ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.3 , No.5, Pages : 72-76 (2014)
Special Issue of ICACSSE 2014 - Held on October 10, 2014 in St.Ann's College of Engineering & Technology, Chirala, Andhra Pradesh

Optimal Location of STATCOM for Voltage Security Enhancement Using PSO

K.Praveena kumari[1], V.Srikanth Babu[2]
[1]M.Tech (student),Department of EEE, GMRIT, AP, India, praveenakilli@gmail.com
[2]Assistent professor, Department of EEE, AP, India,vsrikanthbabu@gmail.com

Abstract *:* Maintaining the power system security is a major task for the power system. Contingency analysis is used to know the effect at of the outages like failure of the equipment, transmission lines, etcs. Contingency analysis calculates the voltage violations. FACTS devices are used to reduce the voltage violations in the power system. STATCOM is the one of the shunt connected FACT s device which injects or observe the reactive power in the transmission lines.PSO algorithm is used for finding the optimal location of the STATCOM due to the cost of the FACTs devices. After placing the STATCOM perform the contingency analysis. The proposed methodology test on IEEE30 bus system.

Key words : Contingency analysis, Flexible AC Transmission lines, Partical Swarm Optimization.

INTRODUCTION

The power system operation is said to be normal when the power flows and the bus voltages are within acceptable limits despite changes in load or available generation. From this perspective, security is the probability of a power system's operating point remaining in a viable state of operation[1].

Contingency Analysis (CA)[4] is one of the "security analysis" applications in a power utility control center that differentiates an Energy Management System (EMS) from a less complex SCADA system. Its purpose is to analyze the power system in order to identify the overloads and problems that can occur due to a "contingency". A contingency is the failure or loss of an element or a change of state of a device in the power system. Contingency analysis is used to predict which contingency makes system violations and rank the contingency according to their relative severity. There are various Performance Index [6]for finding the contingency ranking. Reinsertion of a voltage in the power system can be increased by FACTs devices.

FACTS devices are the solid state converters having capability of improving power transmission capacity, improving voltage profile, enhancing power system stability and security, minimizing transmission losses etc. FACTS devices [3] include static synchronous compensator (STATCOM), static var compensator (SVC), thyristor controlled series compensator (TCSC), unified power flow controller (UPFC) etc. TCSC is connected in series with the transmission line to compensate for inductive reactance of the transmission line. SVC and STATCOM are connected in shunt with the system. Though, the primary purpose of STATCOM is to support bus voltage by injecting or absorbing the reactive power by means of thyristor controlled elements, it is capable
of improving the power system stability also. The UPFC is capable of providing voltage, active and reactive power control and it regulates all the three variables simultaneously.

The STATCOM consists of one VSC and its associated shunt-connected transformer. It is the static counterpart of the rotating synchronous condenser but it generates or absorbs reactive power at faster rate because no moving parts are involved. It performs the same voltage regulation function as the SVC but in more robust manner because, unlike the SVC its operation is not impaired by the presence of low voltage[2]. Due to the cost of the FACTS devices, it is necessary to find the optimal location in the transmission line to gain the maximum benefits of the devices. For finding the optimal solution there are conventional [9] and computational techniques [7].

Conventional technique like mixed integer linear and non linear programming is time consuming and they are iterative, and require heavy computational burden and slow convergence. Recently, nature inspired computational techniques such as Genetic Algorithms (GA)[8],Evolutionary programming and Particle Swarm Optimization(PSO) are using to obtain the optimal location of FACTS devices with promising results. Genetic Algorithm has been implemented for finding the optimal location of the FACTs devices. PSO algorithm is implemented for optimal location of various FACTS devices considering the cost of installation and system loading. Voltage security has to be considered for optimal location of STATCOM[5].

In this paper, Voltage violations are consider for finding the optimal location of the STATCOM.As a first step contingency ranking is performed based on performance index and find the bus voltages. After then PSO algorithm implemented for optimal location of the STATCOM to decrease voltage violations. Then after, placing the STATCOM in the Transmission line applied contingency analysis and bus outages.

