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Statcom based Damping Controller for SMIB System Using Particle Swarm Optimization

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Abstract

The prime motto of present paper is to find out the enhancement of damping the power system oscillation through co-ordinated model of 'Static Synchronous Compensator' (STATCOM) situated in shunt with transmission line. This paper also stabilizer the linearized 'Phillips-Heffron' model of a power system installed with a STATCOM and demonstrates the application of the model in anylizing the damping effect of the STATCOM and designing a 'STATCOM' stabilizer to improve power system oscillation stability of single machine infinite-bus system by using 'MATLAB' The effectiveness of proposed controller in damping the low frequency oscillations and hence improving power system dynamic stability have been identified via simulation result with different system conditions, by using 'MATLAB' and design of damping controller with Particle Swarm Optimization (PSO) algorithm is used to find out the optimal controller parameters.

Keywords:- *FACTS Devices, MATLAB, STATCOM, SMIB*

1. INTRODUCTION

An important application area for the synchronous machine Is used almost exclusively in power systems as a source of electrical energy. Keeping voltage within certain limits help to reduce energy losses and improves voltage regulation. Voltage control is a difficult task because voltages are strongly influenced by dynamic load fluctuations. Power system is a complicate nonlinear system which structure, parameter and running mode usually change. The study of the linearized system is necessary for some purposes, such as control loop design. The most common disturbance is load variations, but parameter variations are also common, and the closed loop control system is used to compensate for such variations.

Today, the power system are complicated network with thousands of buses and hundreds of generating stations and load centers being interconnected through power transmission lines. An electric power system can be subdivided into four parts (i) generation system (ii) transmission system (iii)distribution system (iv) load system (utilization) .

In power system the low frequency oscillation are inherent due sudden change of load, machine output, faults occurs on the transmission and machine and such frequent occurrence.Satisfactory damping of the power system oscillations therefore is an important issue when dealing with rotor angle (phase angle) stability of the power system. So recently, Flexible AC transmission system (FACTS) controllers have been proposed to enhance the transient or dynamic stability of power system. During the last decade, a number of control devices under the terms FACTS technology have been proposed and used. Among all FACTS devices, static synchronous compensators (STATCOM) plays great role in reactive power compensation and voltage support because of its altercative steady state performance and operating characteristics.

The STATCOM is one of the most important shunt connected FACTS controllers to control the power flow and
make better transients stability. A STATCOM is a controlled reactive power source. It provides voltage supports by generating or absorbing capacitor banks.

STATCOM has three operating parts: (i) STATIC: based on solid state switching devices with no rotating components,
(ii) SYNCHRONOUS: analogous to an ideal synchronous machine with 3 sinusoidal phase voltage at fundamental frequency,
(iii) COMPENSATOR: rendered with reactive compensation.

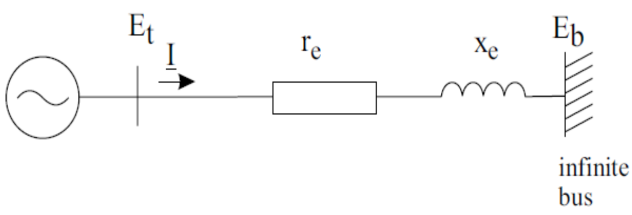

Figure 1: One machine to infinite bus system

Modern electric power system is facing many challenges due to day by day increasing complexity in their operation and structure. In the recent past, one of the problems that got wide attention is the power system instability. With the lack of new generation and transmission facilities and over exploitation of the existing facilities geared by increase in load demand make these types of problems more imminent in modern power systems. Demand of electrical power is continuously rising at a very high rate due to rapid industrial development . To meet this demand, it is essential to raise the transmitted power along with the existing transmission facilities. The need for the power flow control in electrical power systems is thus evident. With the increased loading of transmission lines, the problem of transient stability after a major fault can become a transmission power limiting factor. To solve the problem of transient stability in the late 1980s, the Electric Power Research Institute (EPRI) introduced a new approach to solve the problem of designing and operating power systems; the proposed concept is known as Flexible AC Transmission Systems (FACTS). The two main objectives of FACTS are to increase the transmission capacity and control power flow over designated transmission routes. FACTS are defined by the IEEE as “a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability”.

