Transient Stability Assessment by Coordinated Control of SVC and TCSC with Particle Swarm Optimization

Maulikkumar Pandya, J G Jamnani

Abstract: This paper aims on improving the stability of a 9 bus power system under fault condition using coordination of FACTS device. Flexible A.C. transmission system (FACTS) can be regulated reliable with faster output and can improve local power grid status with control with appropriate control strategies in very small time period. Based on that, a particle swarm optimization (PSO) algorithm was executed, to design the coordinated parameter of static VAR compensator (SVC) and Thyristor Controlled Series Capacitor (TCSC). Simulation is performed on WSCC 9-bus system in MATLAB software. When 3 phase fault is applied near to generator, frequency and rotor angle changes accordingly. With coordinated control of FACTS devices with PSO has implemented both, near to its normal condition. PSO performed in this paper was structured on identifying the values of L and C of SVC and TCSC, for superior coordination.

Index Terms: Static VAR Compensator, Thyristor controlled Series Capacitor, Particle swarm optimization, Coordination

I. INTRODUCTION

The conception of flexible A.C. transmission system (FACTS) have been achievable because of applications of high power electronic devices for power flow, voltage control and additionally enhancing the damping of power oscillation [1]. Power system stability of recent large interconnected system is examined as a key problem for secure work of whole system. It is important to mention that recent major shutdown across the nation prone to system instability, even in advanced as well as protected system, illuminating the issues dodging stable operation of electrical power systems [2]. Many researches have done to assess stability ot the powor system and later they enhanced it, specially transient stability which is deemed as one of the significant aspects that have to be taken into accounted in present-day power system. Number of techniques have been proposed to boost up the transient stability of current power system, which includes Flexible AC Transmission systems (FACTS), and distributed generation units (DG) For improvement in operation of power system. Much type of interactions are possible among various type of FACTS controllers. It is classified on basis of distinct values of frequency. The label coordination [14] doesn't mean a centralized control but it is understood that the tuning of the FACTS controllers will be done together for ensuring the promising, pragmatic improvement of the overall control scheme. It is recommended that one and all controller depend primarily with measurement of current useable quantity. It will act individually on connected FACTS devices [7]. Voltage, frequency, and rotor angle transformation has been discussed in [3], with help of 9-Bus, three generator system, dynamic stability study has also discussed and simulated to test the performance of the system that was already exist. Voltage stability assessment is done by calculation of voltage stability margin (VSM) in [4] by modeling effects of PSS and governor on voltage stability of power system by applied accurate dynamic model of power system. 7-machine CIGRE system has been considered as a case study in [5]. MATLAB package has been employed to implement this study. The simulation results show that the transient stability of the respective system enhanced considerably with available techniques. Voltage stability assessment with appropriate representation of SVC and TCSC is investigated and it is also compare in 6-bus system [13].

II. SVC AND TCSC

Static var compensators (SVCs) are part of the flexible alternating current transmission systems (FACTS) device group. Their main aim is to supply a fast acting, crisp and altered amount of reactive power to the system to which they are connected like in fig. (1). SVCs [8] achieve this by switching in or out one or more thyristor switched capacitors (TSC), and by balancing the firing angle of thyristor controlled reactor (TCR). Some SVC are also comprises a number of fixed capacitors (FC) which supply a steady amount of reactive power.

SVCs are used for voltage compensation [at the receiver end of ac transmission lines], so it replaces shunt capacitor banks. When it is used for this aim, SVC is offering numerous advantage over shunt capacitor bank, like much tighter command of given voltage compensation [11] at the receiving end of AC transmission line and increases stability of the line during load variations. SVCs will improve power factor of whole system, curtail the voltage fluctuation at the system inlet and reduce the plant's operating costs.

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Maulikkumar Pandya, Department of Electrical Engg., Kadi Sarva Vishwavidhyalaya, Gandhinagar, Gujarat, India.

Dr J G Jamnani, Department of Electrical Engg., Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India.

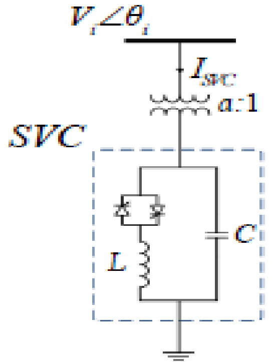

Fig. 1 Firing angle mode of SVC

TCSC configurations as per fig. (2) comprises of controlled reactors side by side with segments of capacitor bank. This duo will allow effortless control of the fundamental frequency capacitive reactance over a wide range. The capacitor bank of each phase is placed on a policy to enable full insulation to ground. The thyristor valve contains a string of series connected high power thyristors. The inductor is of air-core design. A metal oxide varistor (MOV) is covered across the capacitor to block overvoltage.

