Optimal Placement Of Svc Using Fuzzy And Pso Algorithm

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ABSTRACT

In any power system network, voltage stability is a major concern for secure operations. But recently due to their stressed operations for increasing loading, voltage instability and voltage collapse are evitable, which is a major threat to power system. So it is very important to maintain voltage profile within the limits for overloading conditions also, which can possible through optimal placement of Static Var Compensator (SVC). A new approach is proposed in this paper, which is a combination of Fuzzy and Particle Swarm Optimization (PSO). For Optimal locations Fuzzy approach is used. The rating value of SVC is approximated through PSO for different loading conditions. In this paper 125%, 150% and 175% overloading cases are considered. It is observed from the results that the voltage profile of the power system are increased and are within limits, also real power losses are reduced there by optimally locating SVC device in the power system. The proposed method is tested on IEEE 14 bus, IEEE 30 bus system.

Keywords - Fuzzy approach, SVC placement, and Particle Swarm Optimization.

1. INTRODUCTION

The trend of living of individual has been changed in the recent years with the development of technologies, which leads to unpredictable demand of power on generation companies.These considerations throw cautions on transmission system against congestion, line loss and voltage instability [1]-[6]. The main reason for occurring voltage collapse is when the power system is heavily loaded, faulted and having shortage of reactive power. To overcome this problem new transmission line are needed. However there is an alternative solution which is possible with accompanying of FACTS devices. We know that FACTS can control the line parameters such as voltage, voltage angle and line reactance. There are many compensation devices available which are used for reactive power compensation, each of which is having their own advantages and disadvantages. So it is necessary to select the most favorable device for compensation and placing it optimally

In literature there are many approaches used for placement of SVC, such as loss sensitivity index in [2][3], where it is placed in the most negative index. In [4] an approach named Voltage stability index is defined for placement of SVC. In [5][6] genetic algorithm (GA) is used for optimization of devices placed in the locations.

In this paper SVC is used for shunt compensation.

It is a shunt-connected static Var generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to provide voltage support and only when installed in a proper location, it can also reduce power losses. Fuzzy approach gives best optimal locations depending on the objectives considered, and PSO techniques iteratively optimize the sizes of the devices for the concerned locations. A Matlab code is developed for the proposed approach and applied to IEEE 14, 30 bus system and the results are tabulated.

2. MODELING OF SVC

In its basic form, SVC device is a parallel combination of thyristor controlled reactor with a bank of capacitors. From the working point of view, the SVC resembles like a shunt connected variable reactance, which either generates or absorbs reactive power in order to regulate the voltage magnitude where it is connected to the AC network. It is mainly used for voltage regulation. As an important component for voltage control, it is usually installed at the receiving node of the transmission lines. In Fig. 1, the SVC has been considered as a shunt branch with a compensated reactive power QSVC, set by available inductive and capacitive susceptance [6].

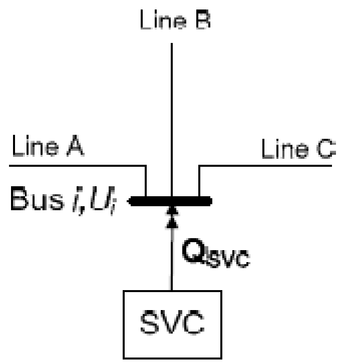

Figure 1: Injection model of SVC

The SVC model is realized as an element, which feeds a certain amount of reactive power at selected bus.

3. FINDING OPTIMAL LOCATIONS USING FUZZY APPROACH

In this paper for optimal location of SVC on load buses [7], fuzzy approach is used; fuzzy logic is developed considering two objectives i.e. (i) reducing real power losses (ii) maintaining voltage profile within the allowable limits (0.9p.u – 1.1p.u). For writing fuzzy rules two inputs Power loss index (PLI) and nodal voltages (p.u) are taken.

$$LR_i = P_i^1 - P_i^2 \qquad (1)$$

for i = 1 to number of load buses.
Where,
LR – Loss Reduction.
P_i^1 - Real power for normal load flow.
P_i^2 - Real power for load flow by total compensation of reactive load at ith node.

