POWER SYSTEM STABLITY IMPROVEMENT OF MULTIMACHINE SYSTEM USING PSO TUNED SSSC CONTROLLER

[1]Kapil Parikh, [2]Raunak Jangid, [3]Sagar Trivedi, [4]Saurabh Singh Gaur

Assistant Professor, SITE Nathdwara

Abstract**:** : Today power system stability is the major issue. FACTS devices play a very important role of stability consideration. In this paper we develop the model of multi-machine power system with FACTs controller is developed in MATLAB/SIMULINK. We use Static Synchronous Series Compensator (SSSC) due to high speed changes its reactance characteristic inductive to capacitive, is effective power flow controller. Tuning process of controller parameter can be performed using a different method. The optimal parameters for the proposed controller are obtained using particle swarm optimization (PSO) and genetic algorithm (GA). We compare two situations as an inter-area mode of oscillation and line power flow in the multi-machine system with 5 cycles self-clearing disturbance like 3-phase, L-L, L-L-G, L-G fault at PSO and GA technique. The simulation results obtainable through various graphs validated that PSO optimized SSSC damping controller is better than GA optimized SSSC controller. So PSO optimized SSSC damping controller reduces frequency oscillation accurately and therefore enhances the system stability.

Key Word***: PSO, GA, POD, FOD, SSSC, FACTS***

I. INTRODUCTION

Now a day the demand for the electricity is increase day by day. The demand of the electricity is growing and market scenario for electricity has administered to the heavily stressed power system. Due to increase in demand for electrical energy consumption the electrical power plant to give a high quality of electrical power. In order to increase the power transfer a new technology based on power electronic named as FACTS is getting used. The pliability electrical of electrical power transmission is that the ability to accommodate within the electric gear or operational condition whereas maintaining adequate steady state and transient limits. Versatile AC gear is outlined as "A power electronic primarily based system and alternative static instrumentation that offer management of 1 or additional AC gear parameters to boost controllability and increase power transfer capability" [1]. The facility flow could be a perform of the electrical resistance of the line, the amplitude of the transmit and receive finish voltages, and therefore the point in time between the voltages.By dominant one or a mixture of the facility flow arrangements, it's doable to manage the active power flow furthermore because the reactive power within the line.FACTS technology parades new potentialities to manage power and improve the usable capability of existing, new and improved lines. These capabilities square measure the results of the power of FACTS controllers to manage contiguous parameters that govern the operation of transmission systems as well as serial electrical resistance, shunt electrical resistance, current, voltage, point in time, and attenuation of oscillations. completely different FACTS technology reminiscent of SVC, STATCOM, SSSC, UPFC etc., bus voltages, line impedances and section angles within the facility are often adjusted quickly and flexibly. Therefore, FACTS will facilitate power flow management, improve power transfer capability, lower production prices, and improve the protection and stability of the energy system. The Static Synchronous Series Compensator (SSSC) is one in every of the foremost wide used FACTS controllers that's put in nonparallel with a line. The SSSC will effectively management power flow in one line thanks to its ability to vary its inductive to electrical phenomenon electrical phenomenon characteristics. The utilization of the SSSC controller for frequency stabilization, stability sweetening and power swing damping are often seen in several references. The impact of the mode of operation, i.e inductive or electrical phenomenon conjointly the degree of compensation by the SSSC on stability has also been cited in several references. Additionally to the present, with linear single-phase models, the controller behavior can't be known for unbalanced faults

