Improvement of Voltage Stability Index & Reduction of Power Losses by Optimal Placements of Static VAR Compensator using PSO

M.V.Ramesh, M.Tech
Associate Professor,
Priyadarashini college of Engineering & technology,
Nellore, AP, India

Dr. V.C. Veera Reddy, PhD
Professor & Head of the Dept, EEE
S.V.University, Tirupathi, AP, India

Abstract

The existing transmission lines mismatch with increasing power demand. Hence, a small disturbance can lead to power system collapse when it is operating under stressed condition. This can be avoided by using different techniques such as the optimal placements of FACTS devices. In this paper, optimal ratings of SVCs are placed at each bus using PSO. The voltage stability index is considered as a criterion to place SVCs in normal & contingency conditions. The simulations are done on an IEEE 30 bus power system and results are presented.

Keywords: SVC, Voltage Stability index, Power loss, Voltage profile, PSO, IEEE 30 bus.

Introduction:

The problem of optimal location of FACTS devices is modeled as an optimization. The aim is to find the maximum amount of power that the power system is able to supply without overloading the lines and acceptable voltage limits. And also to maintain voltage & power losses are within the acceptable limits at normal, over load and contingency conditions different types of techniques are used in power system. FACTS devices are more predominated than compared to other techniques.

In normal operating conditions, the power system losses are the minimum and voltages are prescribed limits. The power system may be collapse due to the following reasons such as outage of a generating unit or of a line, sudden increasing or decreasing of the power demand. Most of the times, the system may remains as it original state within the limitations of voltage & power. But sometimes, it does not become to its original state. This phenomenon is called contingency. Contingency evaluation can be done by Fast-Decoupled Load Flow (FDLF) method. The planning and operation of interconnected large power systems is becoming complex. In this paper, SVC is used to improve voltage magnitudes and Power Flow through the lines. The Newton Raphson (NR) method is considered to obtain power flow with and without SVC. The simulations are performed on a modified IEEE 30 bus system and results are presented.

Voltage stability index:

The voltage-stability index (L - index) can be computed as,

$$L_j = |1-\sum_{i=1}^{g} F_{ji}\frac{v_i}{v_j}| \quad (1)$$

Where j = g +1... n

For a given operating condition

$$\begin{pmatrix} I_G \\ I_L \end{pmatrix} = \begin{pmatrix} Y_{GG} & Y_{GL} \\ Y_{LG} & Y_{LL} \end{pmatrix} \begin{pmatrix} V_G \\ V_L \end{pmatrix} \quad (2)$$

Rearranging (2), we obtain

$$\begin{pmatrix} V_L \\ I_G \end{pmatrix} = \begin{pmatrix} Z_{LL} & F_{LG} \\ K_{GL} & Y_{GG} \end{pmatrix} \begin{pmatrix} I_L \\ V_G \end{pmatrix} \quad (3)$$

Where, $F_{LG} = [Y_{LL}]^{-1}[Y_{LG}]^{-1}$ (4)

The procedure to obtain voltage stability index:

Step1: Form the network admittance matrix for the system.

Step2: Obtain the elements of F_{LG} by using equation (4).

Step3: Obtain the value of L-index by using the formula specified in the equation (1).

STATIC VAR COMPENSATOR: The Static var compensator is a shunt type of FACTS devices, which absorbs or injects reactive power at which it is connected. The size of the SVC is depends on the rating of current and reactive power injected into the bus.

Partial Swarm Optimization:

The step by step procedure for the proposed optimal placement of SVCs using PSO is given below:

Step 1: The number of devices to be placed is declared. The load flow is performed.

Step 2: The initial population of individuals is created satisfying the SVC & IPFC constraints.

Step 3: For each individual in the population, the fitness function is evaluated after running the load flow.

Step 4: The velocity is updated and new population is created.

Step 5: If maximum iteration number is reached, then go to next step else go to step 3.

Step 6: Print the best results.

Step 7: stop.

A CASE STUDY: The PSO based optimal placement of SVCs was implemented using MATLAB 7.5. The system tested on an IEEE 30-bus system. The following parameters are used for PSO based optimal location of FACTS devices.