The LR input is normalized using below equation, so that the values fall between 0 to 1, where the largest number having a value of 1 and the smallest as 0.

$$PLI_i = \frac{LR(i) - LR(min)}{LR(max) - LR(min)} \qquad (2)$$

for i = 1 to number of load buses.

The fuzzy rules are adopted from [8]. The output of fuzzy gives the suitability index for SVC placement. Maximum values will be promising locations for SVC placement

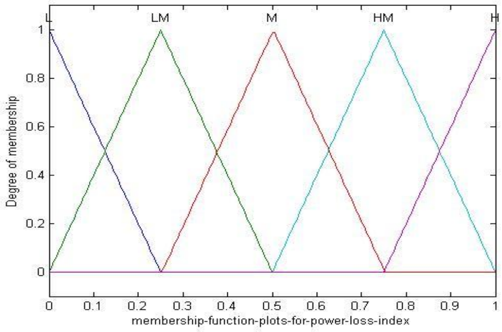

Figure-2. Membership function plot for Power Loss Index (PLI).

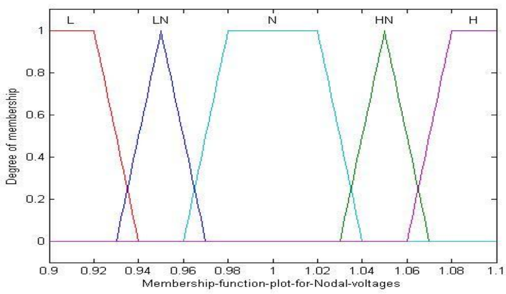

Figure-3. Membership function plot for p.u. nodal voltage.

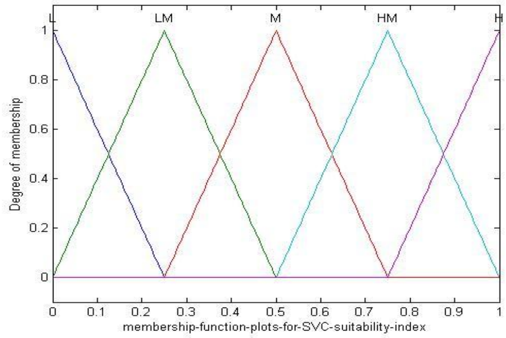

Figure 4: Membership function plot for SVC Suitability Index

4 PARTICLE SWARM OPTIMIZATION METHOD

In 1995 James Kennedy and Russell C. Eberhart proposes an algorithm known as Particle Swarm Optimization (PSO) which was inspired from birds flocks and fish schooling . It is a computational method that optimizes a problem by iteratively trying to improve a candidate solution . Population of birds or fish is known as swarm. Each candidate of swarm is known as particle. These particles are moved (or updated) around in the search-space according to a few simple formulae.

Let *X* is the position of particle and *V* is the velocity of that particle. In a swarm, every particle knows the global best position (i.e. gbest particle) and personal best position (i.e. pbest particle). Every particle using equation (3), (4) modifies its position to reach the gbest particles.

$$\boldsymbol{V_i^{k+1} = K_c[\,WV_i^k + C_1 rand_i(pbest_i - X_i) + C_2 rand_i(gbest_i - X_i)]} \qquad (3)$$

$$\boldsymbol{X_i^{k+1} = X_i^k + V_i^{k+1}} \qquad (4)$$

Where,
K_c = constriction factor.
V_i^k = velocity of a particle i in k^{th} iteration.
W = inertia weight parameter
C_1, C_2 = weight factors
$rand_1, rand_2$ = random numbers between 0 and 1.
X_i^k Position of particle in k^{th} iteration.