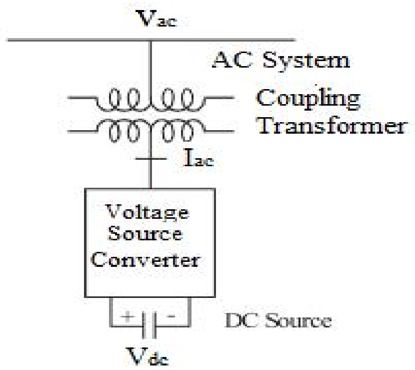

Figure 2: Basic Structure of STATCOM

“A Static synchronous compensator is a shunt-connected static VAR compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage”.The concept of STATCOM was proposed by Gyugyi in 1976. Power Converter employed in the STATCOM mainly of two types i.e. is Voltage Source Converter and Current Source Converter. In Current source Converter direct current always has one polarity and the power reversal takes place through reversal of dc voltage polarity while In Voltage Source Converter dc voltage always has one polarity, and the power reversal takes place through reversal of dc current polarity. The power semiconductor devices used in current source converter requires bidirectional voltage blocking capability and for achieving this Characteristic an additional diode must be connected in series with a semiconductor switch which increased the system cost and its becomes costlier as compared to voltage source converter moreover Voltage source converter can operate on higher efficiency in high power applications. STATCOM is made up of a coupling transformer, a VSC and a dc energy storage device. STATCOM is capable of exchanging reactive power with the transmission line because of its small energy storage device i.e. small dc capacitor, if this dc capacitor is replaced with dc storage battery or other dc voltage source, the controller can exchange real and reactive power with the transmission system, extending its region of operation from two to four quadrants.

2. Phillips Heffron model

For the study of single machine infinite bus system a Phillips Heffron model can be obtained by linearizing the system equations around an operating condition. The obtained hefffron model is as shown in the figure below

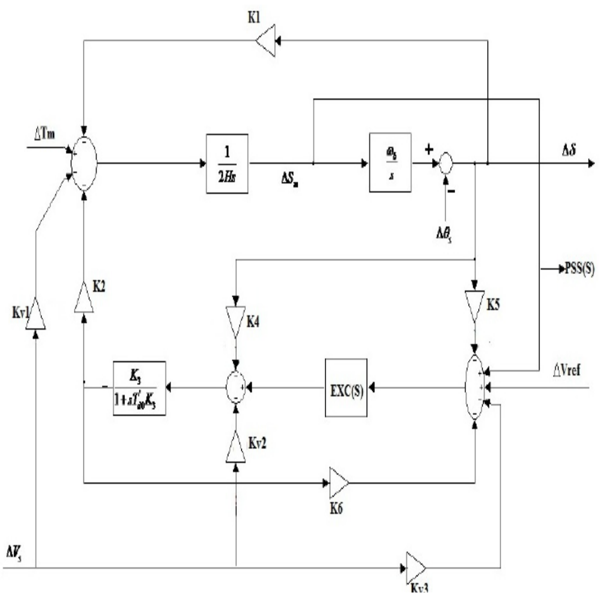

Figure 3: Phillips Heffron model

3. PSO

In computer science, particle swarm optimization (PSO) is a computational method that optimizes a problem by iteratively trying to improve a candidate solution with regard to a given measure of quality. PSO optimizes a problem by having a population of candidate solutions, here dubbed particles, and moving these particles around in

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the search-space according to simple mathematical formulae over the particle's position and velocity. Each particle's movement is influenced by its local best known position but, is also guided toward the best known positions in the search-space, which are updated as better positions are found by other particles. This is expected to move the swarm toward the best solutions.

PSO algorithm is an optimization technique inspired by the natural movement and intelligence of bird flocks and fish schooling. It was first introduced by Eberhart and Kennedy in 1995 to graphically simulate the graceful and unpredictable choreography of a swarm .

The basic idea of the PSO consists in moving a pre-defined number of particles troughout the searching space in order to find the best solution. The movement pattern of the particles towards the best solutions is defined by the social interaction between the individuals from the population.