Therefore, to solve this problem in this paper we have considered three phase models of several components of the power system and SSSC controller. Power system utilities prefer the classic time-shift structured controller because it offers many benefits, such as easy dynamic modeling, inline tuning and minimal effort for development. A large number of standard conventional methods are available for the design problem of controllers such as modern control theory, Eigen value assignment and mathematical programming. But these classic approaches have some problems as they consume a lot of time since the iterations are over, need a heavy computational burden and have a slow convergence. Conventional techniques also have possibilities that the search process can be limited to local minima and an optimal solution cannot be obtained. In recent years, particle grain optimization (PSO) technology has been preferred by researchers for optimization problems. PSO is mainly a stochastic optimization algorithm of population quota. The PSO algorithm is influenced by the social behavior of the schooling of birds in flocking birds[9]. PSO is similar to the genetic algorithm (GA) in many aspects like the initialization of the population and the search for the optimal solution by updating the population. But PSO does not use evolutionary operators like the mutation and the crossover that are used by GA. PSO offers many advantages over GA as a simple algorithm - can be easily implemented and it uses few parameters. In the present thesis work PSO is used for optimization of SSSC-based controller parameters.

II. FOD, POD Controllers

The voltage reference supplied by the SSSC is normally set by a POD (Power Oscillation Damping) controller whose output is connected to the input V_{qref} of the SSSC. The POD controller consists of a general gain, a low-pass filter, a high-pass filter, a line compensator and an output limiter. The input of the POD controller is the supply of L2 the POD structure is shown in fig.1

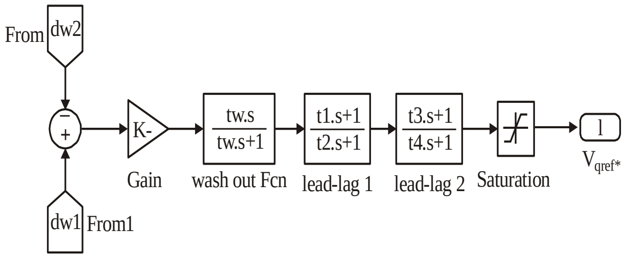

Fig. 1 POD Controller Structure

But the POD controller as shown in later sections cannot capture frequency oscillation. Therefore, FOD controller is another suggestion to adjust V

Its structure consists of a gain block with KS gain, a signal wash block and a two-stage phase compensation block, as shown in fig. From the viewpoint of the washing function, the value of tw is not critical and can be in the range of 1 to 20 seconds. The phase compensation blocks (time constants t1, t2 and t3, t4) compensate for the phase delay between the input signals and the output signals. The inputs of the FOD controller are the speed deviations of Zone 1 and Zone 2 as shown in Figure 2

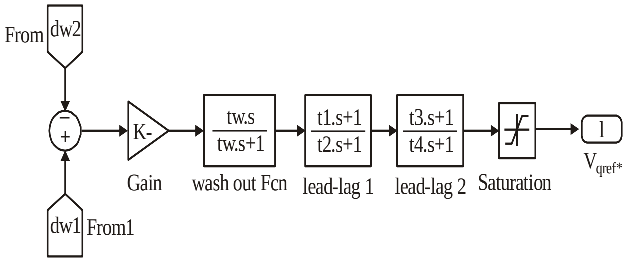

Fig.2 FOD Controller Structure

FOD controller can damp out frequency oscillation, but cause power oscillation damp later than POD controller. So it is necessary reconciliation between FOD and POD performance.

III. Problem Formulation

The minimization of one or all of the above deviations could be chosen as the target. In the FOD control, an absolute integer time error of the speed deviations as an objective function is expressed as follows:

$$FT = \int_{t=0}^{t=t_{sim}} [|w_1 - w_2|].tdt = \int_{t=0}^{t=tsim} [|\Delta w|].tdt \tag{1}$$

FT= Fitness Function

w_1=Area1 speed ,rad/s

w_2= Area2 speed ,rad/s

Δw= Speed difference, rad/s

t_{sim}= Simulation time,s

Minimize J subjected to

$$K^{min} \leq K \leq K^{max} \tag{2}$$

$$T_1^{min} \leq T_1 \leq T_1^{max} \tag{3}$$

$$T_3^{min} \leq T_3 \leq T_3^{max} \tag{4}$$

The above mentioned parameters of SSSC damping controller are optimized using PSO and GA algorithm.

