Power Quality Improvement by Reactive Power Compensation Using PSO

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Abstract— Electrical power is essential component of our life. We usdo it for operating home appliances, computers, machines in industries , transportition ,etc.Every loadl needs good quality of power for proper operation and better life. This power quality can be improved by compensating the lines and reducing the losses. This is done by placing compensating devices optimally at different load buses. The compensation can be done in two steps, In the first step we select the candidate bus which needs compensatio and in the second step supplying appropriate reactive power.In this paper particle swarm optimization(PSO)method for compensation is implemented. This PSO technique randomly selects the compensating values within the limits for a selected bus.

Key words:Load Flow (LF), Particle Swarm Optimization (PSO), power loss, reactive power, voltage profile, Voltage Sensitivity Factor (VSF), Voltage Stability Index (VSI).

1. INTRODUCTION

Most of the loads on power system are inductive in nature and there is always deficiency of reactive power which increases loss and drop in voltage. Loads are connected to Distribution system, and are supplied at low level voltage and spread in a large area and there is always higher loss and drop in the voltage.

By Compensating for reactive power, the voltage profile can be mainained within the limits, and losses be reduced,and hence power quality can be improved. Not only that sysem also becomes reliable and life of equipment increases.The reactive power compensation is an optimization problem for power system engineers.

2. LITERATURE SURVEY

In the recent years, many research papers have been published on optimal capacitor placement and on optimization methods for optimal capacitor placement. Genetic Algorithm (GA) has been used for optimal selection of capacitors in radial system [1]. Ant colony optimization algorithm and sensitivity-based approach have been tested for capacitor placement at various load level to minimize the total losses of the system. To optimally allocate by Loss Sensitivity Factor (LSF) and to find required MVAr demand of shunt capacitors in the system for loss minimization by PSO [2]. In this paper Loss Sensitivity Factors is used for finding candidate buses for optimal capacitor placement and sizing by Particle Swarm Optimization [3-6].

3. SYSTEM UNDER STUDY

3. 1 SYSTEM DETAILS

The system(Fig 1) considered for implementation of PSO algorithm is IEEE 14 bus system with 20 lines, 11 loads,3 transformers, 9 PQ buses, 4 PV buses and 1 slack bus.Bus 1 is selected as slack bus.Base MVA is 100.

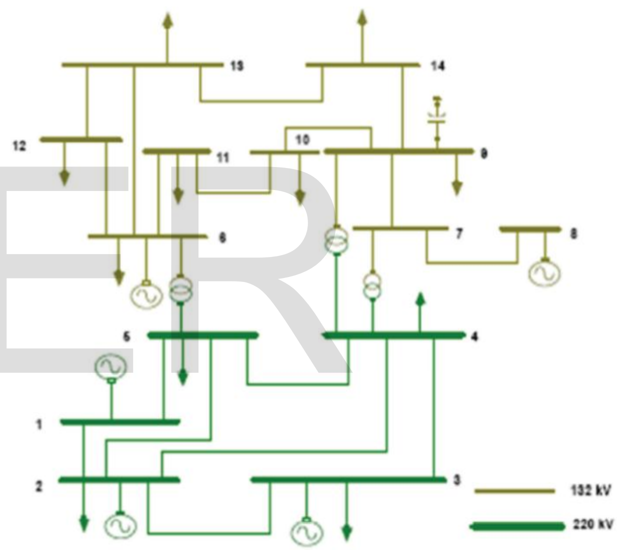

Fig 1. IEEE 14 bus

3.2 BUS DATA FOR GIVEN SYSTEM

Bus data is given below for IEEE 14 bus system. The bus angles are assumed to be zero. A capacitor of 5.263 MVAR is connected at bus 9. Bus 1 is considered as slack bus for analysis.

Table 1. IEEE 14 bus data

Bus	voltage	Pgi	Qgi	Pli	Qli	Qmin	Qmax
1	1.06	0	0	0	0	0	0
2	1.045	40	42.4	21.7	12.7	-40	50
3	1.01	0	23.4	94.2	19	0	40
4	1	0	0	47.8	-3.9	0	0
5	1	0	0	7.6	1.6	0	0
6	1.07	0	12.2	11.2	7.5	-6	24

7	1	0	0	0	0	0	0
8	1.09	0	17.4	0	0	-6	24
9	1	0	0	29.5	16.6	0	0
10	1	0	0	9	5.8	0	0
11	1	0	0	3.5	1.8	0	0
12	1	0	0	6.1	1.6	0	0
13	1	0	0	13.5	5.8	0	0
14	1	0	0	14.9	5	0	0

4. PROBLEM DESCRIPTION

4.1 POWER FLOW DEATAILS

In the power system power flows from generating station to loads through lines. So, we have to find bus voltages and power flow through the lines. Power flow equations are as follows for Newton Raphson method.

