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Power Loss Reduction and Voltage Profile Improvement by DSTATCOM using PSO

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***Abstract*—The objective of this paper is to reduce the power loss and to improve the voltage profile in radial distribution system. Fuzzy and particle swarm optimization algorithm is a two-stage methodology used for placement and sizing of DSTATCOM in this paper. To show the effectiveness of the same a complete result analysis is carried out on 33 and 69 bus systems. Power loss and voltages are calculated for the four optimal locations based on priority.125%,150%,175% overloading cases are also considered in this paper. The result analysis shows that the two-stage methodology effectively improves the voltages and reduces the power loss of the system.**

***Keywords*—*DSTATCOM*, Fuzzy Approach, Particle Swarm optimization.**

I. INTRODUCTION

Distribution networks find more importance in these days as it plays major role in power system planning and quality .The use of advanced equipments in distribution networks for quality improvement became necessary by the introduction of the deregulation in power systems. In distribution networks complete utilization of lines capacity is not possible for several reasons which lead to power flow limit decrease slower response time and increasing of power loss[10,11] . Modern techniques such as flexible AC transmission system (FACTS) works better in these regards. FACTS are initially developed for transmission system now these have been applied for distribution networks too. FACTS are of three types (i) series (ii) shunt (iii) combination of series and shunt. Shunt device DSTATCOM as a shunt connected voltage source converter is frequently used to compensate power quality. Under over loading and the voltage sag the load voltage of a particular bus can be regulated by the injection of compensating current into the system with the help of DSTATCOM[3]. A prototype design of DSTATCOM for voltage sag mitigation is presented for an unbalanced system [6]. A cascade loop control strategy to balance and regulate the voltage at a distribution bus using a DSTATCOM is proposed by [5]. various works [2,9] have been done on optimal location of STATCOM using various techniques such as and genetic algorithm (GA). Optimal placement and sizing of DSTACOM using immune algorithm[14]. Fuzzy approach

gives best optimal locations depending on the considered objectives and PSO technique iteratively optimize the sizes of the devices for the particular location. A MATLAB code is developed for the proposed approach and applied to IEEE 33 and 69 bus system and the results are tabulated. The over loading cases 125%, 150%, 175% are considered in this paper.

2. MODELLING OF DSTATCOM

The STATCOM as a member of the FACTS devices is a regulating power utility which is connected to the power system in shunt mode. Once the STATCOM is used in the voltage level of distribution system is called Distribution DSTATCOM.

A DSTATCOM can work as synchronous voltage source with a variable magnitude and phase angle. Hence it is capable of controlling its bus voltage and correcting the power factor.

Usually DSTATCOM has the ability of injecting active and reactive power. Active power injection depends on the capacity of energy source. In this paper only DSTATCOM application for reactive power injection is considered and injection of active power is neglected.

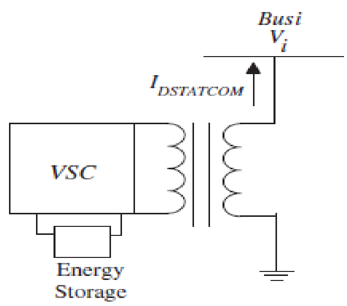

Fig.1. A Typical DSTATCOM Connected To Bus

3.LOAD FLOW ANALYSIS

Generally used load flow analysis like Gauss- Seidel , fast decoupled and Newton Raphson methods cannot be used to find the load flow in radial distribution systems because of high R/X ratio. Many special load flow analysis have been proposed in the literature[1,7].load flow analysis like load flow using conic programming [8], backward forward sweep based power flow analysis are also used. In this paper a direct approach for distribution system load flow solution [4] has been used.

The proposed algorithm is a “novel but classic” technique. The input data used in this algorithm is the conventional bus-branch data which is used most. The aim of this algorithm is to develop a formulation, which solve the distribution load flow directly by taking the advantages of topological characteristics of distribution systems. It senses that the time consuming methods like LU decomposition and forward/backward substitution of the Jacobian matrix substitution or the Y admittance matrix used in the Newton Raphson and Gauss implicit Z matrix algorithms are not necessary in the method used.

A bus- injection to bus-current matrix and a bus-current to bus-voltage matrix are the two developed matrices used here and by a simple matrix multiplication load flow solutions are obtained. The used method is robust and very efficient compared to conventional methods.