IV. The Power System under Study

A. Power System Characterize

For the construction and optimization of the SSSC-based damping controller, a two-machine system with SSSC in Fig. 3 applies. The system consists of two generators, which are subdivided into two subsystems and are interconnected via intertie. Area 1 has a rating of 2100 MVA consisting of 6 machines of 350 MVA. Area 2 has a rating of 1400 MVA consisting of 4 machines of 350 MVA. The load center has about 2200 MW of consuming capacity modeled with a dynamic load model where the active and reactive power absorbed by the load is a function of the system voltage.

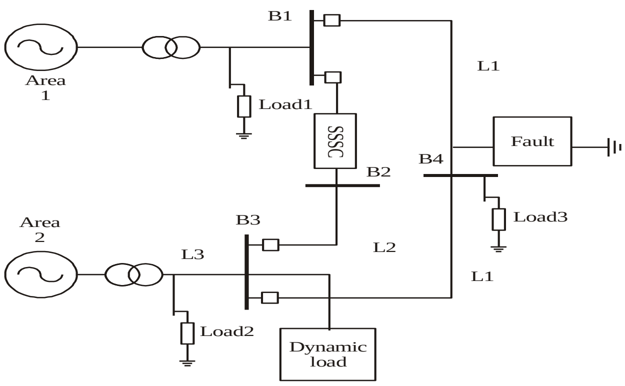

Fig. 3: Two Machine Power System with SSSC

The area 1 is connected to this load by two paths. L2 is 280 km and L1 is 150 km. The area 2 is also connected to the load by a 50 km line (L3). When the SSSC is bypass, the power flow towards the load center is as follow: 664 MW flow on L2, 563 MW flow on L1. The SSSC which is located at B1 is in series with line L2. Fault box is used to implementation three phase short circuit condition. Since the mentioned fault is the worst fault. Type, if a controller can damp out the power and frequency oscillation, the controller is proper in present of other fault. Therefore three phase short circuit is used in simulation process[2].

B. Overview of SSSC and its Control System

SSSC was proposed by Gyugyi in 1989 within the concept of using converter-based technology uniformly for shunt and series compensation as well as for transmission angle control. The concept of using the SSSC for series reactive compensation is based on the fact that SSSC injects an ac voltage with the controllable magnitude and angle into the transmission line by being independent of the line current so it can rapidly change the effective reactance between the two ends of the transmission line and the power flow, whereas the compensating voltage is dependent on the line current in the series capacitor compensation case. The injected voltage (Vq) is in quadrature with the line current I, and emulates an inductive or a capacitive reactance so as to influence the power flow in the transmission lines. Power transmission without SSSC is expressed in 5[1].

Additional statement resulting from SSSC presentation can be negative or positive due to happened condition to stabilize power flow and frequency deviation. In other words, injected voltage changes the stability level. Supplementary description about SSSC structure and its control technique is brought in.

V. Particle Swarm Optimization Technique

Particle Swarm Optimization Technique was developed in 1995 by James Kennedy (Social-Psychologist) and Russell Eberhart (Electrical Engineer) whose inspiration was social behavior of fish schooling or bird flocking. Each particle in search space adjusts its “flying” according to its own flying experience as well as the flying experience of other particles The PSO Uses a number of particles that constitute a swarm moving around in the search space looking for the best solution. PSO is a robust stochastic optimization technique based on the movement and intelligence of swarms.

In PSO, the current optimum particles and his potential solutions, known as particles, fly through problem space. The PSO technique conducts searches using a population of particles, corresponding to individuals. Each particle represents a candidate solution to problem at hand. In a PSO system particles change their positions by flying around in a multidimensional search space until a relatively unchanged position has been encountered or until computational limitations are exceed. In social science context, a PSO system combines a social only model and a cognition only model[10].