In Fig. 3 are represented the main steps for implementing the PSO algorithm. For mathematical representation of the flock, the particles are modeled as vectors in a multi-dimensional search space. The optimization process starts by randomly generating the population and the velocities of the particles. To assign a certain measure of performance, the particles are evaluated according to an objective function. In this way, the personal best of each particle as well as the global best of the entire population are determined. With this information, the velocity of every individual is computed taking into account its previous velocity, personal best and global best . The new positions of the individuals are then updated by adding the computed velocities to the actual position according to (1).

$$\mathbf{v_i^{k+1}=wv_i^k+c_1.rand.(pbest_i-s_i^k)+ c_2.rand.(gbest_i-s_i^k)}$$

where:

$c1$, $c2$ Weighting coefficients

$pbest_i$ Personal best of the ith particle

$gbest$ Global best of the population

s_i^k Position of the ith particle at iteration k

$$S_i^{k+1} = S_i^k + V_i^{k+1} \quad \text{………… (1)}$$

where:

$s_i^{k\square 1}$ The position of the ith particle at iteration $k+1$

$v_i^{k\square 1}$ Velocity of the ith particle at iteration $k+1$

The searching process is continued until a relatively unchanged position has been encountered or computational limits are exceeded. An important aspect of the PSO is that the ratios of the three elements that influence the particle velocity in the optimization process can be modified. Therefore, the particle performance toward the optimal solution can be enhanced controlling the weighting coefficients.

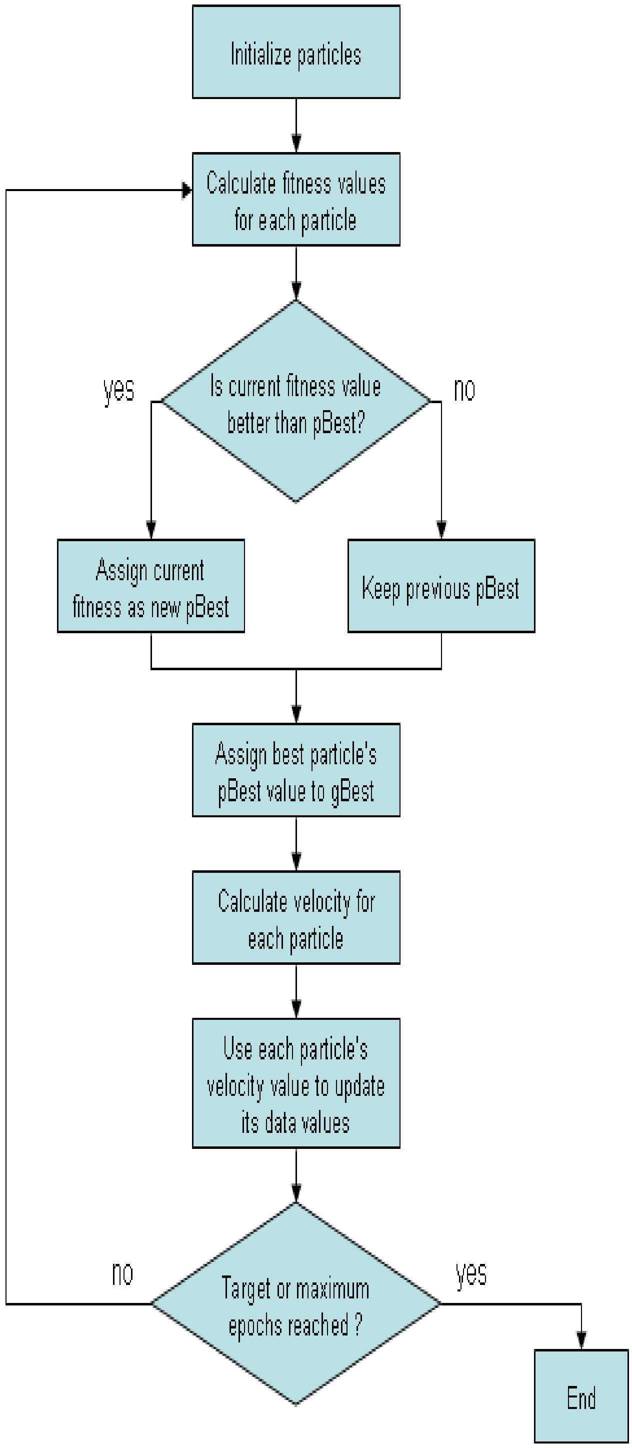

Figure.4. Block diagram of PSO algorithm

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IV. MODELING AND SIMULATION METHODOLOGY

The overall framework of simulation methodology is shown in Fig.

