International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 8, August - 2013

Allocation of FACTS Devices For Congestion Relief Using Particle Swarm Optimization

Ajilly Ann John
PG Scholar
Electrical and Electronics Department
Saintgits College of Engineering

Asst.Prof.Tibin Joseph
Electrical and Electronics Department
Saintgits College of Engineering
Kottayam,India

Prof.Sasidharan Sreedharan
Electrical and Electronics Department
Vidya Academy of Science and Technology
Thrissur,India

Abstract

Electric power systems are exposed to various contingencies. Network contingencies often contribute to overloading of branches, violation of voltages and leading to problems of stability. One of the major operating challenges in the power system is to manage the transmission system congestion to ensure its secure operation. FACTS devices are used to reduce the flows in heavily loaded lines and thereby eliminating the chances for congestion in transmission lines. This paper presents a method for finding an optimal location for Thyristor Controlled Series Compensator (TCSC) and Static Var Compensator(SVC).

Particle swarm optimization algorithm is used to find the optimal location of the device. It minimizes the real power loss and voltage deviations to ensure the voltage security of the power system. The effectiveness of the proposed method is tested for IEEE 14 bus system using MATLAB/PSAT software.

1.Introduction

Increase in load demand, changes in generator sources and changes in plant sizes will result in uncertainity of transactions. Power flow in lines and transformers should not be allowed to exceed a particular level. But the increased transactions may lead to the operation of power system closer to the operating limit and result in congestion. To relieve the congestion mainly two types of techniques used. Cost free means such as outageing of congested lines, operation of transformer taps and operation of FACTS devices. Non cost free means are re-dispatching of generation amounts and load curtailment.

Operation of FACTS devices are utilized as the technology which reduces the congestion. FACTS devices are solid state converters that have the capability of control of various electrical parameters in transmission networks. FACTS devices include Thyristor Controlled Series Compensator(TCSC), Static Var Compensator(SVC), Unified Power Flow Controller(UPFC), Static Compensator(STATCOM) etc[5]. FACTS devices can control the line reactance, bus voltage and line active and reactive power flows. Therefore the FACTS devices are used to increase the capacity over existing transmission lines by proper power flow control over designed corridors and to provide voltage support in the network [3].

A priority list method based on locational marginal prices (LMPs) has been proposed in [4] for TCSC allocation. A decision tree method has been proposed to identify critical transmission lines for optimal allocation of TCSC to maximize loadability[6]. SVCs make it possible to enhance the functioning of a transmission network by increasing significantly its loading margin using Benders decomposition in [10].In [7], an overload sensitivity factor is used for optimal location of series FACTS devices for congestion management. A loss sensitivity factor method is used in [8] to determine the location for FACTS devices.

FACTS devices could be connected either in series or in shunt with the power system or even in a combined pattern to provide compensation for the power system. Variable series capacitors, phase shifters and unified power flow controllers as the most used FACTS devices can be utilized to change the power flow which result in many benefits like losses reduced, stability margin increased etc. Due to such features of FACTS, integrating it into the congestion management becomes more and more popular. the insertion of FACTS devices is found to be highly effective in maintaining voltage stability [14]. However, the benefits and performance of FACTS controllers are determined by their location and size [15].Owing to high cost, the number of FACTS devices to be used should be minimized and their benefits may be maximized through efficient optimization methods [14].

The changes that occurs in network due to contingencies will cause increase in load demand in the system causing voltage collapse. The reactive power flows in the system also differs widely under different contingencies. The steady state transmittable power can be increased and the voltage level along line controlled by appropriate reactive shunt compensation. The voltages at buses fall below the specified lower limit during heavy load conditions and the voltage may exceed upper limit during light load conditions. FACTS devices can be used to maintain the voltage within limits and also it can minimize the active power losses.