Operators of Particle Swarm Optimization

(i) Mutation

Mutation operators are an integral part of evolutionary computation techniques, relenting loss of diversity in a population of solution, which allows a greater reason of the search space to be covered. Like evolutionary computation techniques, that state the lack of population diversity in PSO algorithms is understood to be factor in their convergence in local minima. Therefore the addition of a mutation operator to PSO should enhance its global search capability and thus improve its performance. Mutation operation have been added a PSO to improve its performance.

(ii) Crossover

Therefore, the cross over operator defines the idea that the individual best position after updating crosses with the best one achieved according to fitness. Through crossover, there is a chance changing the global best position, and the algorithm may not be trapped in to local optima. On the other side, particles can make use of the other’s advantage by sharing information mechanism. The crossover just is carried out in one dimension that is randomly selected. In the meantime, the fitness of the best position is compared with two offspring produced by cross over operator. Then, we choose better one as the individual best position.

(iii) Recombination

Work on multi-parental recombination techniques showed that n-parental inheritance can be advantageous. Based on previous research work develop a multi-parental recombination operator for constructing the offspring population. It has been discovered the linkage configuration in order to make good use of the obtained information, it specifically a new design of recombination operator. Use this recombination process to generate the next population. By repeating the process, construct a new population in which each particle is composed of the building blocks.

A. PSO Flow Chart'

The fig. 4 below shows the flow chart of PSO technique.

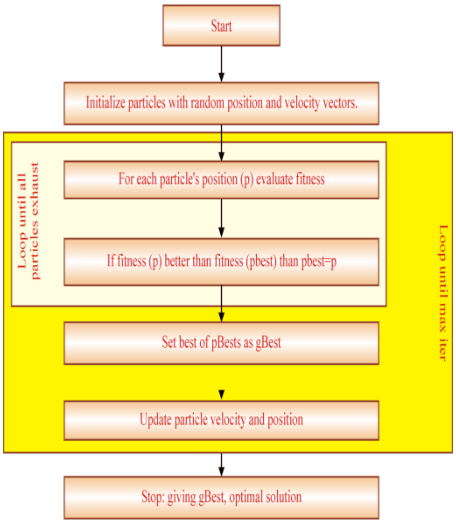

Fig. 4: Flow Diagram of Particle Swarm Optimization

VI. Genetic algorithm Optimization Technique

Genetic algorithm (GA) has recently found extensive applications to solve global optimize-tion search problems. They are useful when the technique in the form of closed optimization cannot be applied. Genetic algorithm analyze simultaneously from several points in the parameter space, so that it converges towards a more minimal overall solution. Genetic algorithm is heuristic research and optimization techniques that mimic the natural evolutionary process[5].

A. Basic Idea of the Genetic Algorithm (GA)

Like his kin in the group of transformative calculations, the genetic algorithm (GA) is a populace based met heuristic enhancement calculation motivated by characteristic organic advancement. The accompanying flowchart gives a review of the means taken by the calculation. The populace is made out of individuals who speak to conceivable answers for the issue to be explained and are normally randomized. An alleged physical capacity depicts the nature of the people and compares to the target work enhancement regularly. After the wellness has been surveyed, a choice of parent happens. These guardians can increase and create posterity, for example, making you a solitary cross after the offspring is changed.

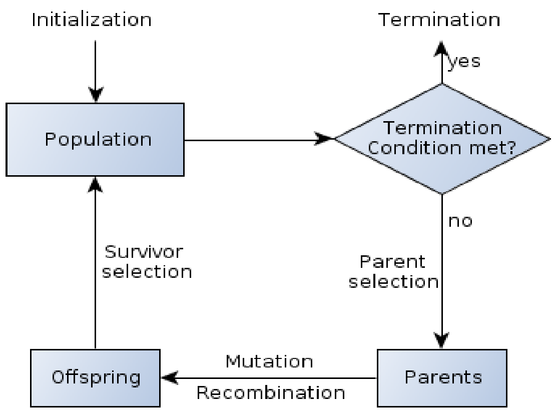

Fig.5. Basic Flow of GA

B. Working of Genetic Algorithm (GA)

A genetic algorithm (GA) is a probabilistic research system that mimics the way toward computing natural development. It impersonates development in nature, every now and again changing a populace of hopeful arrangements until an answer is found.