ISSN 2278-3091
International Journal of Advanced Trends in Computer Science and Engineering, Vol.3 , No.5, Pages : 72-76 (2014)
Special Issue of ICACSSE 2014 - Held on October 10, 2014 in St.Ann's College of Engineering & Technology, Chirala, Andhra Pradesh

II.PROBLEM IMPLIMENTATION

STATCOM is a second generation FACTS device used for shunt reactive power compensation. The principle of STATCOM is that by adjusting reactive power, the voltage magnitude of connected system can be controlled. The STATCOM is a combination of a voltage source converter and a reactance, which is connected in shunt to power system. The converter supplies leading current to the AC system if the converter output voltage is made higher than the corresponding AC system bus voltage and then it supplies reactive power to the AC system by capacitive operation. Conversely, the converter absorbs lagging current from the AC system, if the converter output voltage is made less than the corresponding AC system bus voltage. In this condition, it absorbs reactive power from the AC system by inductive operation. If the output voltage is equal to AC system voltage, no reactive power will be exchanged.

In a power system, it is desirable to keep the voltage deviations within say ± 5% to their base case magnitude to maintain the secure operation of power system. In general, if the load requirement to increase the voltage at corresponding bus may drop below 0.95p.u. and consequently an additional voltage support will be provided by a STATCOM. In this paper, the optimal location of STATCOM will be determined by using PSO for maintaining load bus voltages within ± 5% of their base case value respectively. The main objective function of this work is to determine the optimal location of the STATCOM in a power system to enhance the voltage security. This can be achieved by minimizing bus voltage limit violations and MVAR rating of the STATCOM.

A.Objective function:

$$MinJ = \sum_{i=1}^{Nbus} (V_i - 1)^2 + \eta/100 \quad \textbf{(1)}$$

Minimize $|V_i - 1| \leq 0.05$

J=Objective function
Vi is the voltage at bus I in p.u
Vi-1 is the voltage deviation at bus I in p.u
N_{bus} is the total number of load buses
η =STATCOM rating.

B.Contingency Analysis And Ranking:

To measure the severity of particular outage in a power system, the voltage performance index (VPI) is considered, which evaluates the severity of a contingency from the viewpoint of voltage violation limit at buses. The voltage performance index used in this paper is as follows.

$$VPI = \sum_{i}^{n} \left(\frac{\Delta V_i}{\Delta V_{\max}} \right)^{2m} \quad (2)$$

Where ΔVi is the difference between the voltage magnitude as obtained by using full AC load flow for the line outage simulation and the base case voltage magnitude and $\Delta Vmax$ is a value set by the utility engineers indicating how much they wish to limit a bus voltage from changing on one outage case.

III.OVERVIEW OF PSO

PSO is an population based computation technique developed by Eberhart and Kennedy in 1995, and was inspired by the social behavior of bird flocking and fish schooling [10,11]. It utilizes a population of individuals, called particles, which fly through the problem hyperspace with some given initial velocities. In each iteration, the velocities of the particles are stochastically adjusted considering the historical best position of the particles and their neighborhood best position, where these positions are determined according to some predefined fitness function. Then, the movement of each particle naturally evolves to an optimal or near-optimal solution.

PSO technique finds the global best solution by simply adjusting the trajectory of each individual toward its own best location and toward the best particle of the entire swarm at each time step (iteration). The PSO method is becoming very popular due to its simplicity of implementation and ability to quickly converge to a reasonably good solution[12]. In the PSO algorithm, the trajectory of each individual in the search space is adjusted by dynamically altering the velocity of each particle, according to its own flying experience and the flying experience of the other particles in the search space. The position vector and the velocity vector of the *ith* particle in the *d*-dimensional search space can be represented as *Xi*=[*xi1*,*xi2*,………,*xid*] and *Vi*=[*vi1*,*vi2*,………,*vid*] respectively. According to a user defined fitness function, say the best position of each particle (which corresponds to the best fitness value obtained by that particle at iteration *k*) is *Pi*=[*pi1*, *pi2*,…, *pid*], and the fittest particle found so far at iteration *k* is *Pg*=[*pg1*, *pg2*,…, *pgd*]. Then, the new velocities and the positions of the particles for the next fitness evaluation are calculated using the following two equations:

$$v_i(k) = w_i . v_i(k-1) + c_1 . rand_1 . (p_i - x_i(k-1)) + c_2 . rand_2 . (p_g - x_i(k-1)) \quad (3)$$

