters collaborate to form the SMIB and setting up wrong values can result in undesired output. The regulation command tracking refers the wellness of controlled variables. The command tracking is determined by the proportions of risetime and settling time. Many methods are applied for controlling these parameters, and here we emphasize the applications of ABC for the same. This method (inherited from nature) compute the value ofK_P, K_I and K_D based on their previous values.

Figure 2 and Figure 3 show Simulink models for proposed FOPID and SMIB-FOPID systems respectively.

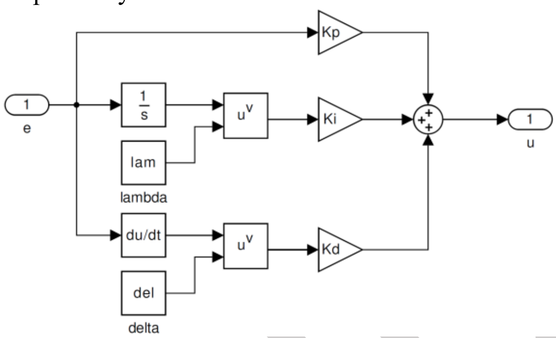

Figure 2: Simulink Model for FOPID

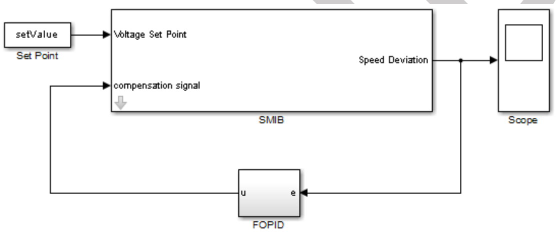

Figure 3: Simulink Model for SMIB with FOPID

Power System Stability Analysis using ABC

Fitness Function for PSS

$$f(d_v) = \int_0^t |(d_r - d_v)|\, dt \qquad (4)$$

Where,

$d_r = 0$ (Reference speed deviation)

$$d_v = f(v)$$

This fitness function is regarding Integral absolute error (IAE).

Artificial Bee Colony Algorithm

The ABC algorithm is a swarm based, ameta-heuristic method based on the foraging behavior of honey bee colonies. The model is composed of three important elements: employed and unemployed foragers, and food sources. The employed and unemployed hunters are the first two elements, while the third element is the rich food sources close to their hive. The model also describes the two leading modes of behavior. These behaviors are necessary for self-organization and collective intelligence: recruitment of forager bees to rich food sources, resulting in positive feedback and simultaneously, the abandonment of poor sources by foragers, which causes negative feedback.

Pseudo Code of the ABC Algorithm

1. Initialize the population of solutions x_{ij}
2. Evaluate the population
3. Cycle=1
4. Repeat
5. Produce new solutions (food source positions) v_{ij} in the neighbourhood of x_{ij} for the employed bees and evaluate them.
6. Put on the greedy selection process between x_i and v_i
7. Compute the probability values P_i for the solutions x_i by means of their fitness values. In order to calculate the fitness values of solutions.

$$\begin{bmatrix} \frac{1}{1+f_i} & if\ f_i \geq 0 \\ 1 + abs(f_i) & if\ f_i < 0 \end{bmatrix} \qquad (5)$$

   Normalize p_i values into [0, 1]
8. Produce the new solutions (new positions) v_i for the onlookers from the solutionsx_i, selected depending onp_i, and evaluate them
9. Put on the greedy selection process for the onlookers between x_i and v_i
10. Determine the abandoned solution (source) if exists, and replace it with a new randomly produced solution x_i for the scout using the equation

$$x_{ij} = min_j + rand(0,1) * \left(max_j - min_j\right) \qquad (6)$$

11. Memorize the best food source position (solution) achieved so far
12. cycle=cycle+1
13. until cycle= Maximum Cycle Number (MCN)

IV. Simulation And Results

The performance of proposed algorithm isstudied using MATLABsimulation.

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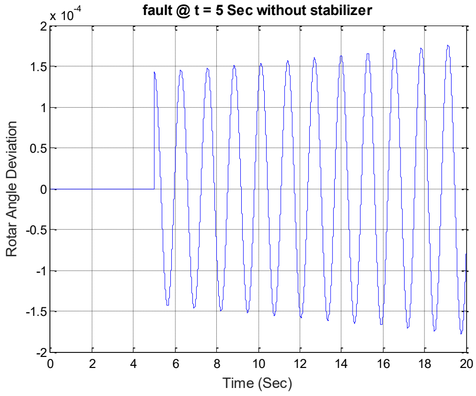

Figure 4: Rotor angle deviations without stabilizer

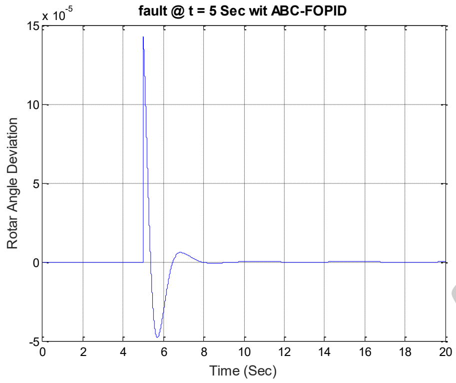

Figure 5: Rotor angle deviations for ABC-FOPID

Settling Time (S) for ABC-FOPID: 8.7688

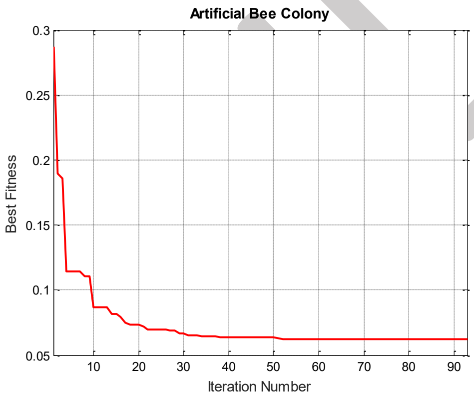

Figure 6: Iteration count for ABC

V. Conclusion

The study presented in this paper deals with the application of ABC in the optimization of the parameters of the stabilizing device of the PSS power system. The aim of the paper is to provide the necessary damping to the electromechanical oscillations of the generators when the system undergoes perturbations around its operating point. A fitness function is derived which is aimed to minimize rotor speed deviation as a function of stabilizers parameter. It is noticeable that the proposed tuning method the stabilizer gives stable study state.

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