The GA-advancement cycle starts with an underlying irregular populace. Changes in the populace made by process of selection based on fitness and alteration using mutation and crossover. The utilization of selection and alteration change of results in a populace with a higher extent of improves solution. The developmental cycle proceeds until an adequate arrangement is found in the present generation of the populace or a controller parameter with the end goal that the quantity of generations is surpassed.

The littlest unit of a GA is known as gene denotes a unit of data in the issue zone. Various gene that are recognized as a chromosome means a conceivable answer for the issue. Every gene in the chromosome speaks to a segment of the setup of the arrangement. The most widely recognized type of the portrayal of an answer as a chromosome is a grouping of binary digits. Each bit in this string is a gene. The technique for changing over the arrangement from their one of unique form into the bit string is called coding.

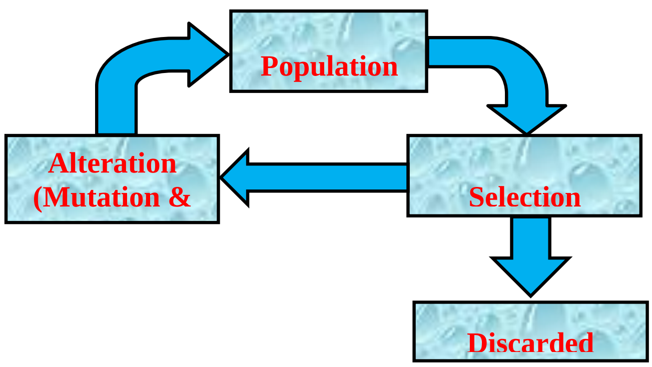

Fig.6 Genetic Algorithm Evolutionary Cycle

C. Selection

In natural advancement, just the most grounded and their hereditary legacy add to the making of the people to come. The decision of GA is additionally in view of a comparable procedure. In a typical type of selection, which is perceived as a corresponding choice of wellness, every chromosome opportunity to be chosen as tolerable, relative to their wellness esteem. Every person of the populace is appointed a piece of a roulette wheel. There are various other selection strategies accessible and it is up to the client to choose the privilege for each procedure. All choice techniques have comparable essential standards, the Fitter chromosomes is a more prominent probability of selection.

VII. Result Analysis & Discussion of PSO Tuned SSSC Controller in MATLAB / SIMULINK

The models have been designed using Sim power system toolbox of MATLAB / Simulink. Sim Power system is a widely used MATLAB based design tool used by engineers & scientists to build models and for simulation. The Sim power system tool consists of models of various equipments like machines, governors, transformers, excitation system, FACTS devices and transmission lines. It also consists of a powergui block which is required for simulation of a model having Sim power system blocks. The powergui block performs load flow & machine initialization.

VIII. Proposed MATLAB/SIMULINK Model Multi-machine System with SSSC Controller

To design and optimize the SSSC-based damping controller, a two machine system with SSSC shown in Fig.6 is considered. The system consist of two generator divided in two subsystem and are connected via intertie. Area 1 has rating of 2100 MVA that consist of 6 machines of 350 MVA. Area 2 has rating of 1400 MVA that consist of 4 machines of 350 MVA. The load center has approximately 2200 MW consuming capacity that is modeled using a dynamic load model where the active and reactive power absorbed by the load is a function of the system voltage. The area 1 is connected to this load by two paths. L2 is 280 km and L1 is 150 km. The area 2 is also connected to the load by a 50 km line (L3). When the SSSC is bypass, the power flow towards the load center is as follow: 664 MW flow on L2, 563 MW flow on L1. The SSSC which is located at B1 is in series with line L2. Fault box is used to implementation three phase short circuit condition. Since the mentioned fault is the worst fault. Type, if a controller can damp out the power and frequency oscillation, the controller is proper in present of other fault. Therefore three phase short circuit is used in simulation process[8].