(3)

$$x_i(k) = x_i(k-1) + v_i(k) \quad \textbf{(4)}$$

$$W_i = (W_{\max} - W_{\min}) * \frac{W_{\max} - iter}{iter_{\max}} + W_{\min} \quad \textbf{(5)}$$

Where

C_1=C_2=2

W_{max}=0.9 and W_{min}=0.4

Where *c1* and *c2* are constants known as acceleration coefficients, and *rand1* and *rand2* are two separately generated uniformly distributed random numbers in the

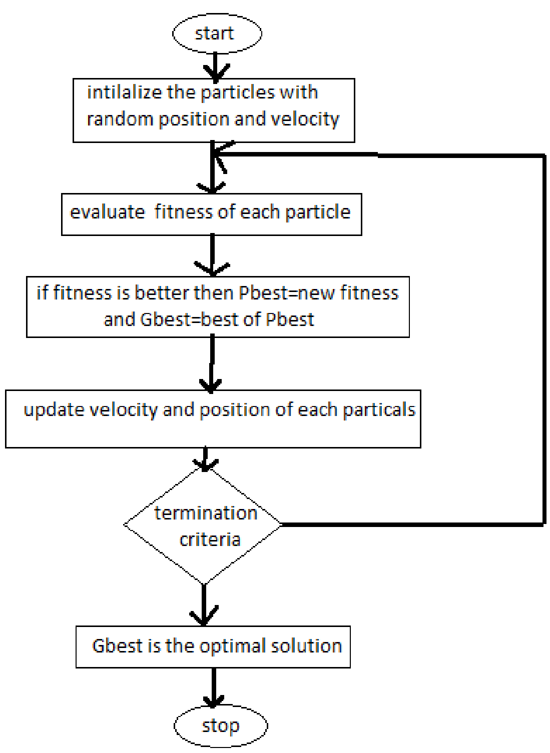
ISSN 2278-3091
International Journal of Advanced Trends in Computer Science and Engineering, Vol.3 , No.5, Pages : 72-76 (2014)
Special Issue of ICACSSE 2014 - Held on October 10, 2014 in St.Ann's College of Engineering & Technology, Chirala, Andhra Pradesh

range [0, 1].The first part of (3) known as "inertia" or "momentum"

or "habit" represents the previous velocity. This provides the necessary momentum for particles to roam across the search space. The second part, known as the "cognitive" or "memory" component, represents the personal thinking of each particle.

The cognitive component encourages the particles to move toward their own best positions found so far. The third part is known as the "social knowledge" or "cooperation" component, which represents the collaborative effect of the particles, in finding the global optimal solution. The social component always pulls the particles toward the global best particle found so far. Initially, a population of particles is generated with random positions, and then random velocities are assigned to each particle. The fitness of each particle is then evaluated according to a user defined objective function. At each iteration, the velocity of each particle is calculated according to (3) and the position for the next function evaluation is updated according to (4). Each time if a particle finds a better position than the previously found best position; its location is stored in memory.

Flow Chart of PSO Algorithm



The implementation of PSO algorithms considering single line outages for optimal location of STATCOM is summarized in following steps:

Step1: Initialization

Initially the particle is defined as a vector which contains the randomly selected STATCOM location (the bus number at which a STATCOM is placed) as shown below.

Particle: [λ,η]

Where

λ:is the STATCOM bus location number.

η: is the STATCOM size in MVAR

Step2: Calculation of fitness function

The constrained optimization problem of optimal location of STATCOM device is converted into an unconstrained optimization problem using penalty factor as given below.