4. OPTIMAL LOCATIONS USING FUZZY APPROACH

For Optimal Location of DSTATCOM on load buses fuzzy approach is used in this paper [12,13]. Fuzzy logic is developed by considering the following two objectives (i) power loss reduction (ii) maintaining voltage profile within the acceptable limits (0.9p.u – 1.1p.u). Power loss reduction (PLI) and per unit nodal voltages (p.u) are taken as inputs to write fuzzy rules to determine the DSTATCOM placement suitability of each node. DSTATCOM can be placed on the nodes with highest suitability index.

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

Where i= 1 to number of load buses.
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 i^{th} node.

The LR input is normalized by the following equation , so that the values will fall between 0 to 1. Where the largest value will assign as 1 and the smallest as 0.

$$PLI = \frac{LR(I) - LR(\min)}{LR(\max) - LR(\min)} \quad (2)$$

The Fuzzy rules used in this paper are taken from (8f). DSTATCOM suitability index can be get by the output of the fuzzy. Maximum suitability index values are the optimal locations for DSTATCOM placement.

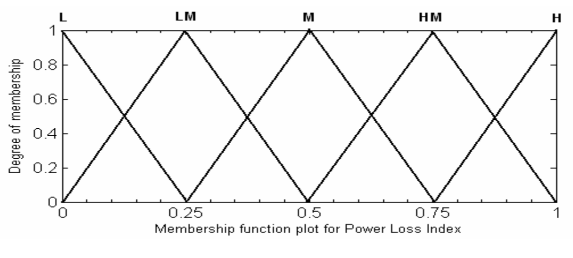

Fig.2. membership function plot for power loss index (PLI)

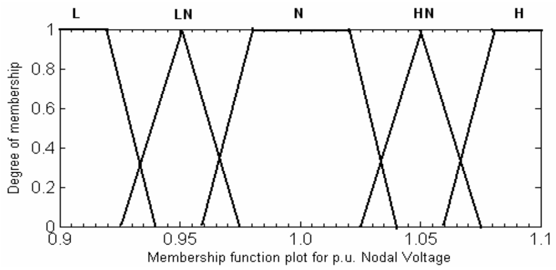

Fig.3. membership function plot for p.u nodal voltage

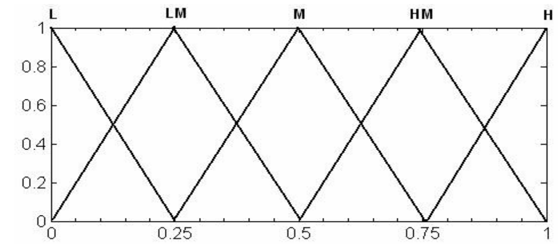

Fig.4. membership function plot for DSTATCOM suitability index

By using the fuzzy rules from [13] the optimal placement of the DSTATCOM have been determined here in this paper.

5. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) is proposed by James Kennedy and Russel C. Eberhart in 1995 which was inspired by fish schooling and bird flocks. It is a computational method that optimizes a problem by trying iteratively to improve the particular solution. Population of birds or fish is called as swarm. The particles selected from a particular range will move around in the search space according to a few formulae[13,15].

Let X and V are the position and velocity of the particles respectively. In a swarm by updating the position and velocity by the following formulas we will get personal best position (i.e. pbest) and global best position (i.e. gbest) the aim of the particles is to reach the gbest particle by using the formulas (3) and (4) .

$$V_i^{k+1} = WV_i^k + C_1 rand_1(pbest_i - X_i) + C_2 rand_2(gbset_i - X_i) \quad (3)$$

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

Where,

V_i^k = velocity if the particl i at K^{th} iteration.
W = Inertia weight parameter.
C_1 = cognitive parameter.
C_2 = social parameter.
X_i^k = particle position at K^{th} iteration.
$rand_1$, $rand_2$ = random numbers between 0 and 1.

Inertia weight can calculated by using the following equations for the better exploration of the search space .

$$W = w_{max} - ((w_{max} - w_{min})*t)/T \quad (5)$$

w_{max},w_{min} are the inertia weight factor constraints.
t = current iteration count.