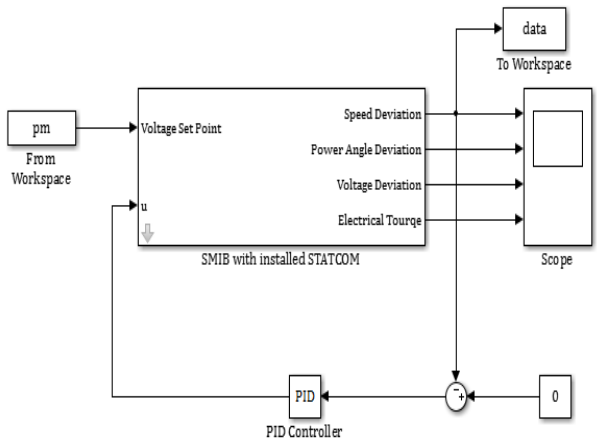

Figure. 5 Simulation Methodology

V. RESULT

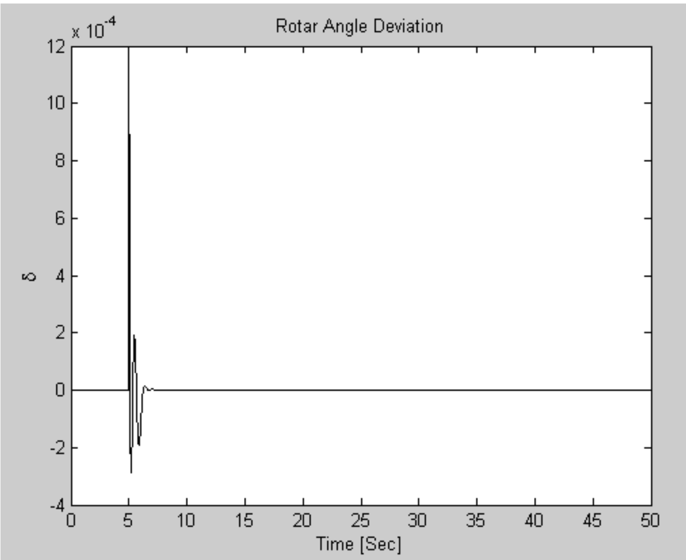

Figure 6 Response of rotor angle deviation of machine with statcom

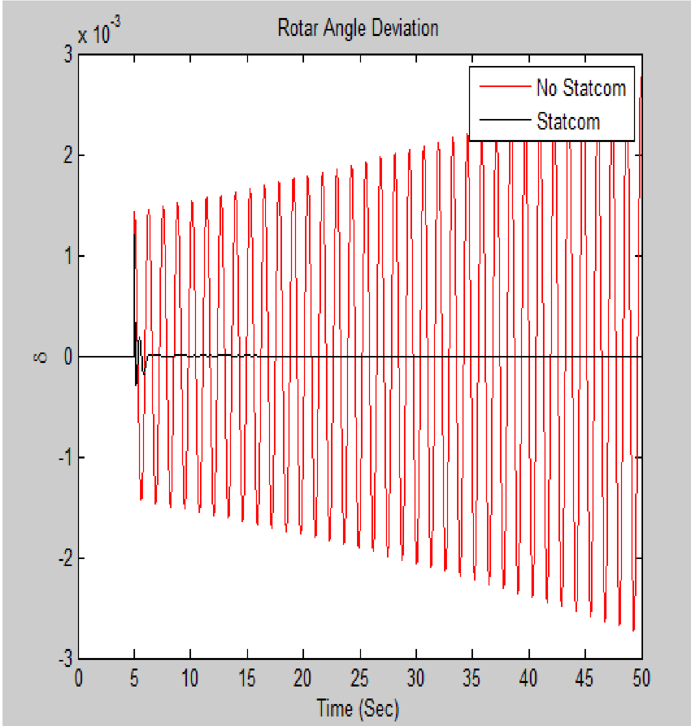

Figure 7. Response of rotor angle deviation of machine with & without statcom

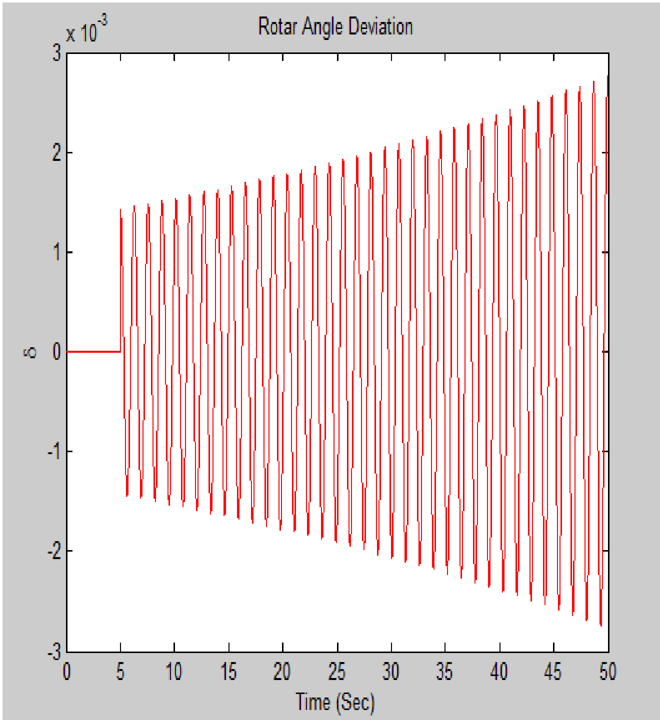

Figure 8. Response of rotor angle deviation of machine without statcom

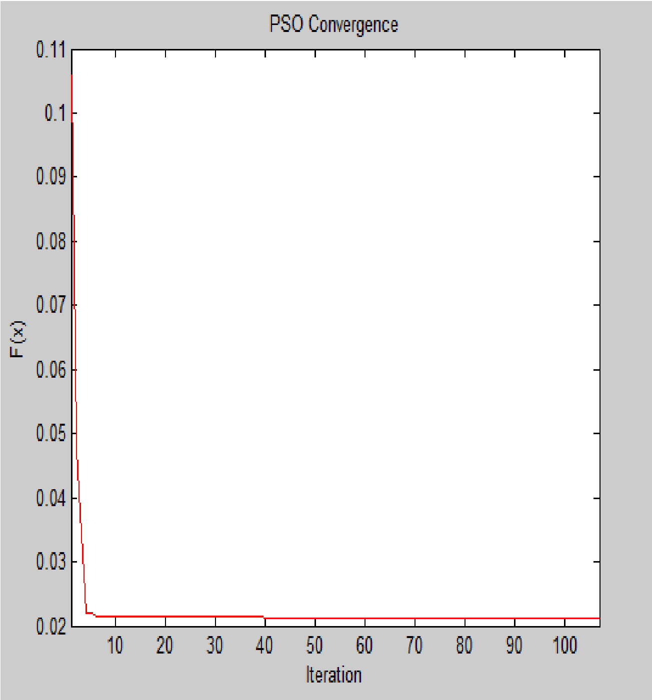

Figure 9. PSO convergence

VI. CONCLUSION

Solving an optimization problem is one of the common scenarios that occur in most engineering applications. In this study, the power system stability enhancement via PSS and STATCOM-based stabilizer when applied independently and also through coordinated application was discussed and investigated. For the proposed stabilizer design problem, an eigenvalue-based objective function to increase the system damping ratio was developed. The tuning parameters of the proposed stabilizer were optimized using PSO. The proposed stabilizers have been applied and tested on power system under severe disturbance condition. The nonlinear time domain simulation results show the effectiveness and the robustness of the proposed stabilizer and its ability to provide good damping of low frequency oscillation and improve greatly the system voltage profile.

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