Fitness function = Objective function J + Penalty Factor

$f(x) = J + PF$

The fitness function used in PSO algorithm consists of two terms:

J the original fitness function and the penalty factor PF corresponding to the constraints violation.

Step3: New velocity and position for each particle is calculated using (3) and (4).

Step 4: Repeat step (2) to step (3) until certain Termination condition is met.

Step5: The optimal location and size of STATCOM is evaluated using PSO-TVAC algorithm implemented through

Step 1 to 4 considering most severe line outages one by one.

IV.SIMULATION RESULTS

PSO algorithm is implemented for finding the optimal location of the STATCOM in IEEE 30-Bus system [24]. This system comprises of 1 slack bus, 5 PV bus, 24 PQ buses and 41 lines. Under base case condition, voltage at all buses is slightly above 1p.u. except at bus no.30 (0.9943 p.u.), therefore system is secured. However during single line outage contingencies voltages at some buses violating voltage limit condition, and this is indicated by *VPI*. For placement of STATCOM, the 24 PQ buses (load buses) have been considered as possible locations to overcome voltage limit violation condition. The Newton-Raphson Load Flow Program converged for 37 lines out of 41 lines.

The contingency analysis of Voltage Performance Index is shown in Table1 and BUS outages in table 2. The most sever contingency performance index lines are 36,4 and 5.

Optimum location has been obtained by applying PSO algorithm. The numbers of particles considered for selecting the optimal location of the STATCOM are 24 (equal to number of load buses), each having some randomly selected values of STATCOM location. The Newton-Rapson Load Flow Program has been used for calculating the two objective functions as given by (1). The PSO algorithm is run for 200 maximum iterations. The acceleration coefficients ranges $c1$ and $c2$ from 2.0($c1$) to 0.5($c1$) and 0.5($c2$) to 2.0 ($c2$) and the weight varying from 0.9 to 0.4.The global optimal solution thus obtained by the particle having STATCOM location at bus 26 and 30 having global best value is 801.8436. The Statcom location as obtained by implementing PSO algorithm, so that voltages at the connected bus is maintained at 1.0 p.u..

ISSN 2278-3091
International Journal of Advanced Trends in Computer Science and Engineering, Vol.3 , No.5, Pages : 72-76 (2014)
Special Issue of ICACSSE 2014 - Held on October 10, 2014 in St.Ann's College of Engineering & Technology, Chirala, Andhra Pradesh

The new bus voltages after placing the STATCOM is shown in table 3. The VPI is increased for line 36 to 0.0359 From 0.8773 and for line 4 to 0.0157 from 0.6304 are shown in table 4.

Table1: Contingency Ranking

Line NO	VPI	Ranking
1	0.0998	5
2	0.0961	6
3	0.0041	40
4	0.6304	2
5	0.5047	3
6	0.0042	39
7	0.0395	7
8	0.0140	10
9	0.0193	9
10	0.0112	23
11	0.0110	37
12	0.0112	24
13	0.0108	38
14	0.0134	11
15	0.0018	41
16	0.0113	15
17	0.0132	12
18	0.0114	13
19	0.0114	14
20	0.0113	16
21	0.0113	17
22	0.0113	18
23	0.0113	19
24	0.0111	34
25	0.0111	35
26	0.0111	36
27	0.0112	25
28	0.0112	26
29	0.0113	20
30	0.0113	21
31	0.0112	27
32	0.0113	22
33	0.0112	28
34	0.0285	8
35	0.0112	29
36	0.8773	1
37	0.0112	30
38	0.3112	4
39	0.0112	31
40	0.0112	32
41	0.0112	33

Table2: BUS outages of the IEEE30 bus system

BUS NO	Voltage
1	1.0600
2	1.0430
3	1.0194
4	1.0071
5	1.0100
6	1.0118
7	1.0050
8	1.0100
9	1.0430
10	1.0353
11	1.0820
12	1.0437
13	1.0710
14	1.0352
15	1.0352
16	1.0351
17	1.0300
18	1.0174
19	1.0142
20	1.0195
21	1.0185
22	1.0173
23	1.0046
24	0.9835
25	0.9256
26	0.9158
27	0.9019
28	1.0115
29	0.8995
30	0.8645

By observing the table 2 and table 3 the bus voltages are increased after locating the STATCOM. And from the table 1 and table 4 the performance index is increased and the severity of the transmission lines are decreased due to STATCOM.

