VOLTAGE STABILITY MARGIN ENHANCEMENT THROUGH OPTIMAL LOCATION OF VAR COMPENSATOR

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Abstract:

It is well known that voltage stability enhancement margin is interrelated with reactive power loss. To minimize the reactive power loss, location and placement of reactive power improvement devices is a major task. This paper introduces a PSO based method to find the location of series capacitors to be implanted to minimize the total reactive power loss in a power system network. The established indicator dQ_{loss}/dK_s *is used for the voltage stability assessment and also to find the change in reactive power loss. So obtained the series compensation requirement with the degree of compensation* K_s*, the voltage stability assessment is carried out on an IEEE-14 and IEEE-30 bus system. The Evolutionary computing algorithms are applied to minimize the series reactive power loss with the optimal degree of compensation. The stability assessment of the system also was carried out with* K_s *using PSAT. The Particle Swarm optimization results are compared with the solution obtained by the Genetic Algorithm(GA) .The comparison shows that the proposed Particle swarm optimization(PSO) technique of series reactive power loss minimization with the optimal location of series capacitors is more efficient and effective.*

1. Introduction:

Voltage stability is the ability of a system to maintain steady acceptable voltages at all the buses in the system at all conditions. The ability to transfer reactive power from production source to consumption areas during steady-state operating conditions is a major problem of voltage stability. A system mainly enters a state of voltage instability when a disturbance, increase in load demand, or change in system condition causes a progressive and uncontrollable decline in voltage. Voltage instability [1, 2] can be mainly avoided by: (a) appropriate load shedding on the consumer network; (b) blocking the on-load tap changers; (c) reactive compensation (series and/or shunt).

A key contributing factor in voltage collapse is the rapid and progressive loss of voltage controllability due to reactive limit violations. The voltage stability problem can be analyzed with the conventional Q-V Curves. The Q-V curves is plotted from the results of load flow simulations with the slightly modified initial conditions Since the voltage stability is strongly related to reactive power balance as well as active power balance, the total loss of reactive power in the network can be an assessed with the static voltage stability index. Voltage stability problems normally occur in heavily stressed systems.

One of the major aspects of voltage stability is the capability of a system to transfer reactive power sources to sinks under steady operating conditions. Some of the reasons for minimizing transfer of reactive power through the network include the following.

a) To minimize the real and reactive losses for economic considerations. This can be illustrated by the following simple set of equations (1)

$$\left.\begin{aligned} I^2 &= \bar{I}.\bar{I}^* = \left[\frac{P-jQ}{\bar{V}^*}\right]\left[\frac{P+jQ}{\bar{V}}\right] = \frac{P^2+Q^2}{V^2} \\ P_{loss} &= I^2R = \frac{P^2+Q^2}{V^2}R \\ Q_{loss} &= I^2X = \frac{P^2+Q^2}{V^2}X \end{aligned}\right\} \rightarrow (1)$$

Note that the real and reactive losses across the series impedance of the transmission line are given by I^2R and I^2X, respectively. Observing the above equations we can see that the losses are minimized when the reactive power transfer is low and bus voltages are high;

b) To minimize the temporary voltage drop and hence achieve a faster recovery, the reactive power transfer mainly determines the magnitude of the over-voltage/under voltage.

c) Handling large amounts of reactive power consumed by the load requires equipment of larger size and rating, which leads to the higher cost of installation

Work has been done on reactive power dispatch and how it is linked to voltage stability. There are number of ways to minimize reactive power loss one of them is the incorporation of series capacitors. Series compensation in the form of capacitors helps reduce the series reactive power loss [3]. Yokoyama et al. [4] tried different line configurations and showed that the margin of total load demand is maximum when the total loss of reactive power is minimum.

Tare and Bijwe [5] developed an algorithm for reactive power optimization for voltage stability enhancement. They optimized the reactive power loss both at the present load and the critical load by monitoring the PV bus voltage magnitudes and transformer tap ratios. Chebbo et al [6] worked on reactive power dispatch incorporating voltage stability. Work has also been done on optimal reactive power planning strategy against voltage collapse in [13]

In this paper, the effect of series compensation on total reactive power loss (RPL) is analyzed since it has direct effect on total RPL and works best when it is most needed. The line currents are increased when the loads are increased. Since the decrease in RPL due to series capacitor is proportional with the square of the line current and the reactance of the transmission line, series compensation works best when the system gets closer to the instability point. The simulation results for IEEE-14 bus and IEEE-30 bus system.