Inertia weight is calculated using below equations for better exploration of the search space.

$$\boldsymbol{W = w_{max} - \frac{(w_{max} - w_{min}) * t}{T}} \qquad (5)$$

Where,
w_{max}, w_{min} are the constraints for inertia weight factor.
t = current iteration count.
T = maximum number of iterations.

Constraints considered are,

$V_i^{min} \leq V_i \leq V_i^{max}$
(6)
$X_i^{min} \leq X_i \leq X_i^{max}$
(7)

4.1. Algorithm to find the SVC sizes using PSO method [9]

Step 1: Initially [nop x *n*] number of particles are generated randomly within the limits, where nop is the population size and *n* is the number of SVC devices. Each row represents one possible solution to the optimal SVC-sizing problem.

Step 2: Similarly [nop x n] number of initial velocities is generated randomly between the limits. Iteration count is set to one.

Step 3: By placing all the '*n'* SVC devices of each particle at the respective candidate locations and load flow analysis is performed to find the total real power loss P_L^{SVC}. The same procedure is repeated for the 'nop' number of particles to find the total real power losses. Fitness value corresponding to each particle is evaluated using the equation (8) for maximum loss reduction.

Fitness function for maximum loss reduction is given by:

$$\textbf{Fitness } F_A = P_L - P_L^{SVC} \qquad (8)$$

Where,
P_L is Original total real loss,
P_L^{SVC} is Present total real loss with SVC,

Fitness with negative value is replaced with minimum and the corresponding particle position is also assign with minimum from equation (7). Initially all fitness is copied to pbest-fitness, maximum of pbest-fitness gives gbest-fitness, which is a measure for maximum loss reduction. And the corresponding particle represents gbest-particles.
Step 4: New velocities for all the particles within the limits are calculated using equation (3) and the particle positions are updated using equations (4)
Step 5: Once the particles are updated, load flow analysis is performed; new-Fitness is calculated using equation (6). If the new-fitness is greater than pbest-fitness then the corresponding particle is moved to the pbest-particle.
Step 6: Maximum of pbest-fitness gives the gbest-fitness and the corresponding particle is stored as gbest-particle.
Step 7: From pbest-fitness maximum fitness and average fitness values are calculated. Error is calculated using the below equation.

$$\textbf{Error = (max. fitness – avg. fitness)} \qquad (9)$$

If this error is less than a specified tolerance then go to step 9.
Step 8: The current iteration count is incremented and if iteration count is not reached maximum then go to step 4.
Step 9: gbest-fitness gives maximum loss reduction and **g**best-particle gives the optimal SVC sizes.

4.2 Data used for PSO,
nop = 100; C_1 = 2.05; C_2 = 2.05, w_{max} = 0.9, w_{min} = 0.4, T= 1000.

5. RESULTS

The proposed approach is used for SVC placement for the objectives considered, is placed on the node having maximum los reduction and poor voltage profile which is discussed below.

5.1 Results of 14 bus system

IEEE **14 bus system [10]** contains 5 generator buses (bus numbers: 1,2,3,6 and 8), 9 load buses (bus numbers: 4, 5, 7,9,10,11,12,13 and14) and 20 transmission lines. The load is increased by125, 150 and 175%. Optimal location on load buses, rating of SVC and real power losses after SVC placement for different load scenario using PSO are shown in Table 1.

Table 1: result for 14 bus system.

Loading condition	Losses without SVC	SVC Loc.	PSO: Rating of SVC	PSO: Losses with SVC
Normal loading	13.393	5, 14	5.5566 6.9525	13.3333
125% loading	22.636	5, 14	36.9381 10.0891	22.1017
150% loading	35.011	5, 14	66.9741 13.0955	33.7691
175% loading	51.295	9, 14	58.5849 15.9442	49.4955

(a) Normal loading.