TCSC [15] brings a number of significant merits in the solicitation of series compensations as; Removal of sub-synchronous resonance hazard, damping of active power oscillation, contingensy stability development after fault, Dynamic power flow control etc. Oscillations of active power in power transmission system may occur in arcades between generating areas because of poor damping of the interconnection, particularly during heavy power transformation [9]. TCSC will become an appealing substitute to examine. It will offer cost affective, sturdy power oscillations damping out, insensitive to their locations in that system and no interaction in between local oscillation modes. In many cases, it becomes effective to be the best practicable solution.

The TCSC have a powerful meaning of commending and expanding power transfer level of the system by differencing remarkable impedance of the said transmission line. A TCSC can be utilized in priliminary way for contingency to escalate power system stability [16].

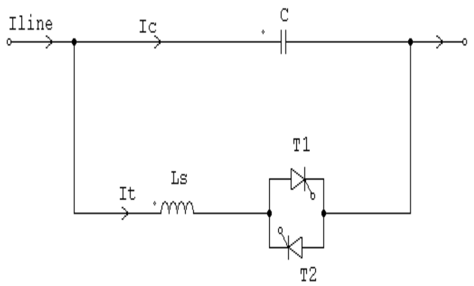

Fig. 2 Layout of TCSC

III. POWER SYSTEM STABILITY

Due to environment issues on the extension of the transmission capacity, increased electricity consumption and novel economic constraint imposed by the restricted power market, power system is operated closer and closer to their stability limit. During normal operation, focus is an economic optimization of system operation, while during more challenging network conditions the focus shifts to stability consideration rather than economy. It is vital to give top priority to dynamic stability before other parameters like optimal load flow, economical operation and fair deregulation in power system. The severity of transients is classified based on the rate at which the wave rises from 10% of its value to 90%. Class A type of transients are known as ultrafast transients and categorized as suge phenomena. Class B type transients are medium fast and due to short circuit phenomena, while class C represents slow transients which comes the under category of transient stability varying in time range of few seconds to few minutes. The major are: Angular or Rotor angle stability, Voltage Stability [7] [13] and frequency stability.

Analysis of stability [12], including key factors that contribute to instability and devising methods of improving steady functioning is greatly facilitate with the classifications of stability into various categories. Transient stability [10] is defined to come again to stable operating condition, subjected to any unforeseen problem in power system. However, system's stability cannot be guaranteed even after fault clearance, as total clearing time will decide the system behavior in post fault region. With recent advancements in powor electronics and especially Thyristor technology, FACTS devices have a key role in power system performance improvement. These FACTS devices are used not only in transient stability improvement but also used in normal healthy operation to improve power transfer capability, voltage profile, security etc.

IV. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is a sturdy technical optimization technique, which is based on the motion as well as inteligence of swarm. PSO [6] appeals to the intension of social interaction to solve the problem, which is polished 1995 by psychologist James Kennedy and an electrical engineer Russell Eberhart [17]. PSO arrives with compliant & smooth adjustable mechanism to increase the global and local expedition capacity. In PSO, each of the particle tries to improve themself by imitating traits from their successful peers. Proceeding, each particle has a memory and so it is capable of remembering the best position in the search space ever visited by it. The position corresponding to the best fitness is known as p_{best} and the overall best out of all the particles in the population is called g_{best}. Altered velocity and position of each particle can be calculated using current velocity and the distance from the p_{best} to g_{best} is according to given equation:

$$Vi = w v_i^k + c_1 rand_{1(...)} \times \left(p_{best} - s_i^k\right) + c_2 rand_{2(...)} \times \left(g_{best} - s_i^k\right) \quad (1)$$

Number of iteration was conducted to get smooth voltage profile. The optimization issue considered at this occasion is to reduce the cost as well as stability criterion. Attention in this optimization problem is to handle voltage magnitude as a fitness function in the issue.

Table 1: PSO Parameters

Total Particle	10
Maximum Inertia weight	0.9
Minimum Inertia weight	0.4
C_1 and C_2	0.5 and 3.5
Number of iteration	10

As new features in optimization process arriving, function of normal PSO is different compare to Genetic Algorithm [18] & it was observed that PSO appear [19] with its terminal parameter value in very less no. of generation than genetic. Comparison with GA, PSO was gentle to enact and it contains very less variable to adapt [20]. All particles in process are kept as a fellow of society through the course of procedure. PSO is the single algorithm which will not execute the existent of the fitness. Also, PSO came with various variant like discrete PSO, MNLP PSO, hybrid PSO etc. Normal PSO has disadvantage of the short of convergence directed to global optima.