2. The Location of Series Capacitors to Minimize the Total Reactive Power Loss

If the transmission line is from bus i to bus j with an impedance of $R_L+jK_SX_L$ where K_S=1, the SRPL across the line can be expressed as:

$$Q_{loss} = \left[V_i^2 + V_j^2 - 2V_iV_j \cos(\delta_i - \delta_j)\right] X_L \Big/ (X_L^2 + R_L^2) \longrightarrow (2)$$

So the change in SRPL for the compensated line can be expressed as $\frac{dQ_{loss}}{dK_s}$. The best line for the compensation can be found by searching the lines to maximize:

$$\left(\frac{X_{org}}{X_L}\right) * \sum_{i=1}^{N_{line}} dQ_{loss} \Big/ dK_S \longrightarrow (3)$$

If the line is not compensated, the last term in the summation will be equal to zero.

Where N_{line} is the total number of the lines, K_S is always taken as unity, $\frac{dQ_{loss}}{dK_s}$ Values are scaled with X_{org} $/X_L$, X_{org} is the original reactance of the compensated line.

Continuation power flow Continuation power flow (CPF) has been used in voltage stability studies and power flow equations are adapted to continuation method. Locally parameterized continuation method is simulated using PSAT and is used to obtain the entire, more specifically, the nose of the Q–V curve [9, 10].

Since the summation of power at any of the buses is equal to zero we have:

$0 = P_{Gi} - P_{Li} - P_{Ti}$

Where

$$P_{Ti} = \sum_{j=i}^{N} V_i V_j Y_{ij} \cos(\theta_{ij} + \delta_i - \delta_j) \longrightarrow (4)$$

$0 = Q_{Gi} - Q_{Li} - Q_{Ti}$

Where

$$Q_{Ti} = -\sum_{j=i}^{N} V_i V_j Y_{ij} \sin(\theta_{ij} + \delta_i - \delta_j) \longrightarrow (5)$$

The subscripts *Gi*, *Li*, and *Ti* denote for load, generation, and injection for bus i, respectively. The voltages at bus i and j are represented as V_i angle δ_i and Vj angle δj, respectively and Yij angle θij is the (i, j) *th* element of the bus admittance matrix $[\mathbf{Y}_{BUS}]$ Eqns. (3) and (4) can be rewritten as:

$$F(\delta, V, K_S) = 0 \longrightarrow (6)$$

The dimension of F is $2n_1+n_2$ where $n1$ and $n2$ are the number of PQ and PV buses respectively. Taking the derivative of both side of Eq. (5) will lead to a relationship between the voltages and the degree of the compensation as in Eq. (6).

$$d[F(\delta,V,K_S)] = F_\delta d\delta + F_V dV + F_{Ks} dKs = 0 \longrightarrow (7)$$

where,

$$F_\delta = \partial F/\partial\delta,\ F_V = \partial F/\partial V,\ F_{Ks} = \partial F/\partial Ks \longrightarrow (8)$$

Solving further we get:

$$F_\delta d\delta/ dKs + F_V dV/ dKs = - F_{Ks} \longrightarrow (9)$$

Since $\partial(P_{Gi} - P_{Li}, Q_{Gi} - Q_{Li})/ \partial(\delta, V, Ks) = 0$ for PQ buses and $\partial(P_{Gi} - P_{Li})/ \partial(\delta, V, Ks) = 0$ for PV buses the final expression is obtained as :-

$$\begin{bmatrix} d\delta/dK_s \\ dV/dK_s \end{bmatrix} = \begin{bmatrix} \partial P_t/\partial\delta & \partial P_t/\partial V \\ \partial Q_t/\partial\delta & \partial Q_t/\partial V \end{bmatrix}^{-1} \begin{bmatrix} \partial P_t/\partial K_s \\ \partial Q_t/\partial K_s \end{bmatrix} \longrightarrow (10)$$

If compensated line is not connected to bus i then $\partial P_T/\partial K_S$, $\partial Q_T/\partial K_S$ are equal to zero

After compensation which is decreasing the reactance of lines the voltage magnitudes and angles can be updated using:-

$$\left.\begin{aligned} V^{k+1} &= V^{k} + X_{org} \Big/ X_{L} * \left(dV^{k} \Big/ dK_{s} \right) * \Delta K_{s} \\ \delta^{k+1} &= \delta^{k} + X_{org} \Big/ X_{L} * \left(d\delta^{k} \Big/ dK_{s} \right) * \Delta K_{s} \end{aligned}\right\} \rightarrow (11)$$

Where dK_S could be any compensation step i.e. 0.01 means 1% compensation at each iteration. The larger step size gives larger error at the voltage values.