Population based co-operative and competitive stochastic search algorithms are very popular in the recent years in the research area of computational intelligence. The particle swarm intelligence algorithm is introduced by Kennedy and Eberhart [11],[12].PSO is applied for solving various optimization problems in electrical engineering. PSO algorithm begins by initializing a random swarm of particles each having unknown parameters to be optimized. In each iteration the fitness of each particle is evaluated according to the selected fitness function. The algorithm stores and progressively replaces the best fit parameters of each particle as well as a single most fit particle among all the particles in the group.

In this paper, identification of optimal location for placement of TCSC and SVC in IEEE 14 bus system is carried out. An optimization problem is formulated and by using PSO optimal solution is obtained. The problem is formulated considering the minimization of real power losses. The section two explains about FACTS device used and problem formulation in section three. In section four the PSO algorithm is presented in detail. The results and discussions are presented in section five. Finally conclusions are summarized in section six.

2.FACTS devices modelling

2.1. Modelling of Thyristor Controlled Series Compensator(TCSC)

The TCSC is a series compensation component which consists of a series capacitor bank shunted by Thyristor controlled reactor as shown in figure. 1.

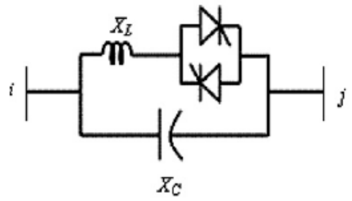

Figure 1.TCSC basic structure

The power flow control with the TCSC is used to decrease or increase the overall lines effective series transmission impedance, by adding a capacitive or inductive reactive correspondingly. The TCSC is modeled as variable impedance as in figure 2. Figure 2 shows a model of transmission line with one TCSC which is connected between bus-i and bus-j.

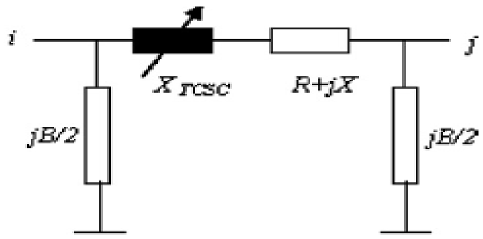

Figure 2. TCSC model

After installing TCSC, the new reactance of line is presented by equation(1).

$$X_{ij}=(1+k)X \qquad (1)$$

where X is the transmission line reactance and k is the level of reactance compensation.

2.2.Modelling of Static Var Compensator

A Static Var Compensator(SVC) is a shunt compensator that have both inductive and capacitive nature. It absorbs reactive power due to its inductive nature and injects reactive power due to its capacitive nature[2]. It is connected in parallel with bus and if the bus voltage falls below lower limit then SVC acts as a capacitor and generates reactive power. If the bus voltage exceeds the upper limit then SVC acts as an inductor and absorb reactive power.

The SVC consists of a series capacitor bank shunted by Thyristor Controlled Reactor as shown in figure 3. SVC is modeled as a variable admittance. The reactive power provided is limited as equation (2).

$$b_{SVCmin} \leq b_{SVC} \leq b_{SVCmax} \qquad (2)$$

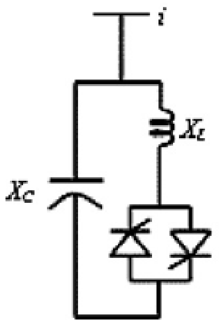

Figure 3.SVC basic structure

The active and reactive power value of an SVC from the injected power equations is:

$$P_i=0 \qquad (3)$$

$$Q_i=V_i^2 b_t \qquad (4)$$

where P_i and Q_i are injected real and reactive power to bus i respectively and V_i is the voltage at bus i at which an SVC is shunted.
The total susceptance with SVC shunted at bus i is:

$$b_t=b_i+b_{svc} \qquad (5)$$

The rating of SVC at bus i is obtained by using (4).

