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Research paper

Enhancement of Power System Transient Stability By Fractional Order Controlled STATCOM Tuned By PSO

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Abstract

This paper discusses the application of Fractional order PI controlled Static synchronous compensator for improvement rotor angle stability of inter connected power system. FACTS Controllers plays important role in enhancing the power system stability.Besides improving the stability margin of the power system it also aids the damping of inter area power oscillations. In the present work STATCOM is connected in multimachine power system .The dynamic response of the STATCOM is controlled by using fractional order controllers.The controller gains of the fractional controller are tuned by using PSO algorithm.It gives acceptable solutions to continuous non-linear systems with less computational effort. The performance of the proposed controller has been compared with integer order PI controllers at different locations of fault. In this paper a 3 machine 9 bus WSSC test power system is considered and simulated in MATLAB/SIMULINK.

Keywords:*-FOPI Controller, Voltage Stability, Power Oscillations, TLBO, MATLAB*

1. Introduction

A large interconnected power system is a multi-variable system whose dynamic response depends on wide range of operating conditions and different devices connected to it. Stability of an interconnected power system has been a issue of great importance in system operation. The classification of power system stability is given in fig(1).The maximum loading of any line in a power system is kept at much lower to ensure stability of the system under different operating conditions. During a disturbance the chances of a synchronous machine going out of step is much more when size of the system becomes very large. The inter area power oscillations followed by a disturbance may settle down or may grow continuously leading to the problem of transient stability[1]. One of the conventional method of handling these power oscillations is by the application of power system stabilizers (PSS).If the location of fault is far away from the generators, the chances of synchronous generator going out synchronism are more.

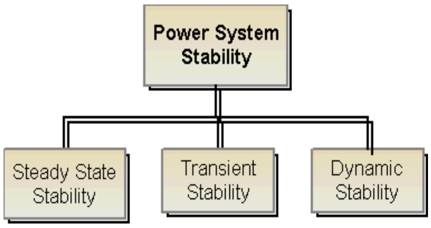


Fig1. Power System Stability Diagram

2. Transient Stability Controller

The ability of the power system to remain in synchronism when subjected to large disturbance is known as transient stability. The problem of transient stability mainly arises due to sudden loss of a line,majour faults or over loading of lines. Transient in stability may cause un damped low frequency power oscillations in the power network. These oscillations if allowed to grow may cause the system collapse. Hence the need arises for fast acting controllers to restore the normal operation after being subjected to major disturbance.

FlexibleACTransmission Systems(FACTS)is one of the efficient fast acting transient stability controllers. These power electronic based controllers also improve the line loading capacity and hence it is possible to transfer more power under normal study state conditions. The major advantage of FACTS controllers over PSS is that they can be located in any key location. These controllers can provide continuous control of power under steady state conditions.

3. Facts Controllers

Facts Controllers are basically classified into the following categories [2]

Shunt controllers

Series controllers

Shunt-series controllers

Series-series controllers

The transfer of power between any two areas in a power system is a function of line impedance, magnitude of bus voltage, phase angle difference of bus voltages. Active and reactive power flow in the transmission line is given by the equations (1) and (2) respectively.
By varying any of these parameters it is possible to control the power flow in the power system. In the fig V_1 and V_2 represents the voltage magnitude,δ_1 and δ_2 represents the phase angles of area 1 and area 2 respectively.