- Population =50
- Maximum iterations=200
- Wmax=0.9 and Wmin=0.4
- Acceleration constants C1=1.4 and C2=1.4

The location and rating of the devices are found in different load and contingency conditions. The voltages at each bus, total power losses, the location and SVCs ratings are mentioned.

The voltage profiles and Line index values under different load conditions:

	Before compensation		After compensation	
Bus number	Voltage	Line index	Voltage	Line index
1	1.0600	-------	1.0600	-------
2	1.0430	-------	1.0430	-------
3	0.9949	0.0678	1.0060	0.0560
4	0.9938	0.0684	1.0072	0.0541
5	1.0100	0.0486	1.0100	0.0486
6	1.0018	0.0652	1.0158	0.0505
7	0.9945	0.0706	1.0097	0.0546
8	1.0100	0.0584	1.0100	0.0584
9	1.0396	0.0585	1.0764	0.0226
10	1.0272	0.0761	1.0829	0.0210
11	1.0820	0.0175	1.0820	0.0175
12	1.0401	0.0819	1.0818	0.0405
13	1.0710	0.0508	1.0710	0.0508
14	1.0204	0.1002	1.0810	0.0390
15	1.0149	0.1039	1.0749	0.0425
16	1.0140	0.1064	1.0789	0.0401
17	0.9984	0.1205	1.0764	0.0395
18	1.0030	0.1117	1.0671	0.0452
19	1.0002	0.1117	1.0663	0.0430
20	1.0059	0.1038	1.0695	0.0383
21	1.0105	0.0947	1.0792	0.0253
22	1.0111	0.0943	1.0807	0.0241
23	1.0014	0.1143	1.0753	0.0380
24	0.9945	0.1161	1.0662	0.0412
25	0.9931	0.1164	1.0737	0.0330
26	0.9694	0.1437	1.0591	0.0475
27	1.0038	0.1039	1.0754	0.0308
28	1.0004	0.0715	1.0186	0.0526
29	0.9770	0.1341	1.0643	0.0414
30	0.9615	0.1524	1.0566	0.0489

The locations of SVCs are considered at all the buses in IEEE 30 bus system.

	Before compensation the real power losses	After compensation the real power losses

Different load conditions	35.975	33.289
Contingency conditions (between 10 & 20)	36.897	33.6642

Optimal location of SVCs in different load, contingency conditions and its ratings in Mvar:

Optimal location of SVC at each bus	At different load conditions	At contingency conditions (10-20)
1	0	0
2	6	0
3	20	23
4	0	14
5	0	6
6	16	3
7	14	4
8	15	12
9	12	4
10	12	15
11	0	0
12	9	21
13	10	14
14	8	4
15	5	0
16	5	8
17	9	3
18	0	0
19	5	4
20	0	3
21	13	18
22	13	14
23	8	5
24	1	9
25	5	1
26	2	4
27	2	5
28	2	0
29	2	2
30	5	4

By comparing the above cases, the total power losses of the system are reduced and voltage levels are improved by the optimal location of SVC type of FACTS devices in an electrical power network.

Conclusion

In this paper, the optimal location of SVC are studied at different load & contingency conditions and various parameters such as voltage profile and real and reactive power flow in transmission lines are investigated using PSO. In this paper, we have proposed a PSO algorithm to places SVCs in an IEEE 30 bus system. The future scope of this paper is a complete cost benefit analysis has to be carried out to justify the economic viability of the SVC using different combination of optimization techniques.

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Authors:

M.V.Ramesh: B.Tech(EEE) from S.V.H.College of Engineering, Machilipatnam in 2000. M.Tech in

Power Electronics from J.N.T. University, Hyderabad (Autonomous) in 2005. Pursuing PhD in J.N.T. University, Hyderabad.

Dr. V.C.Veera Reddy: B.Tech(EEE) from J.N.T. University in 1979. M.Tech in power systems & operation control from S.V. University in 1981. Completed PhD from S.V. University in 1999.