Table 3: Bus voltages after location of STATCOM

BUS NO	Voltage
1	1.0600
2	1.0430
3	1.0254
4	1.0171
5	1.0100
6	1.0148
7	1.0050
8	1.0100
9	1.0530
10	1.0467
11	1.0820
12	1.0599
13	1.0710
14	1.0450
15	1.0402
16	1.0471

ISSN 2278-3091

International Journal of Advanced Trends in Computer Science and Engineering, Vol.3 , No.5, Pages : 72-76 (2014)
Special Issue of ICACSSE 2014 - Held on October 10, 2014 in St.Ann's College of Engineering & Technology, Chirala, Andhra Pradesh

17	1.0415
18	1.0304
19	1.0277
20	1.0317
21	1.0345
22	1.0350
23	1.0296
24	1.0237
25	1.0203
26	1.0027
27	1.0269
28	1.0128
29	1.0071
30	0.9957

Table4: Improved VIP for 36,4 and 5 lines after placing STATCOM

Line NO	VPI
36	0.0359
4	0.0059
5	0.0270

CONCLUSION

In this paper PSO technique is implemented for finding the location of the STATCOM for voltage security enhancement. The contingency ranking is performed to determine the severity of line outages. After placing the STATCOM the voltages are maintained 1.0 p.u..Through the approach is implemented for IEEE 30 bus system. The same can apply for large system.

REFERENCES

[1] P. Kundur, Power system stability and control, New York McGraw-Hill,

[2] E. Acha, C.R. Fuerte, H. Ambriz and C. Angeles. FACTS :Modelling and Simulation in Power Networks, John Willey & Sons, Ltd.

[3] N.G.Hingorani, L.Gyugyi. "Understading FACTS:Conceot and technology of Flexible AC Transmission Syatem", IEEE Press,NewYork(2000).

[4] V.J.Mishra,Manisha D.K. "Contingency Analysis of Power System" International Conference on Emerging Frontiers in Technology for Rural Area (EFITRA) 2012.

[5] Stott B, Alsac O and Monticelli A.J, "Security Analysis and Optimization", Proc. IEEE, vol. 75,No.12, pp. 1623-1644,Dec 1987.

[6] Ejebe G.C and Wollenberg B.F, "Automatic Contingency Selection", IEEE Transactions on Power Apparatus and Systems, Vol. PAS-98, No.1, pp. 97-109, January 1979.

[7] L.J. Cai, I. Erlich, G. Stamtsis. "Optimal choice andallocation of FACTS devices in deregulated electricity market using genetic algorithms", *IEEE PES Power Systems Conference and Exposition, vol.1, pp. 201-207, (2004).*

[8] S. Gerbex, R. Cherkaoui, A.J. Germond. "Optimal location of multitype FACTS devices in a power system by means of genetic algorithms", *IEEE Transactions on Power Systems, vol. 16, pp. 537 – 544, (2001).*

[9] W. Ongsakul, P. Jirapong. "Optimal allocation of FACTS devices to enhance total transfer capability using evolutionary programming", IEEE International Symposium on Circuits and Systems,vol. 5, pp. 4175 – 4178, (2005).

[10] R. C. Eberhart and Y. Shi. "Particle swarm Optimization: Developments, applications and resources," in Proc. IEEE Int. Conf. Evolutionary *Computation*, , vol.1, pp. 81–86, (2001).

[11]] J. Kennedy and R. Eberhart. "Particle swarm optimization", Proc. IEEE Conf. Neural Networks,vol. 4, pp. 1942-1948, (2000).

[12]] R. Benabida, M. Boudour, M.A. Abido. "Optimal location and setting of SVC and TCSC devices using non- dominated sorting particle swarm optimization",Electric Power Systems Research, vol. 79, pp. 1668-1677, (2009).