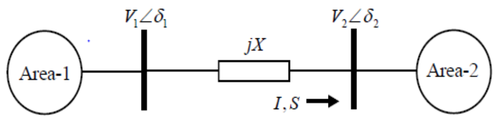
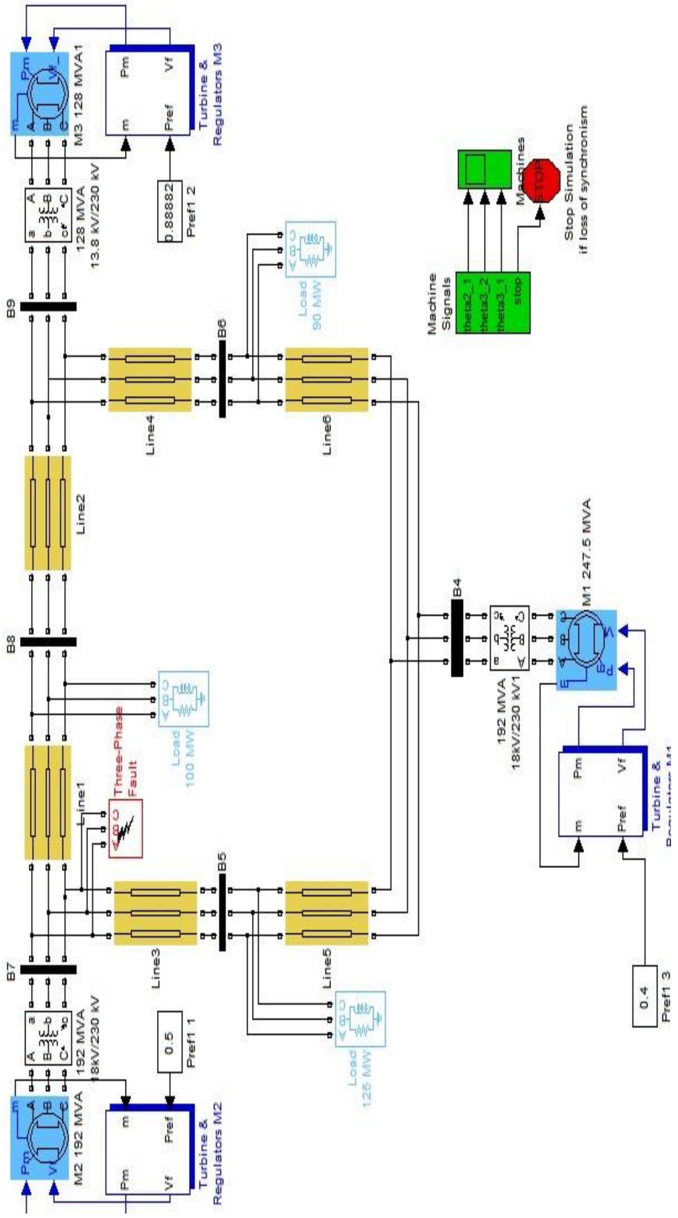


Fig 2: power flow diagram

$$P = \frac{V1V2}{X}\sin(\delta 1 - \delta 2) \quad (1)$$



$$Q1 = \frac{V1V2cos(\delta 1 - \delta 2) - V1}{X} \quad (2)$$

FACTS based controllers alters one or more parameters [3]. Shunt controllers regulates the bus voltages and controls the reactive power flow in the line where as the series controllers directly controls the line impedance and active power flow in the line. However the shunt compensation also aid for active power control in addition to the improvement of bus voltage profile. Hence shunt compensation aids for transient stability improvement.

4. Static Synchronous Compensator (Phasor Type)

Static synchronous compensator (STATCOM) is an advanced shunt compensation device used to improve the stability of the power system**.** It consists of a voltage source converter connected to the bus through a transformer. STATCOM supplies both lagging and leading reactive power.STATCOM has two internal controllers.In this paper A.C voltage controller is controlled by fractional order controller.

Fig 3: Statcom Block

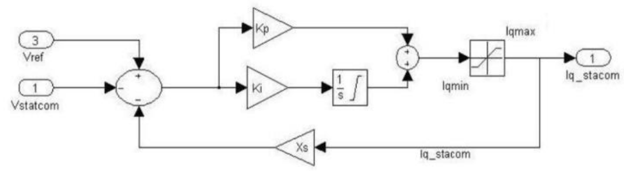


Fig4: Voltage controller of STATCOM

STATCOM has two internal controllers,a.c controller and d.c voltage controller.in this paper the d.c controller is made use to get the dynamic response under the conditions of fault as shown in fig(2).A.C voltage controller with fixed gains PI controller is used .The gains of the d.c controller are varied to obtain the required dynamic response.