3. Problem Formulation

3.1. Objective Function and Constraints

During contingencies ,voltage variations occur and this can be eliminated by proper placement of FACTS devices. So the objective function is to minimize the real power losses and voltage variation by optimally locating the FACTS devices. The objective function is

$$F=\sum_{n=1}^{nl} P_{Ln} \qquad (6)$$

where

F - Objective function

P_{Ln} - Active power loss at n^{th} line

subjected to the equality constraints

$$\sum P_{Gi}=\sum P_{Di}+P_L \qquad (7)$$

where

$\sum P_{Gi}$ - Total power generation at bus i

$\sum P_{Di}$ - Total power demand at bus i

P_L - Losses in the transmission network

$$P_i=P_{Gi}-P_{Di}-\sum_{j=1}^{N_b} V_i V_j Y_{ij} Cos(\delta_i-\delta_j-\theta_{ij}) \qquad (8)$$

$$Q_i=Q_{Gi}-Q_{Di}-\sum_{j=1}^{N_b} V_i V_j Y_{ij} Sin(\delta_i-\delta_j-\theta_{ij}) \qquad (9)$$

where

P_i -Real power injected at bus i

Q_i - Reactive power injected at bus i

and the inequality constraints are,

Apparent power flow limit:

$$S_{ij} \leq S_{ijmax} \qquad (10)$$

Bus voltage limit:

$$V_{imin} \leq V_i \leq V_{imax} \qquad (11)$$

Active power flow limit:

$$P_{ij} \leq P_{ijmax} \qquad (12)$$

4. PSO algorithm

Particle swarm optimization (PSO) is one of these algorithms that can be and has been used successfully in locating problems. In PSO, the potential solutions, called particles, are flown through the problem space by following the current optimal particles. Each individual in PSO flies in the search space with a velocity which is dynamically adjusted according to its own flying experience and its companions flying experiences. Each individual keeps track of its coordinates in the problem space, which are associated to the best solution (fitness) it has achieved so far. This value is called P_{best}, while the overall best value obtained so far by any particle in the population, the so-called G_{best}, and its location is tracked by the global version of the particle swarm optimizer. At each time step, the particle swarm optimization consists of velocity changes of each particle towards its P_{best} and G_{best} [13].

After finding the best values, the particle updates its velocity and position according to the following equations:

$$V_i^{k+1}=W*V_i^k+C_1*rand*(P_{besti}-S_i^k)+C_2*rand*(G_{besti}-S_i^k) \quad (13)$$

$$S_i^{k+1}=S_i^k+V_i^{k+1} \quad (14)$$

where

V_i^k = Velocity of agent i at k^{th} iteration

V_i^{k+1} = Velocity of agent i at $(k+1)^{th}$ iteration

W = inertia weight

$C_1=C_2$= Weighting factor(0 to 4)

S_i^k= Current position of agent i at k^{th} iteration

S_i^{k+1}= Current position of agent i at $(k+1)^{th}$ iteration

W_{max}= initial value of inertia weight

W_{min}= final value of inertia weight

P_{besti}= best position of agent i

G_{besti}= best position of the group

4.1.Algorithm of Proposed Methodology

Step 1: The bus data , line data and FACTS device (TCSC) data are given as inputs.

Step 2: Specify PSO parameters and maximum number of iterations.

Step 3: The initial population of particles are generated with random position and velocity.

Step 4: Set the iteration number equals one.

Step 5: Evaluate the objective function in equation (6)

Step 6: Calculate the total active power loss of the system by connecting TCSC device to the system.

Step 7: For each particle the objective function is calculated and if it is higher than the individual P_{best} , then it is the current P_{best} and store the current position.

Step 8: The particle with the minimum P_{best} value among all particles is chosen as the overall G_{best} value.
Step 9: Particle positions and velocities are updated by the equations (13) and (14).

Step 10: If the maximum iteration reached, then the optimal solution is the position of the global best particle. Otherwise increase the iteration and go to step 4.
Step 11: Obtain the optimal location for TCSC devices.

