Genetic Algorithm application to control of STATCOM for damping of sub synchronous resonance

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Abstract- This paper presents results of study on sub synchronous resonance (SSR) and STATCOM application for damping of SSR. STATCOM is employed with PI controller to regulate bus voltage and with an auxiliary signal which derived from generator speed deviation. To adjust the parameters of the controller a fitness function is introduced. A genetic algorithm is employed to minimize the fitness function to achieve a satisfactory damping of SSR. The study is performed on IEEE Second Benchmark Model .The results are verified by some simulations.

Key words: SSR , STATCOM , Genetic algorithm

1. Introduction

Spread of energy transmission system become difficult continuously. This problem along with energy source restriction, constraint electrical generator companies to use uttermost of transmission lines capability. So transmission lines are very important section in power system which their role is power transmit from generation to distribution. But there are some locks which the most important is reactance of transmission lines. In order to reduce this reactance series compensation is used and in fact in this way transmission lines electrical length become shorten. Series capacitors usually are used to compensate lines reactance and often place in midpoint of lines. Important purposes are followed in series compensation for example transient and steady state stability improvement, voltage rapid oscillation reduction, lines losses reduction so power transmission capability increment and power factor correction. This however may lead to the phenomenon of sub synchronous resonance or SSR. SSR occurs when a natural frequency of a series compensated transmission system aligns with the complement of one of the torsional modes of the turbine-generator and Under such situation , the turbine-generator oscillates at a frequency corresponding to the torsional mode frequency, and the torsional oscillations may grow and result in the failure of the turbine shaft [1].but we know Series compensation of long lines is an economic solution to the problem of enhancing power transfer and improving system stability so along with series compensation another solution is need to control SSR. The power transfer capability enhancement can be achieved by suitable combination of passive elements as in series capacitors and active FACTS controllers. In this paper, series passive compensation and shunt active compensation provided by static synchronous compensator (STATCOM). This paper examines the application of STATCOM for damping torsional oscillations in series compensated ac system. The IEEE second benchmark system has been modeled with STATCOM at the generator terminal. The STATCOM considered is a voltage source inverter, and is equipped with a PI-controller that regulates the generator terminal voltage. The PI controller has an additional input derived from the generator speed deviations.

Genetic algorithms (GA) are one of the efficient tools that are employed in solving optimization problems[2]. The basic idea of genetic algorithm is as follow[3][4]: the genetic pool of a given population potentially contains the solution, or a better solution, to a given optimization problem. This solution is not active because the genetic combination on which it relies is split between several subjects. Only the association of different genomes can lead to the solution. Optimization in genetic algorithm is based on optimization of a fitness function which is a function of environment individuals or genes. Each new generation is generated by applying Crossover and Mutation operand on old generation. Then in new generation good genes that lead to better fitness function have more chance to survive. So, after some generations the optimal solution will be attained.

2. Power system modeling

In order to analyze of SSR it's require to consider a detailed modeling of overall electrical system entail of synchronous machine, excitation system, STATCOM, mechanical system and power system stabilizer . We consider IEEE Second Benchmark Model (SBM) which connected with 12 pulses STATCOM at the generator terminal as illustrated in Fig. 1.

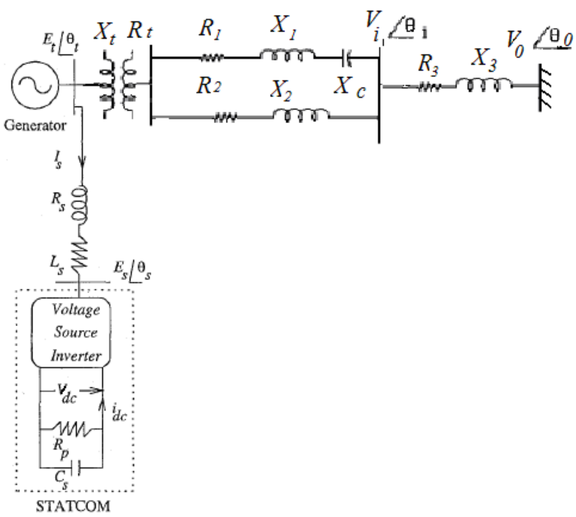

Fig.1. Power system model

Mechanical modeling comprises six masses, high pressure turbine (HP), intermediate pressure turbine (IP), two low pressure turbines (LPA and LPB), the generator (GEN), and the exciter (EXC) in general. It should be noted that static exciter doesn't inter in mechanical modeling [5]. Fig. 2. shows mechanical components.