5. Fraction Controllers

One of the possibilities of improving the performance of integer order PI controller is to extend as fractional order controllers[6].In FOPI controllers there are three parameters, gain of the proportional controller K_p.gain of the integral controller K_i and power of integral controller λ.Hence fractional order controllers gives more flexibility and enhanced control area to the controller. The Laplace transform of fractional order PI controller is given by the following equation [3].

$$G_c(s) = k_p + \frac{k_i}{s^{\lambda}} \quad (3)$$

The advantages of fractional order controllers over conventional controllers are, less sensitive to changes in the system parameters and availability of extra variables for better response.

6. Simulation diagram of power system

Converter Voltage	230KV
Frequency	60HZ
Converter Rating	100MVA
Converter Impedance [R(pu) L(pu)]	[0.44/30,0.22]
Converter initial current [Mag(pu).Ph(deg)]=	[50,35]
V_{ac} regulator gains[Kp.Ki.µ]	[1002000 0.7]
V_{dc} regulator gains [Kp.Ki]	[0.0001,0.0032]
Current regulator gains [Kp.Ki.Kf]	[0.3,19,0.33]

STATCOM parameters are shown in table

7. PSO

Particle swarm optimization (PSO) is a population based optimization method first proposed by Kennedy and Ebaerhart . Many popular algorithms are deterministic, like the gradient based algorithms. The PSO, similarly to the algorithms belonging to the evolutionary algorithm family, is a stochastic algorithm that does not need gradient information derived from the error function. This allows PSO to be used on functions where the gradient is either unavailable or computationally expensive to obtain. The PSO is a heuristic global optimization method, which is developed from swarm intelligence and based on the research of bird and fish flock movement behavior . Birds are searching for food from one place to another, there is always transmitting information so that they flock to the place where food can be found. The PSO algorithm is concerned, solution swarm is compared to the bird swarm, the birds moving from one place to another is equal to the development of the solution swarm, good information is equal to most optimist solution and the food resource is equal to the best optimist solution in entire course. The most optimist solution can be found in PSO by the mutual cooperation of each individual particle. Due to its many advantages including its simplicity and easy implementation, this
algorithm can be used widely to solve many complex engineering problems.The PSO algorithm is given in the algorithm.

Step(1): Generate n number of particles and assign velocities to each particle in the specified range.

Step(2):Calculate fitness function to each particle and based on that decide the global best value G_{best}'

Step(3): Update the iteration count and inertia weight.

Step (4):Using global best position individual best position update the velocity and position of each particle by the following equations

$$V_{i,itr+1} = w\,V_{i,itr} + c_1{*}r_1\,(P_{i,itr}^{best} - X_{i,itr}) + c_2{*}r_2(G_{i,itr}^{best} - X_{i,itr})$$

$$X_{i,itr+1} = X_{i,itr} + V_{i,itr+1}$$

Step(5): Each particle is evaluated and decide the globle best and individual best

Step(6): Update the velocities and positions till the stopping criterion is reached.

8. Simulation Results

Test Power System is simulated in MATLAB/Simulink. A three phase fault is applied at bus 4 for 6 cycles. Self-clearing fault is assumed in the present study. STATCOM is placed at bus 6,it is operated in VAR control mode. The reference voltage to the STATCOM controller is the steady state voltage of the bus. The initial conditions to the power network are applied by performing power flows by N-R method. Relative rotor angle of the second and third machine with respect to first machine are as shown fig(6) and fig(8). The FOPI controller parameters tuned by TLBO are shown in table [1]. The performance of the FOPI controller is compared with the integer order PI controller and fig (7) and fig(9) shows the relative rotor angle with integer order controller. It is observed that with the application fractional order controllers there is reduction in first swing of all the three generators. Low frequency power oscillation damping is observed to be more with FOPI controllers.