Table 1. Optimal value of PSO parameters

Parameters	Optimal value
Number of particles	20
Number of iterations	60
C_1	2.5
C_2	2
Initial inertia weight	0.9
Final inertia weight	0.4
Particle velocity	1

5. Simulation results

5.1. Specification of IEEE 14 bus test system

In order to find out the effectiveness of proposed approach, it was tested on IEEE 14 bus system. IEEE 14 bus system consists of 5 generators,14 buses,16 lines,4 transformers and 11 loads as shown n figure 5.

The system has generators located at buses 2,3,6,8 and 10 and four transformers with off-nominal tap ratio in line 4-7,4–9,5- 6 and 8-9. The lower voltage magnitude limits at all buses are 0.95 p.u. and the upper limits are 1.1 p.u.

FACTS devices are optimally placed by calculating the minimum active power loss . Solved by using Newton Raphson Power flow method and the program was coded in MATLAB software.

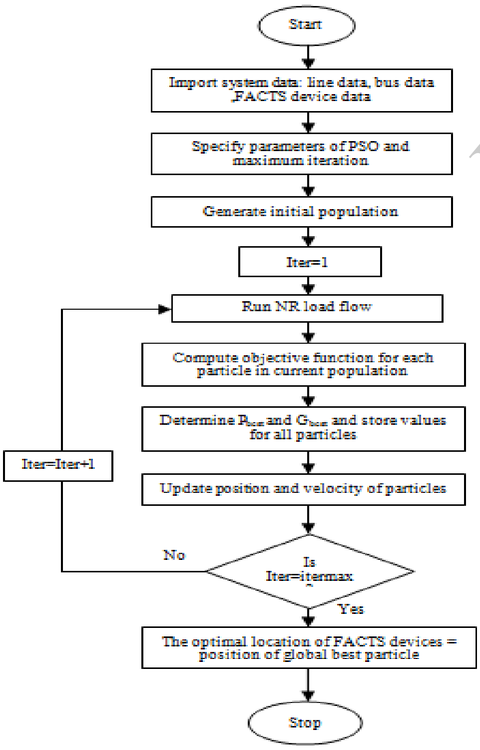

Figure 4. PSO flowchart of proposed method

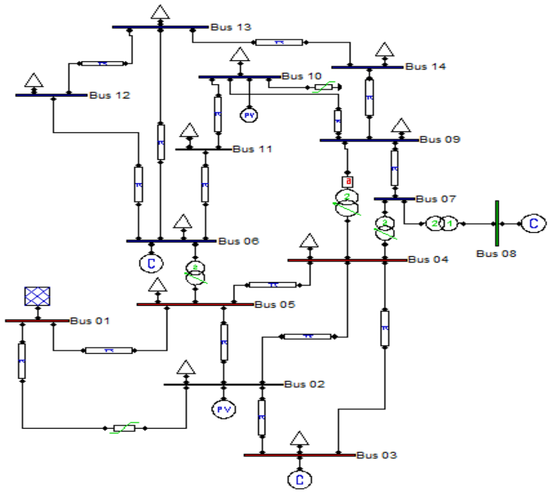

Figure 5.PSAT model of IEEE 14 bus system with TCSC and SVC

Figure 6. Voltage levels with and without TCSC and SVC

In figure 6.voltage levels with TCSC and SVC is compared against voltage levels without TCSC and SVC. It is clear from the figure that with the optimal placement of TCSC and SVC the voltage level is increased without exceeding the voltage limits. Thus the voltage levels are improved with the use of TCSC and SVC. The voltage levels are within 0.9p.u. and 1.1p.u.