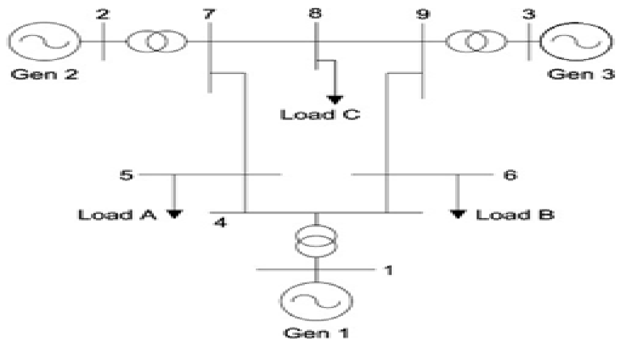

Fig. 3 WSCC 9-Bus system

V. Problem Definition & Simulation

In order to work out with coordinated control, [16] 9-bus system is adopted as a problem definition, which is shown in fig. (3). All information and values related to this system is according to [21]. As per Fig. 3 Bus no.s are figured as 1,2,…,9. Load flow analysis for SVC and TCSC realization is carried out, by using Matlab. Basically, system rating of taken SVC and TCSC may be calculated with different sizing method [22] . As the system is consisting of three generator buses, we will apply a fault near to Bus-2 and Bus-3. Based on this we also place FACTS devices near to. Accordingly when fault takes place near to generator 2, SVC has been placed at line 5-7 and TCSC is in between bus-2 and bus-3. Similarly, to see the effect of coordination at other bus, will make a fault near to generator 3 and gain TCSC is in between bus-2 and bus-3.These are preliminary selection for problem formulation.

With identification of problem, PSO algorithm is exploited for rectification of data of SVC & TCSC controller coordinately with help of eq.(1). As normal PSO has a disadvantage of its inadequate convergence towards global optima, PSO implemented here is built on finding the values of L and C of SVC and TCSC respectively. Same PSO which is for coordination purpose, is taken with some modification, like change in PSO range and number; with a change as selection procedure for particles and control technique, with reference to normalize PSO. According to PSO algorism, primarily we will set the values of L, C, L1, and C1 from input variables. Objective function of PSO here will be maintenance of voltage magnitude within limits i.e. from 0.95 pu to 1.05 pu. So here coordinated controller parameters of PSO will be L, C, L1 and C1 of SVC and TCSC, for coordinated control. When simulation completes, we have to check the Voltage Difference with Value equal to 1 pu. Same will provide us for other parameters like voltage stability, generator parameters and frequency stability to be within limits.

VI. Results and Discussion

The verification for system's projected coordinated control is carried out as per discussion in section V. Where, SVC installed near to bus-2 i.e. line 5-7 and TCSC in between line 6-9. Besides, between transmission lines 8-9, TCSC is connected. Now, we have made a three phase line to ground fault at Bus-2 and Bus-3, which is simulated for 300 ms. By observing, it is seen that fault has occurred at 0.04 sec and it is vanishes in 0.10 sec. As a result, according to fig. (4) and (5), stability of the generator is improving using SVC and TCSC coordination except single SVC and TCSC.. Fig. (4) shows the result of electrical power exchanged at Bus-2 in terms of stability. Similarly fig. (5) shows the same result for Bus-3.

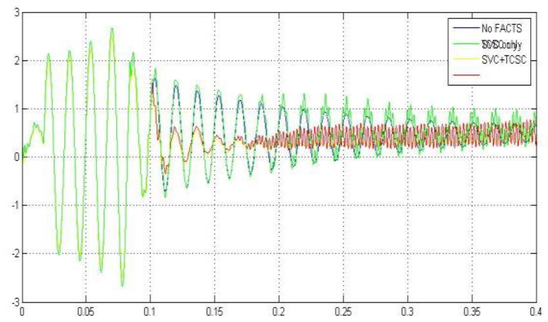

Fig. 4 Stability of P_e at Gen3

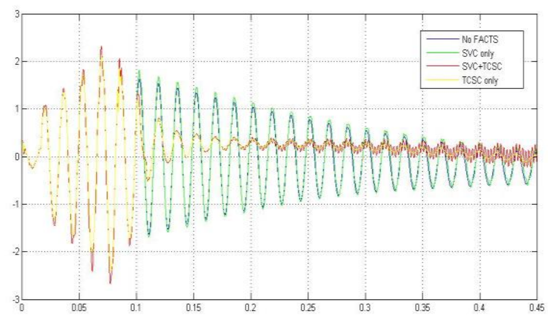

Fig. 5 Stability of P_e at Gen 2

Fig. (6) and (7) shows result of rotor angle deviation at gen 2 and gen 3. It can be seen that Oscillation has been damped out at 0.15 sec. Fig. (8) and (9) shows the load angle at gen 2 and gen 3 respectively. Load angle has been resulted as within limit and system is getting stable at 0.08 sec, which shows that transient stability of the system has been improved.