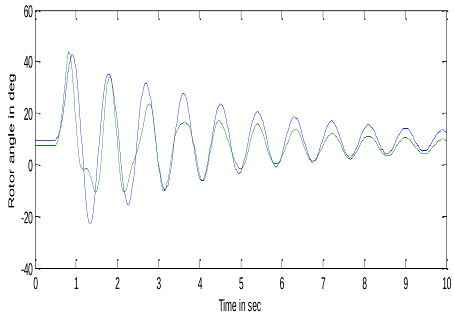


Fig (6): Relative rotor angles with Integer order PI controller

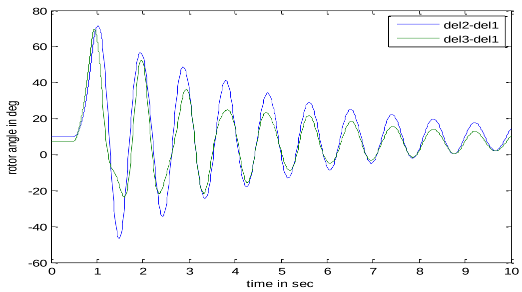


Fig (7): Relative rotor angles with Integer order FOPI controller.

When Fault is applied at bus 9 and STATCOM is placed at bus 6,the following are the relative rotor angles of the second and third machines with respect to first machine.

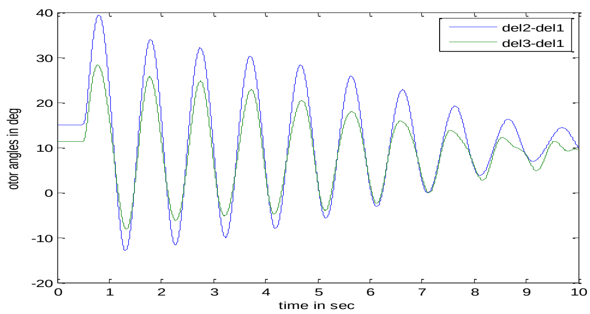
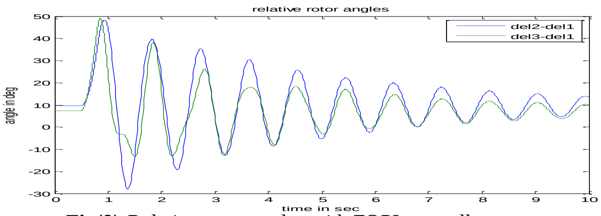


Fig (8): Relative rotor angles with Integer order PI controller.



Fig(9): Relative rotor angles with FOPI controller.

The figures show the relative rotor angles of second and third generators with respect to first generator. Both Integer order

and Fractional order controller gains are tuned by PSO. It is observed from the results that the FOPI controlled STATCOM has better performance compared to Integer order controlled STATCOM. The reduction in first swing of the generators clearly emphasis the improvement of stability margin and settling time is also considerably reduced. The optimal gains of the controller for integer order and fractional order controllers are as shown in the following table

	FOPI	IOPI
K_p	0.002	0.0012
K_I	0.034	0.023
λ	0.4	----

9. Conclusion

In this paper, FOPI controlled STATCOM is applied to WSSC-3 machine, 9-bus test system. The performance of the proposed FOPI controller is compared with Integer order controller and it is concluded that FOPI has better damping characteristics. The gains of the both IOPI and FOPI controller are tuned by a new optimization algorithm PSO. It is observed that with fractional order controlled STATCOM; there is reduction of first swing of all the generators which shows the improvement of transient stability. The settling time is also improved with the application of FOPI controllers. Hence it is concluded that shunt compensation not only improves the voltage profile of the power system but also aids for power oscillation damping.

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