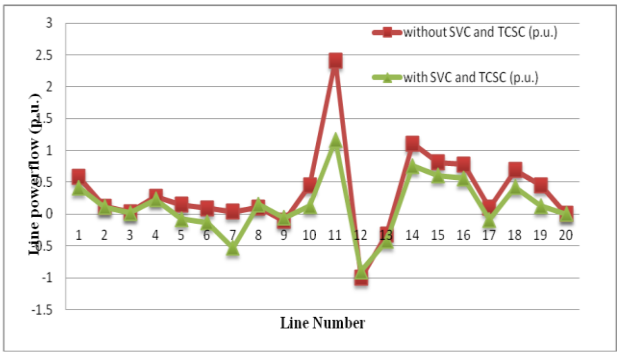

Figure 7. Line power flows with and without TCSC and SVC

Figure 7. shows the active power flows with and without TCSC and SVC. Line power flows are reduced with the placement of TCSC at line 11 and SVC at bus 10. With the placement of TCSC and SVC active power flows in the lines are reduced and the active power losses are also reduced. So the transmission efficiency can be increased.

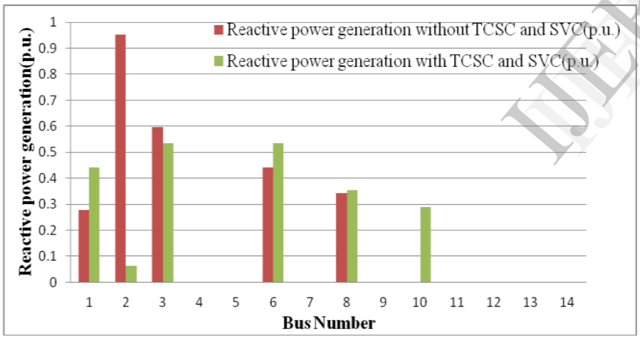

Figure 8.Reactive power generations with and without TCSC and SVC

Figure 9. shows the reactive power generation at buses with the TCSC and SVC at optimal locations.It shows reactive power generation without TCSC and SVC and reactive power generation with TCSC and SVC.

Table 2. shows the active power losses with and without TCSC and SVC. The total active power losses are reduced by TCSC and SVC at optimal location.

Table 2. Active power loss with and without TCSC and SVC

	Active power losses(p.u.)
Without TCSC and SVC	0.2945
With TCSC and SVC	0.1448

6. Conclusion

In this paper, an approach based on PSO has been presented and applied to find out the optimal location of TCSC and SVC. The problem is formulated as an optimization problem to minimize the real power losses and voltage variations in a system. The particle swarm optimization algorithm has been used to obtain the optimal location of TCSC and SVC with minimum active power losses and without voltage violations.

The proposed method was tested in IEEE 14 bus system. IEEE 14 bus system is modeled in PSAT and by using MATLAB code optimal location for TCSC is found out. The location obtained gives minimum active power losses therefore the transmission efficiency of the system can be improved. It is found out that the proposed method is able to find out the optimal location in less computational time and with relatively small number of iterations.

Acknowledgment

The authors gratefully acknowledge Dr Federico Milano, for his excellent simulation software PSAT [11].

References

[1]R. Benabid, M. Boudour, M.A. Abido," Optimal location and setting of SVC and TCSC devices using non-dominated particle swarm optimization",Electric Power Systems Research,vol.79,no.12,pp1668-1677,2009.

[2] I. Pisica, C. Bulac, L. Toma, M. Eremia, and S. Member, "Optimal SVC Placement in Electric Power Systems Using a Genetic Algorithms Based Method," Power, no. 2, pp. 1-6, 2009.

[3] H. Hashemzadeh, M. Ehsan, "Locating and Parameters Setting of Unified Power Flow Controller for Congestion management and Improving the Voltage Profile." Asia-Pacific Power and Energy Eng. Conf., Mar. 2010.

[4] N.Acharya, N.Mithulananthan, "Locating Series FACTS devices for Congestion Management in Deregulated electricity markets", Electric Power Systems Research,77(3-4),352-360,2007.