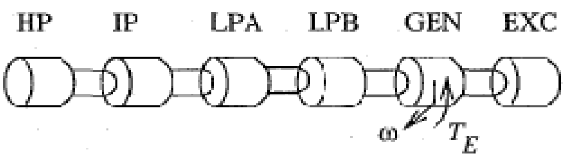

Fig .2. Six masses mechanical model

3. STATCOM modeling

The state space model in D-Q coordinates for STATCOM circuit in Fig. 1. can be written as below:

$$\begin{bmatrix} \dot{I}_{sd} \\ \dot{I}_{sq} \\ \dot{V}_{dc} \end{bmatrix} = \begin{bmatrix} -\frac{R_s}{L_s} & \omega_\circ & \frac{k\cos\theta_s}{L_s} \\ -\omega_\circ & -\frac{R_s}{L_s} & \frac{k\sin\theta_s}{L_s} \\ -\frac{1.5k\cos\theta_s}{C_s} & -\frac{1.5k\sin\theta_s}{C_s} & -\frac{1}{R_P C_s} \end{bmatrix} \begin{bmatrix} I_{sd} \\ I_{sq} \\ V_{dc} \end{bmatrix} + \begin{bmatrix} \frac{1}{L_s} & 0 \\ 0 & \frac{1}{L_s} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} E_{sd} \\ E_{sq} \end{bmatrix} \quad \textbf{(1)}$$

Where $\omega_\circ = 377 rad/s$, $k = 2\sqrt{\frac{6}{\pi}} \approx 2.764$ for 12 pulses inverter , $E_t = \sqrt{(E_{td}^2 + E_{tq}^2)}$, $\theta_t = \tan^{-1}\frac{E_{tq}}{E_{td}}$

$\theta_s = \theta_t + \theta_d$ and θ_d, as a phase difference is the angle between E_s and E_t.

STATCOM in Fig.1. consists of 12 pulses GTO based VSI, C_s on DC side as dc source, R_p resistance parallel with C_s, represents capacitor losses and on the other side STATCOM connect to generator terminal with a coupling transformer represented using L_s , leakage inductance and R_s , resistance [6].

4. STATCOM control

The main function of STATCOM, like SVC, is to regulate the transmission line voltage at the connection point. But in order to SSR damping we need auxiliary signal. The generator speed contains components of all the turbine modes. Consequently, if the generator speed is used to control STATCOM, all the torsional modes, in addition to the mode corresponding to the generator mass will be afflicted [7]. Therefore generator speed deviations used as auxiliary signal. The speed signal is then filtered, compared with synchronous speed and normalized to obtain the per unit speed deviation [8].we use control system as presented in [8] to control STATCOM for damping of SSR as shown in Fig.3.

Because of the simplicity and robustness, PI controllers are frequently used controllers in industries[9][10]. Paremeter adjustment of PI controllers is an old challenge in the field of control system design. Some of methods have been proposed to select the PI coefficients, but they are not completely systematic methods and result in a poorly tuned controller that needs some trial and error[11][12]. Genetic algorithm can be a good candidate to be employed to select PI coefficients[11],[13]…[16].

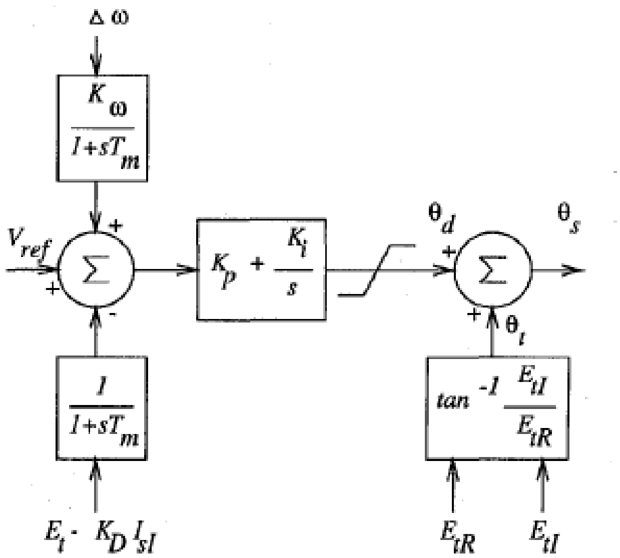

Fig .3. STATCOM control block

In order to adjust controller parameters, have been utilized following fitness functions :

$$f(K_P, K_I) = A\left(\int_{t=0}^{t=t_{sim}} t|\Delta\omega|dt + B(T_{\text{settling}})\right) \qquad (2)$$

$$A + B = 1$$

Where $\Delta\omega$ is the generator speed deviation, T_{settling} is the settling time of rotor angle, t_{sim} is the simulation time.