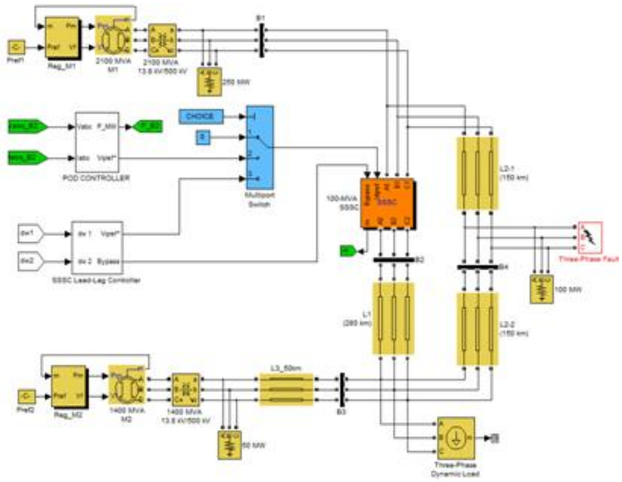

Fig. 7: MATLAB Model of Multi-machine System with SSSC Controller

Fig.7 shows the convergence of objective function for gbest in multi-machine system.

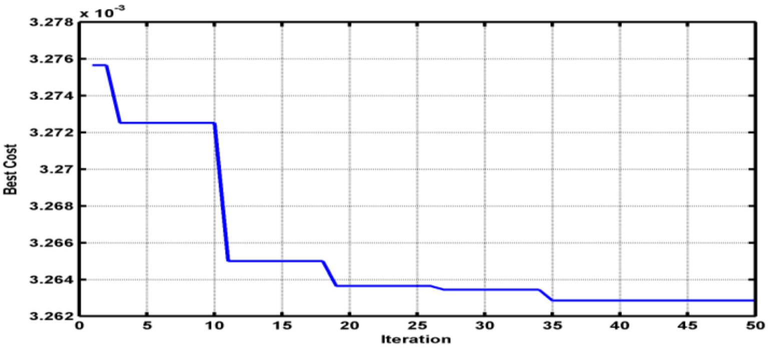

Fig. 8: Convergence of objective function for *gbest* in Multi-machine System

A. **Speed Deviation and Line Power Deviation in Two Machine System with 5-Cylce Self Clearing 3-Phase Fault**

In fig. 9 to 10 shows speed deviation and line power deviation in two machine system with 5-cylce self clearing 3-phase fault at with SSS controller tuned by GA and PSO technique. The effectiveness of SSSC tuned PSO give better result than GA.