[5] S. Sutha and N. Kamaraj," Optimal Location of Multi Type Facts Devices for Multiple Contingencies Using Particle Swarm Optimization",International Journal of Electrical and Computer Engineering 3:13 2008.

[6] E. A. Leonidaki, D. P. Georgiadis, and N. D. Hatziargyriou, "Decision trees for determination of optimal location and rate of series compensation to increase power system loading margin," IEEE Trans. Power Syst., vol. 21, no. 3, pp. 1303–1310, Aug. 2006.

[7] S. N. Singh and A. K. David, "Optimal location of FACTS devices for congestion management," Electr. Power Syst. Res., vol. 58, pp. 71–79, June 2001.

[8] P. Preedavichit and S. C. Srivastava, "Optimal reactive power dispatch considering FACTS devices," Electr. Power Syst. Res., vol. 46, pp. 251– 257, Sep.1998

[9] Seyed Mohammad Hosseini Nabavi, Nazanin Alsadat Hosseinipoor, SomayehHajforoosh," Social Welfare Maximization by Optimal Locating and Sizing of TCSC for Congestion Management in Deregulated Power Markets",International Journal of Computer Applications (0975-8887),vol.6,September2009

[10] R. Minguez, F. Milano, R. Zarate-Minano, and A. J. Conejo, "Optimal network placement of SVC devices," IEEE Trans. Power Syst., vol. 22,no.4,pp.1851-1860,Nov.2007.

[11] F. Milano, "An Open Source Power System Analysis Toolbox," IEEE Transactions on Power Systems, vol. 20, no. 3, pp. 1199-1206, Aug. 2005

[12] J. Kennedy, R. Eberhart, "Particle swarm optimization in," Proceedingsof the IEEE International Conference on Neural Networks, pp. 1942- 1948 1995.

[13] Y. Shi, R. C. Eberhart, "Empirical study of particle swarm optimizationin," Proceedings of the International Congress on Evolutionary Computation, vol.3,pp.101-106,1999.

[14] H. Hashemzadeh, S. H. Hosseini, "Locating Series FACTS Devices Using Line Outage Sensitivity Factors and Particle Swarm Optimization for Congestion Management," IEEE General Meeting., 2009.

[15] M. Kowsalya, K. K. Ray, D. P. Kothari, and S. Member, "Voltage Stability Enhancement Through Optimal Location of Var Compensator," pp. 360-365, 2008.

[16] S. Sakthivel, D. Mary, and V. S. Kannan, "Optimal Location of SVC for Voltage Stability Enhancement under Contingency Condition through PSO Algorithm," International Journal, vol. 20, no. 1, pp. 30-36, 2011.

[17] M. R. AlRashidi, M. E. El-Hawary, "A survey of Particle Swarm Optimization Applications in electric power systems," IEEE Transactions on Evolutionary Computation, vol. 13, no. 4, pp. 913-918, 2009

[18]"Proposed terms and definitions for flexible AC transmission system(FACTS)", IEEE Transactions on Power Delivery, Volume 12, Issue 4, October 1997, Pages 1848-1853

[19]M. Joorabian, F. Ramandi, M. Ebadi, and X. A. X. Bu, "Optimal Location of Static VAR Compensator (SVC) Based on Small Signal Stability of Power System," Power, no. 8, pp. 1333-1338, 2008.

[20] M. N. Nwohu,"Voltage Stability Improvement using Static Var Compensator in Power Systems," Sciences-New York, no. 14, pp. 167-172, 2009.

[21] M. H. Hemmatpour and M. Mohammadian, "A Novel Approach for Optimum Reconfiguration and SVC Planning Considering Variable Load Pattern Based on Voltage Security Margin," Canadian Journal on Electrical and Electronics Engineering, vol. 2, no. 11, pp. 514-525, 2011.

[22] Hingorani, N. G., Gyugyi L., "Understanding FACTS: concepts and technology of flexible transmission systems", IEEEPress,2000.