T = maximum number of iterations .
Considered constraints are as follows

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

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

6. IMPLEMENTATION OF PROPOSED WORK

The PSO approach for solving optimal sizing of DSTATCOM to minimize the power loss and to improve the voltage profile takes the following steps:

step1: Get the inputs which are the line impedance and the bus data.

step2: Initially [nop x n] number of particles are generated where nop is the number of population and n is the number of DSTATCOOM devices.

step3: Generate initial [nop x n] number of velocities randomly between the limits. Iteration count is 1.

step3: load flow analysis is performed by placing all the 'n' DSTSATCOM devices at the particular candidate locations and power losses $P_L^{DSTATCOM}$ are calculated. Same procedure is repeated for 'nop' number of particles to find the total real power loses.

step4: for maximum loss reduction fitness function can be calculated by the following formula:
Fitness $F_A = P_L - P_L^{DSTATCOM}$
Where,
P_L is total real loss before placement.
$P_L^{DSTATCOM}$ is the total real loss after placement of DSTATCOM.
Fitness with negative value is replaced with minimum and the respective particle position also assign with minimum from equation (7). Initially all the fitness values are copied to pbest fitness, maximum pbest fitness gives the gbest fitness. Which is a measure of of maximum loss reduction and the respective particles represents gbest particles.

step5: using equations (3) (4) new velocities for all the particles within the limits are calculated and particle positions are updated respectively.

step6: after the updating of particles, load flow analysis is done and new fitness value is calculated using equation (6). If the new fitness is greater than the pbest fitness then the respective particle is moved to the pbest particle.

Step7 : maximum pbest fitness gives the gbest fitness and the respective particle will be stored as gbest particle.

Step8 : maximum fitness and average fitness are calculated by using pbest fitness. Error is calculated using equation (9)
.

Error = (max.fitness – avg.fitness) (9)
If the calculated error is less than the specified tolerance then go to step 10.

Step9 : the current iteration count is incremented, if the iteration coun not reaches maximum then go to step5.

Step10 : gbest fitness and the gbest particle gives maximum loss reduction and optimal sizes of DSTATCOM respectively.

6.1 Data used for PSO

nop = 100; C_1=0.9; C_2=0.9; w_{max}=0.8; w_{min}=0.1
T=100.

7. RESULT ANALYSIS

The proposed approach is used for optimal placement and sizing of DSTATCOM at the node which is having maximum power loss reduction and poor voltage profile are discussed in the following result analysis. The results compared with earlier published works[14].

7.1 Results of 33 bus system

Table.1- Results of 33-bus system for various optimal locations

Total real power loss in kW before DSTATCOM Placement	Various Optimal locations	Size of DSTATCOM (kVAr)	Total real power loss in kW after DSTATCOM Placement
202.7661	30	1253.2	143.6445
	32	1032.2	152.0194
	31	1079.4	150.0601
	12	860.55	171.4469

Voltage levels of the considered 33 bus test system by placing DSTATCOM in various optimal locations obtained by fuzzy method have been plotted in the following Fig.5, Fig.6, Fig.7, Fig.8 respectively

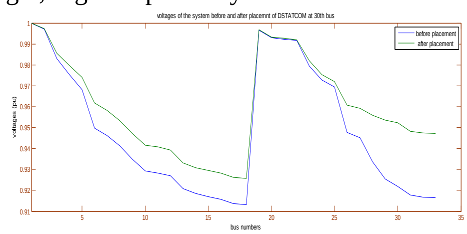

Fig.5.voltages before and after placing of DSTATCOM at 30th bus

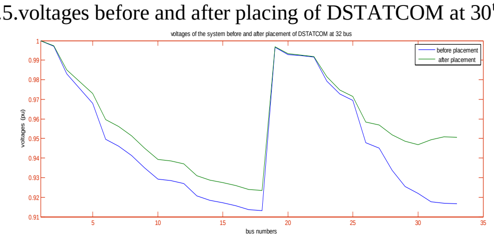

Fig.6.voltages before and after placing of DSTATCOM at 32 bus

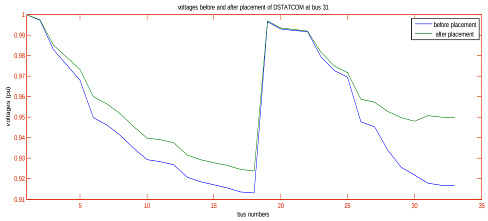

Fig.7.voltages before and after placing of DSTATCOM at 31 bus

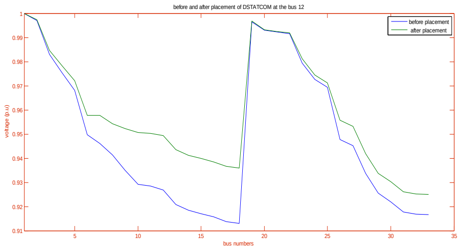

Fig.8.voltages before and after placing of DSTATCOM at 12th bus

Power losses have been calculated for the following test system at over loading conditions. The results have been tabulated as follows.