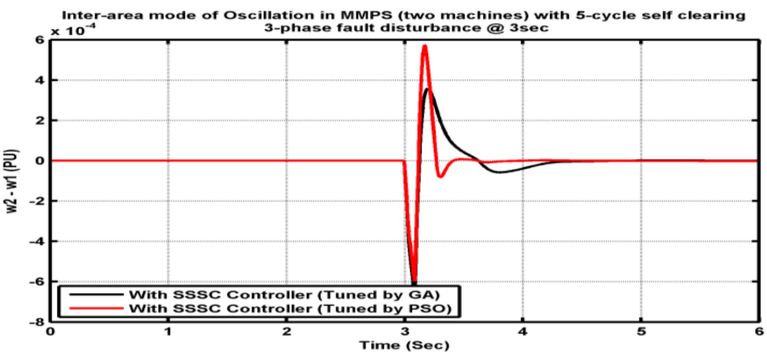

Fig.9 Speed Deviation of Two Machine System with 3-Phase Fault Disturbance

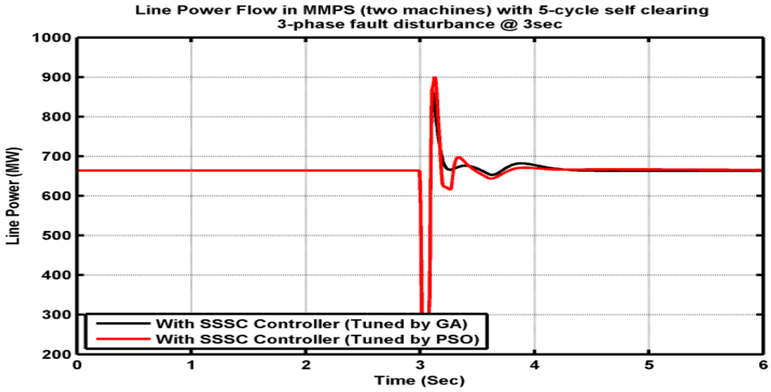

Fig.10 Line Power Deviation of Two Machine System with 3-Phase Fault Disturbance

B. **Speed Deviation and Line Power Deviation in Two Machine System with 5-Cylce Self Clearing L-G Fault**

In fig. 11 to 12 shows speed deviation and line power deviation in two machine system with 5-cylce self clearing L-G fault at with SSS controller tuned by GA and PSO technique. The effectiveness of SSSC tuned PSO give better result than GA.

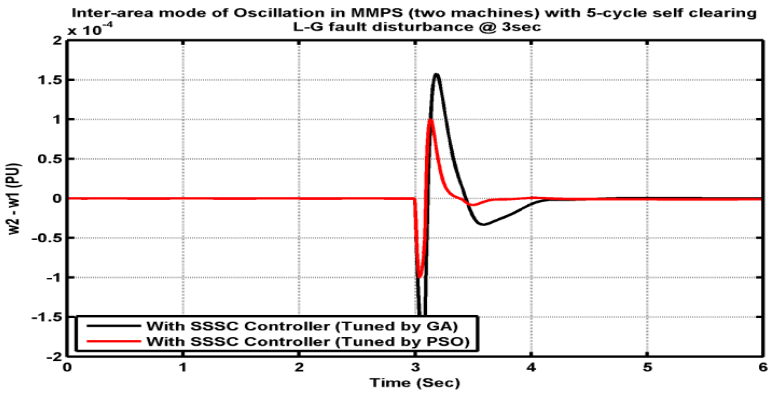

Fig.11 Speed Deviation of Two Machine System with L-G Fault Disturbance

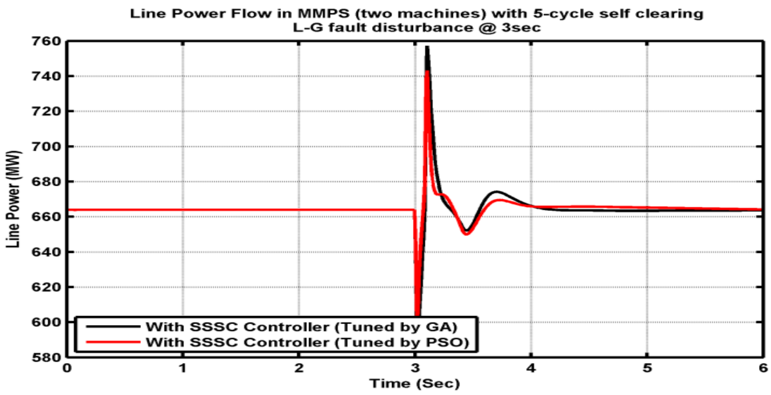

Fig.12 Line Power Deviation of Two Machine System with L-G Fault Disturbance

C. **Speed Deviation and Line Power Deviation in Two Machine System with 5-Cylce Self Clearing L-L Fault**

In fig. 13 to 14 shows speed deviation and line power deviation in two machine system with 5-cylce self Clearing L- L fault at with SSS controller tuned by GA and PSO technique. The effectiveness of SSSC tuned PSO give better result than GA.