3. Particle Swarm Optimization (PSO)

3.1Introduction

Particle Swarm Optimization [10] (PSO) is one of the evolutionary optimization methods inspired by nature which includes evolutionary strategy (ES), evolutionary programming (EP), genetic algorithm (GA), and genetic programming (GP). In PSO algorithm, each member is called a "particle", and each particle flies around in the multi-dimensional search space with a velocity, which is constantly updated by the particle's own experience and the experience of the particle's neighbors. PSO is motivated from the simulation of the behavior of social systems, such as birds flocking and fish schooling. The basic assumption behind the PSO algorithm is that birds (particles) find food by flocking and not individually. This leads to the assumption that information is owned jointly in flocking. PSO is distinctly different from other evolutionary optimization methods in that it does not use the filtering operation (such as crossover and/or mutation) and the members of the entire population are maintained through the search procedure. The PSO algorithm requires less computation time and less memory because of the simplicity inherent in these systems

3.2 Implementation

Since its introduction, PSO has been successfully applied to optimize various continuous nonlinear functions. The objective in the case being discussed is to minimize the series reactive power loss in the system. To do so, the transmission lines, where the SRPL is maximum, are to be located and hence, series compensation is to be applied in these lines to minimize the losses. The objective function is:-

$Q_{loss} = [V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j)] * X_L \;/\; (X_L^2 + R_L^2)$

X_l is the variable in this case. Usually, a practical upper limit, lesser than 1, is chosen for the degree of compensation. This is because for K_{se}=1, the effective line reactance would become zero, so the smallest disturbance in the relative rotor angles of the terminal synchronous machines would result in the flow of large currents. Moreover, the circuit would become series resonant at the fundamental frequency, and it would be difficult tso control transient voltages and currents during disturbances. The practical upper limit chosen in this case is 70% i.e. upper limit for X_l is chosen as [1-(70/100)]* X_l= 0.3 X_l. A lower limit for compensation is also chosen as 10% i.e. 0.9 X_l. Hence, X_l is varied from 0.3 X_l to 0.9 X_l. The algorithm followed to optimize the objective function is as follows:-

STEP 1: The population size and the stopping criterion are chosen (number of iterations).

STEP 2: Each particle is randomly initialized, considering all the constraints. The iteration count is initialized. The constraint in this case is that the value of compensation has to be maintained between 10% to 70% i.e. within 0.3 X_l to 0.9 X_l.

STEP 3: If constraints are satisfied, the original reactance of the line is replaced with the changed reactance and power flow is conducted at each step. The change in voltages and other system parameters are updated accordingly.

STEP 4: The objective function is calculated and closeness of particles to the objective function is noted.

STEP 5: Pbest and Gbest are updated as:-

$$P_{best}(t+1) = \begin{cases} P_{best}(t) & if \quad P(t+1) > P_{best}(t) \\ P_i(t+1) & if \quad P(t+1) < P_{best}(t) \end{cases} \rightarrow (12)$$

$$G_{best}(t+1) = \begin{cases} G_{best}(t) & if \quad P_{best}(t+1) > G_{best}(t) \\ P_{best}(t+1) & if \quad P_{best}(t+1) < G_{best}(t) \end{cases} \rightarrow (13)$$

STEP 6: The constraints are checked again. If satisfied, move to step 7.

STEP 7: The end criterion is checked. If satisfied, move to step 12.

Else move to step 8.

STEP 8: Particle velocity is updated for N-1 dimensions

$$\begin{aligned} V^{t}_{ij} = {} & w * V_{ij}^{t-1} + C_1 * r_1 * (P_{best\ ij}^{t-1} - X_{ij}^{t-1}) \\ & + C_2 * r_2 * (G_{best\ i}^{t-1} - X_{ij}^{t-1}) \rightarrow (14) \\ & i = 1,2,\ldots, N_{D,}\ j = 1,2,\ldots, N_{par}\ . \end{aligned}$$

$$V_{\min} \le V \le V_{\max}$$

$$V_{\max} = \frac{(X_{\max} - X_{\min})}{N_a} \rightarrow (15)$$

$$V_{\min} = -V_{\max}$$

STEP 9: Particle position is updated for the above N-1 dimensions according to:-

$$X_{ij}^{t} = X_{ij}^{t-1} + V_{ij}^{t} \longrightarrow (16)$$

$$X_{\min} < X < X_{\max}$$

STEP 10: The position of the Nth dimension is now adjusted by satisfying its constraints.

STEP 11: The iteration count is incremented and step 4 is repeated for modified values.

STEP 12: END.

4. Genetic Algorithm

4.1 Introduction

Genetic Algorithm is a popular form of evolutionary computation that starts with a population of randomly generated candidates and evolves towards better solutions by applying Genetic operators such as selection, crossover and mutation. Genetic algorithms emphasize genetic encoding of potential solutions into chromosomes and apply genetic operators to these chromosomes. A crucial issue in applying genetic algorithms to a problem is how find a representation which can be searched efficiently.