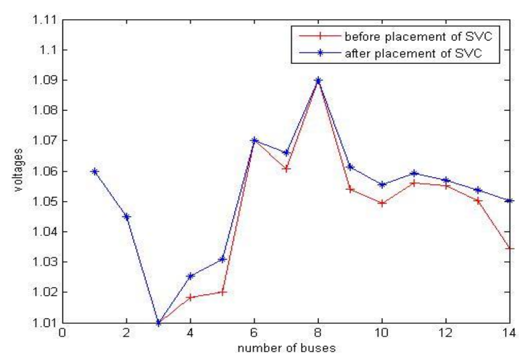

Figure 5: Voltage profile before and after placement of SVC for Normal loading.

(b) 125% loading.

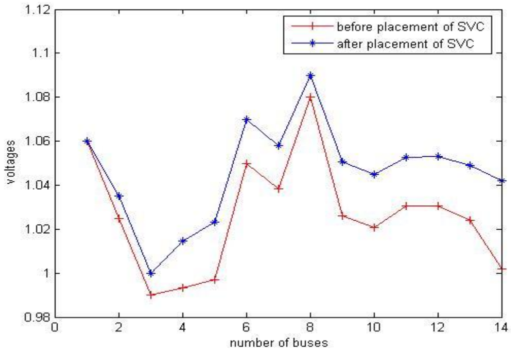

Figure 6: Voltage profile before and after placement of SVC for 125% of Normal loading.

(c) 150% loading.

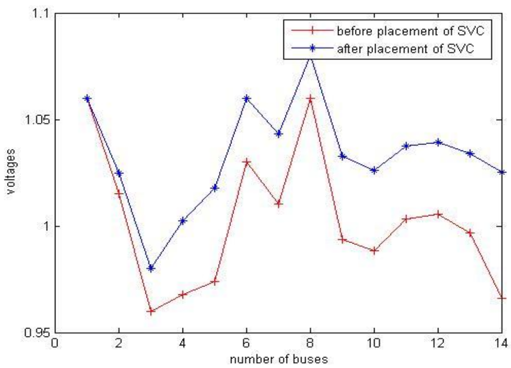

Figure 7: Voltage profile before and after placement of SVC for 150% of Normal loading.

(d) 175% loading.

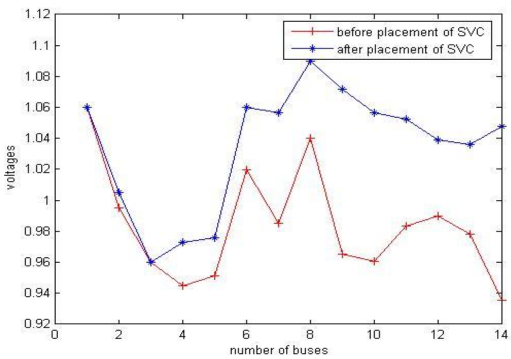

Figure 8: Voltage profile before and after placement of SVC for 175% of Normal loading.

Table 2: Voltages of 14 bus system for 175% loading.

Bus no:	**Voltages (p.u)**	
	Before SCV	**After SCV**
1	1.0600	1.0600
2	0.9950	1.0050
3	0.9600	0.9600
4	0.9448	0.9729
5	0.9514	0.9756
6	1.0200	1.0600
7	0.9851	1.0565
8	1.0400	1.0900
9	0.9651	1.0720
10	0.9606	1.0568
11	0.9833	1.0523
12	0.9898	1.0393
13	0.9785	1.0359
14	0.9358	1.0477

5.2Results of 30 bus system

IEEE **30 bus system[10]** contains 6 generator buses (bus numbers: 1, 2, 5 ,8, 11, and 13), 24 load buses (bus numbers : 3, 4, 6, 7, 9, 10, 12, 14 ,15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 and 30) and 41transmission lines. The load is increased by125, 150 and 175%. Optimal location on load buses, rating of SVC and real power losses after SVC placement for different load scenario using PSO are shown in Table 3.

Table 3: result for 30 bus system.