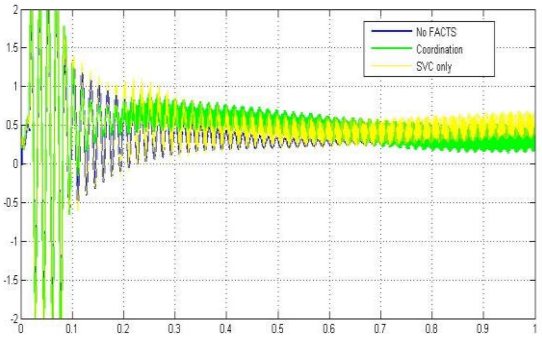

Fig. 6 Rotor angle deviation at Gen 3

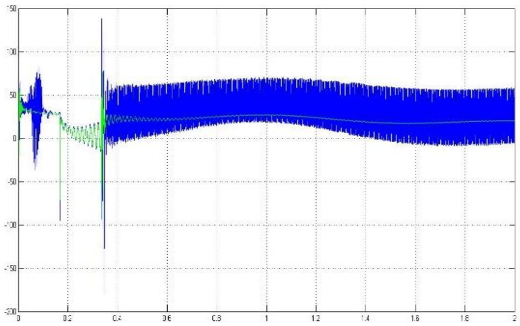

Fig. 7 Rotor angle deviation at Gen 3

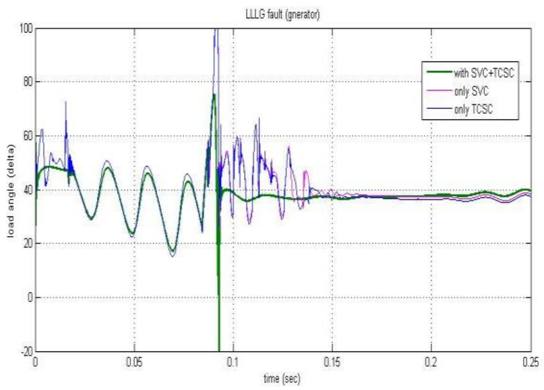

Fig. 8 Load angle deviation at Gen 2

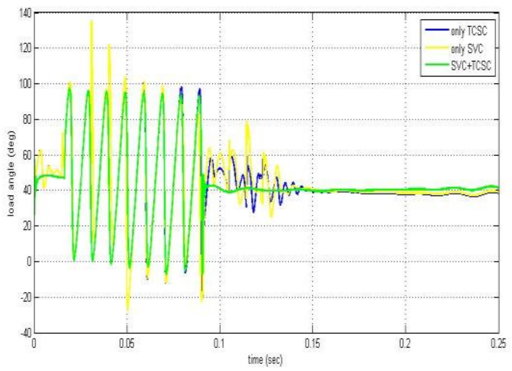

Fig. 9 Load angle variation at Gen 3

The noticeable approach here is that SVC and TCSC coordinated control is having fine outcome than single SVC or TCSC. On the same note, for the Voltage profile, it is improved according to its objective function, by using coordinated control.

VII. CONCLUSION

The information presented in this provides stimulating thought on result of coordination. Their separate contribution in stability improvement has experimented on a 9-bus system. An actual tuning optimize the parameter of the controllers. In addition, a result of simulation is precisely demonstrating that stability is successfully improved with coordinated control . Oscillation of the generator is reduced appreciably when connecting both TCSC and SVC together. However, the oscillation of the generator is not reduced when connecting the TCSC and SVC individually. This approach is also supported by congruence of valid location of FACTS device. In final words, suitable co-ordination of FACTS devices can be productive for power system performance.

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AUTHORS PROFILE

Maulikkumar pandya received B.E (Electrical Engineering) degree from North Gujarat University in 2006, M.E (Electrical Power system) from BVM, S P University, respectively. He is currently working toward the Ph.D degree at Kadi Sarva Vishwavidhyalaya. He has over 12 years of teaching experience. His areas of interest includes Power system modeling and simulation, FACTS devices, Operational amplifiers, Electrical Machines and circuits & networks. He has Published 24 papers in National/International conferences/Journals. He is a member of IEEE and life member of ISTE.

Dr. J. G. Jamnani is working as Associate Professor and Head in the Department of Electrical Engineering at PDPU, Gandhinagar since Oct-2013. He received his M.Tech. degree in 2002 from IIT, Roorkee in Power system. He has done Ph.D. from M. S. University, Vadodaraa. He has over 25 years of teaching experience and also 2 years of Industry experience. His areas of interest include Electrical Power system, High Voltage Engineering and Electrical Machines. He has published more than 35 papers in National/International conferences/Journals and completed many consultancy projects for Industry. He has published 8 books with ISBN number for various subjects in Electrical Engineering. He is a life member of ISTE and member of IEEE.

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