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = [J]\begin{bmatrix}\Delta\delta\\ \Delta V\end{bmatrix} \quad (1)$$

$$[J] = \begin{bmatrix}J1 & J2\\ J3 & J4\end{bmatrix} \quad (2)$$

$[J]$ = Jacobian matrix found from the differentials of active and reactive power. The equations of active and reactive power are :

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j) \quad (3)$$

$$Q_i = -\sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j) \quad (4)$$

Finding mismatch vectors

$$\Delta P_i^r = P_i(scheduled) - P_i^r(calculated) \quad (5)$$

$$\Delta Q_i^r = Q_i(scheduled) - Q_i^r(calculated) \quad (6)$$

Update voltage and angles

$$|V_i|^{(r+1)} = |V_i|^r + |\Delta V_i|^r \quad (7)$$

$$\delta_i^{r+1} = \delta_i^r + \Delta\delta_i^r \quad (8)$$

4. 2 FITNESS FUNCTION

The capacitor placement considered to determine the locations, types, number and sizes of capacitors to be installed in a system. The objective is to reduce the losses in the system and maintain the voltage magnitudes of the system within limits for different load levels.

The objective function of the problem is given by ,

$$Min\ P_{tloss} = \sum_{i=1}^{n_b} P_{i,loss} \quad (9)$$

Where P_{tloss} = total loss of the system
n_b = total number of buses
$P_{i,loss}$ = loss of bus i

With the constraints,

$$V_{min} \le V_i \le V_{max} \quad (10)$$

$$Q_{min} \le Q_i \le Q_{max} \quad (11)$$

where
V_{min}&V_{max} = min and max voltage limits
Q_{min}&Q_{max} = min and max reactive power limits
V_i&Q_i = updated values

5. SELECTION OF THE CANDIDATE BUSES TO LOCATE CAPACITOR

For the selection of the candidate buses to locate capacitor ,two sensitivity factors are choosen.

A. Voltage Stability Index (VSI): It is the change in voltage with respect to change in injected reactive power at i_{th} bus and expressed by using equation (12).

$$VSI = \frac{dV_i}{dQ_i} \quad (12)$$

This is found from the reciprocal of J4 matrix elements of jacobin matrix. these values of all load buses should arrange in descending order and compensation priority is given for higher and positive values of VSI. Because it indicates how much is the change of bus voltage for respective injection of reactive power.

B. Voltage Sensitivity Factor (VSF) : It is the ratio of bus voltages to 0.95 and given by following equation :

$$VSF_{(i)} = \frac{V_i}{0.95} \quad (13)$$

Where $VSF_{(i)}$= normalised VSF of bus i.

$VSF_{(i)}$ is arranged in the ascending order, the values which are below 1.000 are needed for compensation. The table below gives VSI and VSF ordering for the compensation of IEEE 14 bus.

Table 2. Bus order for compensation based on VSI&VSF.

VSI	BUS NO	VSF	BUS NO
0.1842	14	1.0685	4
0.1752	12	1.0713	5
0.1123	11	1.0788	14
0.0898	13	1.0918	10
0.0655	10	1.0940	9
0.0485	7	1.1030	13
0.0397	9	1.1051	11
0.0276	5	1.1085	7
0.0254	4	1.1093	12

6. Sizing of Capacitor

Capacitor sizing is done using particle swarm optimization. This PSO technique is more useful than any other methods. It requires less parameters, contains no derivative term hence computationally less complex with higher speed. Also, has no cross-over and mutation operators like in genetic algorithm.

In PSO thorough investigation is made with the help of a population size of particles corresponding to every individual. Here each one is considered as 'particle', which indicates a candidate solution to the problem. Each particle moves around with a velocity in the multidimensional search space. Velocity is continuously updated by the particle's self experience and also with the nieghbour particle's experience. This common PSO always compares the current global best and the individual best to update a global best. The updating formula of the i^{th} particle's velocity and position at previous iteration is given by,

Update acceleration co efficient matrices,

ac11 = rannum1*ac1 for common PSO w/inertia
ac22 = rannum2*ac2 (14)

where
ac1&ac2= acceleration co efficients.
rannum1&rannum2= matrices of random numbers.