Loading condition	**Losses without SVC**	**SVC Loc.**	**PSO**	
			Rating of SVC	**Losses with SVC**
Normal loading	17.528	26, 30, 7	3.1427 3.3826 12.7310	17.4057
125% loading	29.8508	30, 7, 26	5.8710 32.7977 4.9527	29.0912
150% loading	46.9429	24, 30, 26	17.0266 6.9730 4.5245	45.4175
175% loading	68.9628	24, 21, 30	22.3177 63.7552 14.4736	65.8756

(a) Normal loading

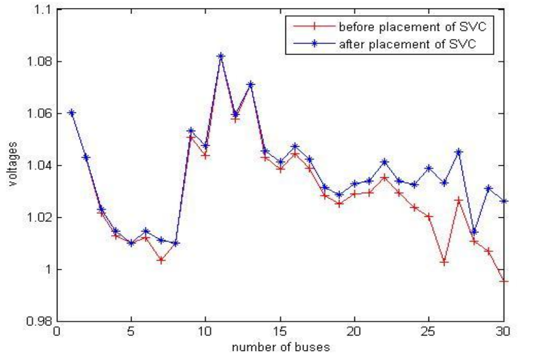

Figure 9: Voltage profile before and after placement of SVC for Normal loading.

(b) 125% loading

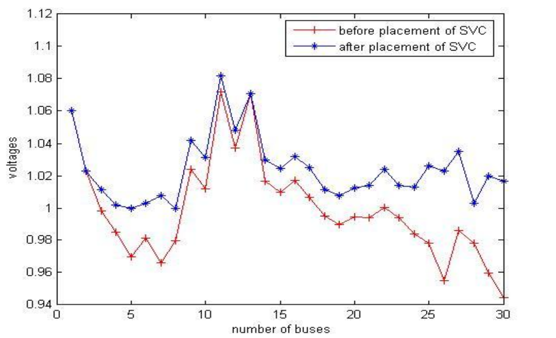

Figure 10**:** Voltage profile before and after placement of SVC for 125% of Normal loading.

(c) 150% loading.

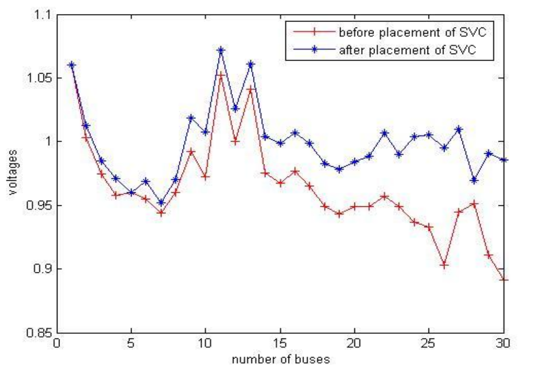

Figure 11: Voltage profile before and after placement of SVC for 150% of Normal loading.

(d) 175% loading.

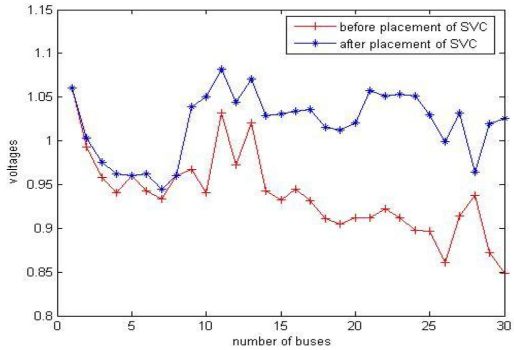

Figure 12: Voltage profile before and after placement of SVC for 175% of Normal loading.

6. CONCLUSION

In this paper a two-fold approach is used for finding optimal locations and sizes of SVC devices is presented. Through fuzzy approach optimal locations are obtained and with PSO method their optimal rating values are calculated. From results it is observed that for all overloads i.e., 125%, 150% and 175% of normal loading, the voltage profile of the system is increased and maintained within the specified limits, and the real power losses are also reduced.

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