Parameters A, B should be manually tuned according to the understudy plant. Now, if procedure is executed to minimize (2), a suitable PI controller will be expected. The optimization algorithm that we employ is a common version of genetic algorithm. We can introduce the following computing procedure based on genetic algorithm for selection controller parameters:

Algorithm:

1. Randomly choose the genetic pool of parameters K_p, K_I
2. Compute the finesses of all genetic strings, taking (2) as fitness function.
3. Choose the best subset of the population of the parameters: K_p, K_I
4. Generate new strings using the subset chosen in step 3 as parents and the "single point crossover" and "mutation" as operators.
5. Verify the fitness of the new population members.
6. Repeat the steps 3 to 5 until the fixed amount of fitness is attained.

This algorithm is illustrated in Fig. 4. For details the reader can refer to the texts about genetic algorithm such as [3][4],[11][17] and also HELP documents of MATLAB.

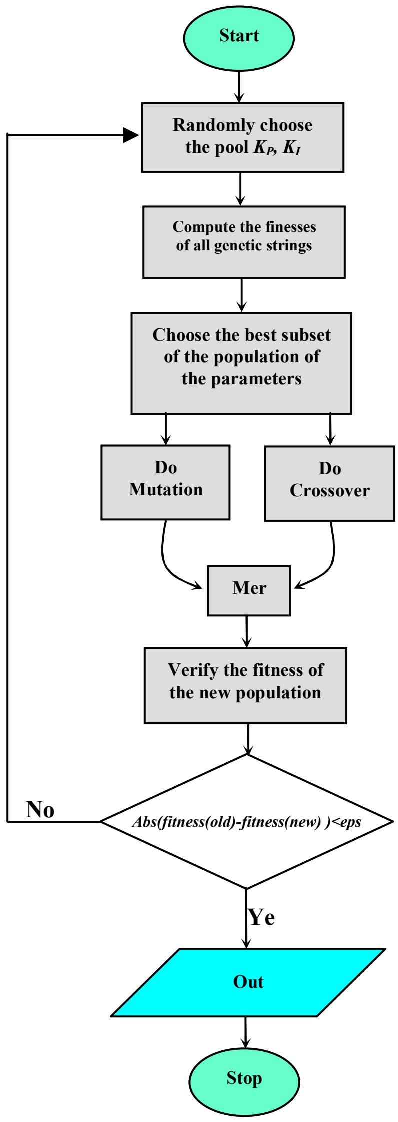

Fig. 4. Genetic algorithm employed for parameter adjustment of PI controller

5. Simulation Results

A numerical simulation was implemented using MATLAB and performed the genetic algorithm to optimize fitness function (2). To show effectiveness of STATCOM for damping of SSR, first we simulated SBM without STATCOM then simulated it with STATCOM which its controller parameters were obtained using genetic algorithm. The characteristics of applied GA were as follow:

Population = 20
Scaling function = Rank
Creation function = Uniform
Selection = Stochastic Uniform
Crossover = 0.80
Elite Count = 2
Generation = 100
Mutation function = Gaussian
Crossover function = Scattered
Scale = 1
Shrink = 1.5
Migration Direction = Forward
Fraction = 0.2
Interval = 20
Iteration = 32

Rotor angle, rotor speed and Gen-LP shaft torque plots are given in Fig.5., Fig.6. and Fig.7. which are for without STATCOM case and SSR effects are obvious. Rotor angle, rotor speed and Gen-LP shaft torque plots are given in Fig.8., Fig.9. and Fig.10. which are for system connected with STATCOM and STATCOM effects on damping of SSR are obvious.

6. Conclusions

The aim of this paper was damping of SSR using STATCOM. To reach that goal a genetic algorithm was employed to adjust controller parameters. In order to adjust these parameters a fitness function was defined. Minimization of such a fitness function by genetic algorithm causes a satisfactory damping of SSR.