Table.2- Results of 33-bus system for various overloading locations

Loading condition	Losses without device	Location of device	PSO	
			Size of device (kVAr)	Losses with device
Normal	202.7661	30	1253.2	143.6445
125%	329.9988	30	1576.8	231.0839
150%	496.5653	30	1905.5	343.1695
175%	709.0218	29	2354.2	488.6277

In the above table device represents DSTATCOM. Graphical representation of the voltages for the four loading conditions is as follows

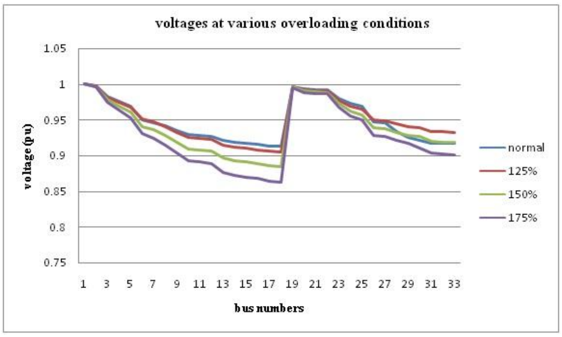

Fig.9.voltages of various loading conditions

7.2 Results Of 69 Bus System

Results for various optimal locations to 69 bus test system according to their priorities obtained by fuzzy has been tabulated as follows,

Table.3- Results of 69-bus system for various optimal locations

Total real power loss in kW before DSTATCOM Placement	Various Optimal locations	Size of DSTATCOM (kVAr)	Total real power loss in kW after DSTATCOM Placement
225.0044	61 64 59 65	1330 1148.3 1383.8 982.2113	152.0446 160.0514 160.8188 169.0628

Voltage levels of the considered 69 bus test system by placing DSTATCOM in various optimal locations obtained by fuzzy method have been plotted in the following Fig.10, Fig.11, Fig.12, Fig.13 respectively.

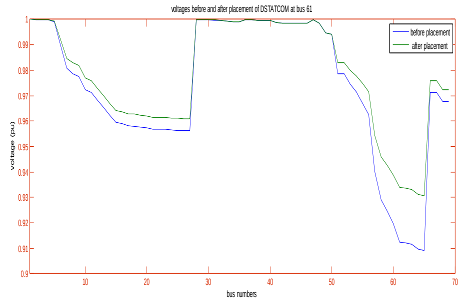

Fig.10.voltages before and after placing of DSTATCOM at 61 bus

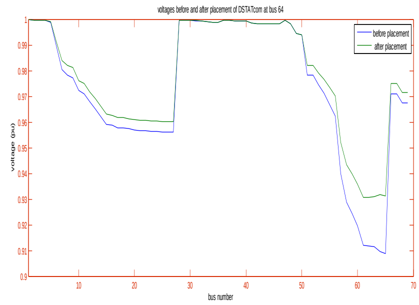

Fig.11.voltages before and after placing of DSTATCOM at 64 bus

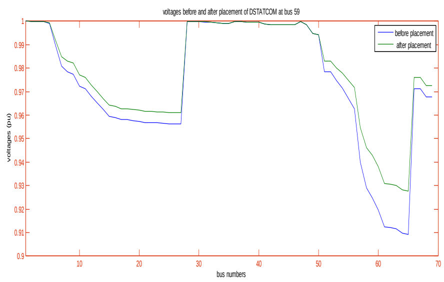

Fig.12.voltages before and after placing of DSTATCOM at 59 bus

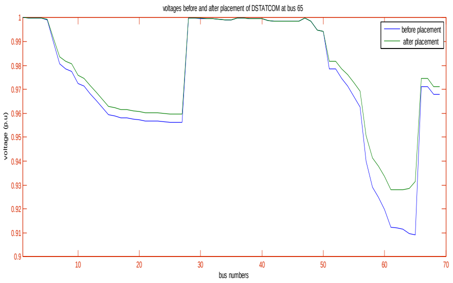

Fig.13.voltages before and after placing of DSTATCOM at 65 bus

Power losses have been calculated for the following test system at over loading conditions. The results have been tabulated as follows.