Update velocity,

$vel_i = iwt_i*vel_{i-1}$ ... previous velocity
$+ac11*(pbest_i-pos_{i-1})$ ... independent
$+ac22*(gbest-pos_{i-1}$ social (15)

where
iwt_i = iteration weight at ith iteration.
vel_i= velocity of particle at ith iteration.
$pbest_i$= best of ith iteration.
gbest= best of gbest.
pos_{i-1}= previous position.

Update new position,

$pos_i = pos_{i-1} + vel_i$ (16)

where
pos_i= updated position of particles at ith iteration.

with weightage factor for ith iteraration,

$$iwt_i = \frac{(iw2-iw1)}{(iwe-1)} * (i-1) + iw1 \quad (17)$$

where
iw1=initial inertia weight.
iw2=final inertia weight.
iwe= iteration at final value.

It is below the iteration at final value. The particle velocity should be within the boundary of limits $[V_{min}\ V_{max}]$.

7. Algorithm

1. Read the system busdata, linedata, transformer tapingdetails and their position.
2. Run load flow and get values of bus voltage, respective line losses, and jacobian matrix.
3. Arrange the buses based on VSI and VSF to select candidate buses for capacitor placement.
4. Set constraints limits and set PSO parameters
5. Initialize randomly the population of particles and their velocities at time zero within the limts.
6. Start iteration and assume pbest is gbest initially.
7. Assign compensation values to candidate buses. Run load flow analysis and store the loss values as pbest.
8. If current fitness value is optimum than previous pbest then assign current fitness value to pbest. otherwise kept pbest as it is.
9. Assign best of pbest to gbest.
10. Update particle velocity and position.
11. Continue upto last iteration.and check the voltages whether within the limts or not.
12. Choose best of gbest as global gbest.
13. Run loadflow analysis. And get the optimum power loss of the sytem with the updated compensation values at candidate buses.

8. Results

8.1 Voltage profile details.

The following table gives the details of voltage profiles before and after compensation. We can observe that after compensation voltage profile is improved. The corresponding graph is also shown for reference.

Table 3. Voltage profile before and after compensation

Bus No.	Before Compensation V (p.u)	After compensation V (p.u)
1	1.06	1.06
2	1.045	1.045
3	1.01	1.01
4	1	1.0227
5	1	1.0292
6	1.07	1.07
7	1	1.06
8	1.09	1.09
9	1	1.05
10	1	1.0506
11	1	1.0586
12	1	1.0599
13	1	1.057
14	1	1.0525

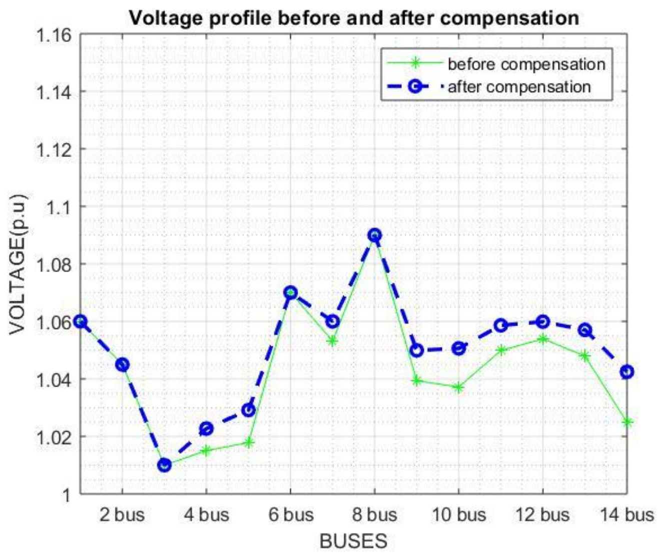

Fig.2 Voltage profile before and after compensation

8.2 Compensation & Reduced loss details

Table 4 gives the details of shunt compensation and table 5. gives reduced losses information.

Table 4. shunt connected MVAR at all buses.

Bus No.	Qsh Before Compensation (p.u)	Qsh After compensation (p.u)
1	-	0
2	-	0
3	-	0
4	-	0
5	-	25.831
6	-	0
7	-	0
8	-	0
9	5.263	2.8665
10	-	5.8714
11	-	2.0524
12	-	0.9831
13	-	6.2405
14	-	5.0494
total	5.263	48.894

Table 5. Reduced losses at all buses.

	MW	MVAR
Before compensation	13.495	56.862
After compensation	13.257	55.326

9. CONCLUSION

PSO algorithm method is successfully used for allocation of compensating device.By compensating the load buses we can improve voltage profile of the system and maintained almost flat and losses be reduced. Hence, power quality can be improved.

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