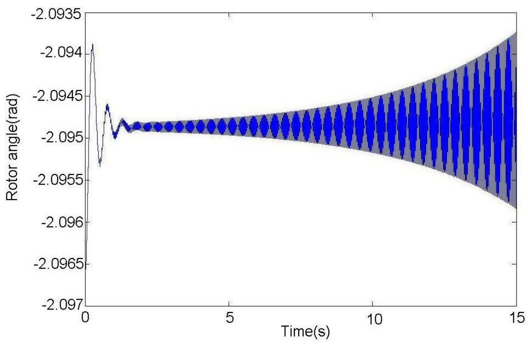

Fig.5. Rotor angle without STATCOM

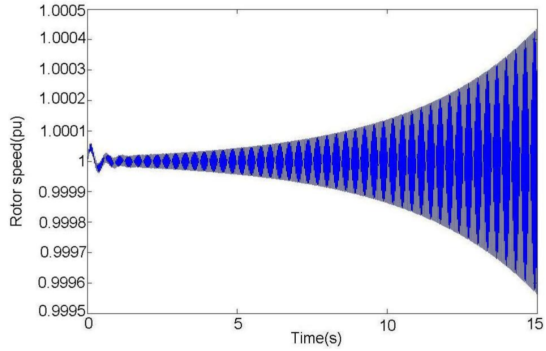

Fig. 6. Rotor speed without STATCOM

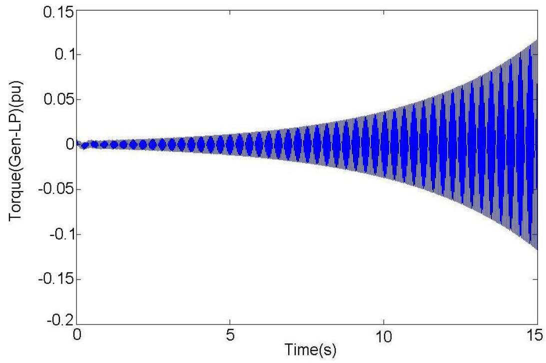

Fig. 7. Generator low pressure torque without STATCOM

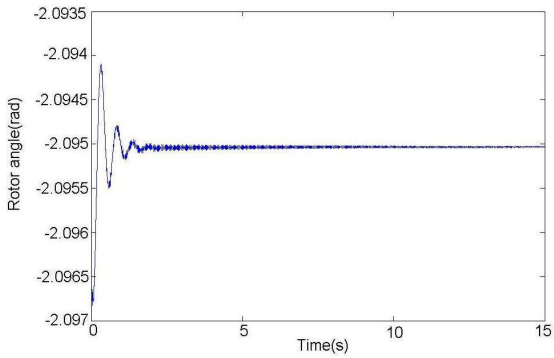

Fig. 8. Rotor angle with STATCOM

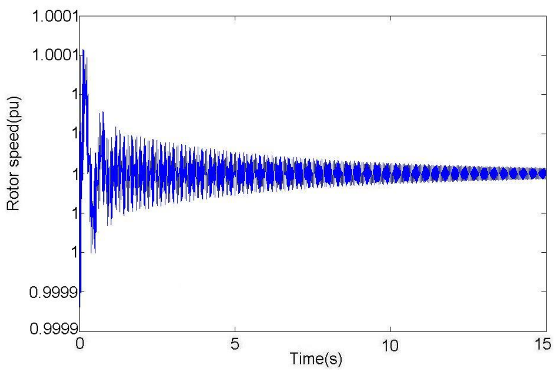

Fig. 9. Rotor speed with STATCOM

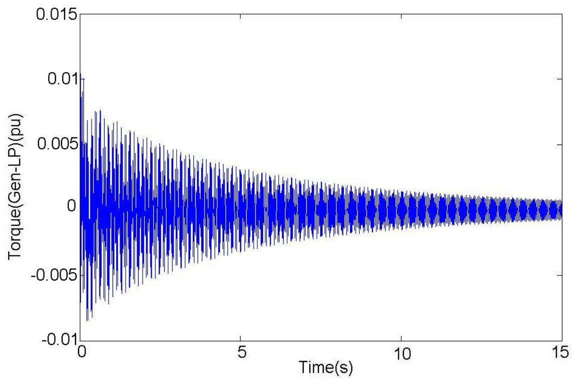

Fig. 10. Generator low pressure torque with STATCOM

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