Table.4- Results of 69-bus system for various overloading locations

Loading condition	Losses without device	Location of device	PSO	
			Size of device (kVAr)	Losses with device
Normal	225.0044	61	1330	152.0446
125%	369.0664	61	1675.1	246.0443
150%	560.5439	61	2026.7	367.7904
175%	809.4927	59	2517.8	555.7028

In the above table device represents DSTATCOM. Graphical representation of the voltages for the four loading conditions is as follows,

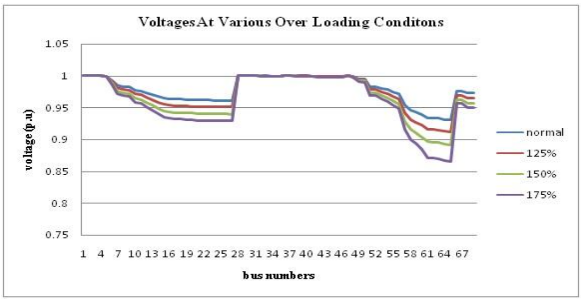

Fig.14.Voltages Of Various Loading Conditions

8. CONCLUSION

The combination of fuzzy and PSO used as a two-stage methodology in this paper to reduce the power loss and to improve the voltage profile in radial distribution system. Various optimal locations are obtained by the DSTATCOM suitability index from fuzzy. Optimal sizes for the respective locations are obtained by using PSO.The result analysis also shows that the power loss of 125%, 150%, and 175% of normal loading is reduced and the voltage profile is maintained within the limits. The voltages of all the loading conditions are also compared in this paper.

10. REFERENCES

1. Kresting WH, Mendive DL. An application of ladder network theory to the solution of three phase radial load flow problem. In: IEEE PES winter meeting; 1976. p. 76044–8.
2. Gerbex S, Cherkaouti R, Germond A. Optimal location of multi-type FACTS devices in a power system by means of genetic algorithms. IEEE Trans Power Syst 2001;16(3):537–44.
3. Sensarma PS, Padiyar KR, Ramanarayanan V. Analysis and performance evaluation of a distribution STATCOM for compensating voltage fluctuations. IEEE Trans Power Del 2001;16(2):259–64.
4. Teng Jen-Hao. A direct approach for distribution system load flow solutions. IEEE Trans Evol Comput 2003;18:882–7.
5. Twining E, Newman MJ, Loh PC, Holmes DG. Voltage compensation in weak distribution networks using a DSTATCOM. In: IEEE conf PEDS, vol. 1; 2003. p. 178–83.
6. Masdi H, Mariun N, Mahmud S, Mohamed A, Yusuf S. Design of a prototype DSTATCOM for voltage sag mitigation. In: IEEE conf power and energy; 2004. p. 61–6.
7. Wang Zhuding, Chen Fen, Li Jingui. Implementing transformer nodal admittance matrices into backward forward sweep-based power flow analysis for unbalanced radial distribution systems. IEEE Trans Power Syst 2004; 19:1831–6.
8. Jabr Rabih A. Radial distribution load flow using conic programming. IEEE Trans Power Syst 2006;21:1458–9.
9. Del Valle Y, Hernandez JC, Venayagamoorthy GK, Harley RG. Multiple STATCOM allocation and sizing using particle swarm optimization. In: IEEE conf power systems and exposition; 2006. p. 1884–91.
10. Somsai K, Kulworawanichpong T. Modeling, simulation and control of DSTATCOM using ATP/EMTP. In: 13th IEEE conf harmonics and quality of power; 2008. p. 1–4.
11. Sumpavakup C,Kulworawanichpong T. Distribution voltage regulation under three-phase fault by using DSTATCOM, vol. 30; 2008. p.855–9 [ISNN 1307- 6884].
12. M. Damodar reddy and N.V.Vijay kumar, "Optimal capacitor placement for loss reduction in distribution system using fuzzy and harmony search algorithm", ARPN journal of Engineering and applied sciences, vol.7, No.1, January 2012, ISSN 1819-6608.
13. M. Damodar reddy and K.Dhanunjaya Babu "optimal placement of SVC using fuzzy and PSO algorithm" International journal of engineering research and applications, vol.3, Issue 1, January- February 2013 ,ISN: 2248-9622.
14. Seyed Abbas Taher and Seyed Ahmadreza Afsari " optimal location and sizing of DSTATCOM in distribution systems by immune algorithm" electrical power and energy systems 60(2014) 34-44.
15. S.Devi and M.Geethanjali " optimal location and sizing of Distribution static synchronous series compensator using particle warm optimization" electrical power and energy systems 62(2014) 646-653.