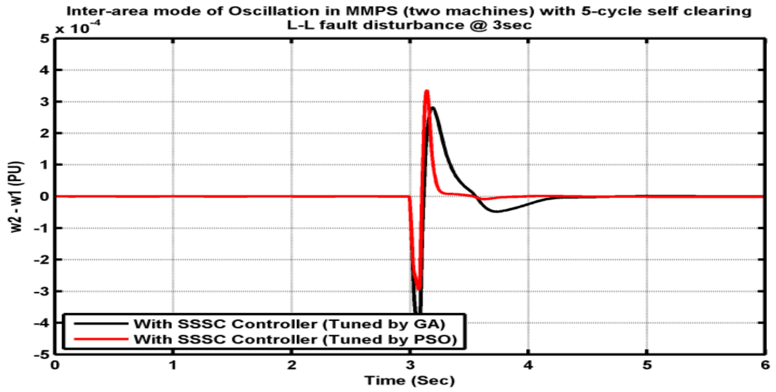

Fig.13 Speed Deviation of Two Machine System with L-L Fault Disturbance

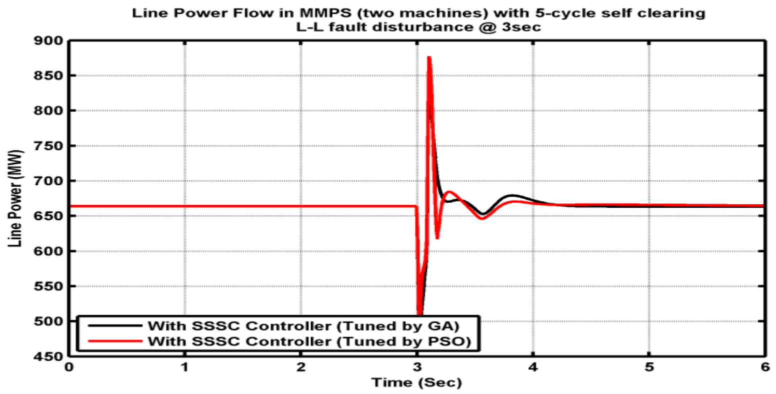

Fig.14 Line Power Deviation of Two Machine System with L-L Fault Disturbance

Table.1 Comparison FOD for 5-cycle at various Fault at PSO and GA Technique

S.NO	Fault Status Controller	**Fault**	Damp Time for Frequency Oscillation **(Settling time)**	Damp Time for Power Oscillation **(Settling Time)**
1.	FOD(SSSC tuned by GA)	3-Phase	4.1992	4.0987
	FOD(SSSC tuned by PSO)		3.3832	3.7277
2.	FOD(SSSC tuned by GA)	L-G	4.0786	4.0358
	FOD(SSSC tuned by PSO)		3.6213	4.5515
3.	FOD(SSSC tuned by GA)	L-L	4.1555	4.1317
	FOD(SSSC tuned by PSO)		3.6571	3.9494

The table1 prove result validation at multi-machine system. We tested result at various operating conditions viz. 5-cylce for various disturbances like 3-phase, L-L, L-G, L-L-G. We get better result when we apply PSO tuned SSSC controller .So System shows good time response (less settling time) when we apply with PSO tuned SSSC controller.

IX. Conclusion

In this paper, power system stability enhancement by PSO and GSA tuned SSSC controller is presented. An objective function based on simulation is developed to design lead-lag structured SSSC controller to achieve the oscillation damping two machine systems. Then, the PSO optimization technique is implemented to search for the optimal controller parameters. .POD and FOD damping controller is evaluated under various operating conditions viz. 5 cycle for various disturbances like 3-phase, L-L, L-L-G, L-G fault with the objective of minimizing the frequency oscillation & power oscillation damping . The simulation results presented through various graphs validated that PSO optimized SSSC damping controller reduces frequency oscillation properly the and therefore enhances the system stability.

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