A simple genetic algorithm is the one which uses binary representation, one point crossover, and bit-flipping mutation. Binary representation means that each individual will be represented by a number by a number of binary bits, 0 or 1. One point crossover is carried as follows: Given two binary strings, x and y, of length n. Generate a crossover point between 1 and n-1 uniformly at random, say r. then the first offspring consists of the first r bits of y and last n-r bits of y. The second offspring consists of the first r bits of y and last n-r bits of x. Mutation is carried out bit wise. That is, every bit of an individual has certain probability of being flipped from 0 to 1 or from 1 to 0. Details regarding the same are understood from [11].

In GA, a population of appropriate representations, of candidate trial solutions is maintained. Each individual of the population represents a search point in the space of the potential solutions, which is each individual represent a possible solution to the problem

4.2 Implementation Of Genetic Algorithm

Since its introduction, GA has been successfully applied to optimize various continuous nonlinear functions. The objective (as sated above) is to minimize the series reactive power loss in the system. To do so, reactive power loss in each and every line is calculated and the lines having maximum reactive power loss are selected and hence, series compensation is applied in these lines to minimize the losses. The objective function is:-

$Q_{loss} = [V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_i - \delta_j)]* X_L / (X_L^2 + R_L^2)$

X_L is the variable in this case. Random values of X_l are generated within the prescribed limits and the value which results in minimum value of the objective function is selected. The practical upper limit chosen in this case is 70% i.e. upper limit for X_l is chosen as $[1-(70/100)]* X_L= 0.3\ X_L$. A lower limit for compensation is also chosen as 10% i.e. 0.9 X_L. Hence, X_L is varied from 0.3 X_L to 0.9 X_L.

STEP 1: The constraint limits for the reactance of the line is set between 10% and 70%.

STEP 2: Random values of reactance are generated between the limits

```
xnew(w,t,1) = xmin + y(t,1).*((xmax-xmin)/((2^l)-1));
```

STEP 3: The values are converted to decimal- 8 bit

STEP 4: The values of generated reactances are put into the objective function

STEP 5: The fitness evaluation is done for the various reactance values

```
fmax (w,1) = max(fx(w,1))
fmin(w,1) = min(fx(w,1)
for i=1:z
ft(i,1) = (fmax(w,1) - fmin(w,1)) - fx(w,1);
    end
ftb = mean(ft);
for i=1:z
rl(i,1) = ft(i,1)/ftb;
end
end
```

STEP 6: The best fit is calculated

STEP 7: Selection based on the roulette wheel concept is done, the values providing the best fit being given a higher percentage on the wheel area so that values providing a better fit have higher probability of producing an offspring.

STEP 8: Crossover is performed on strings using midpoint crossover. Crossover provides incorporation of extra characteristics in the off springs produced.

STEP 9: Mutation is done if consecutive iteration values are the same

STEP 10: The new reactance's that satisfy the objective of minimization of reactive power loss and the corresponding losses are tabulated

5. Test Cases and result:

To verify the effectiveness of the proposed approach, simulation is performed on the IEEE -14 &IEEE -30 bus system. Series capacitors were employed in the system which changes the effective reactance of the line. The effect of this compensation on the system was analyzed and simulation was done using MATLAB and PSAT (Power System Analysis Toolbox). The various graphs and tabulations obtained are as follows:-

5.1 IEEE -14 bus system

Simulation Results for SRPL:

Maximum number of series capacitors: 3
Enter initial compensation value: 5
Enter the steps in which increment in compensation is desired: .01
Time taken for implementation=1.0160
Degree of compensation k=0.29

Table 1
Series Reactive Power Loss in IEEE 14 Bus System (PSO implementation)

From bus	To bus	SRPL (Without compensation)	SRPL(With compensation)
1	2	**12.963**	**4.828**
1	5	**11.643**	**6.774**
2	3	**9.599**	**6.664**
2	4	5.087	2.750
2	5	2.821	1.181
3	4	0.963	0.191
4	5	1.494	1.417
4	7	1.631	1.652
4	9	1.277	1.281
5	6	5.152	5.247
6	11	0.265	0.269
6	12	0.167	0.168
6	13	0.494	0.496
7	8	1.111	1.146
7	9	1.050	1.050
9	10	0.020	0.020
9	14	0.201	0.202
10	11	0.129	0.133
12	13	0.010	0.010
13	14	0.218	0.222

Table 2
Series Reactive Power Loss in IEEE 14 Bus System (Genetic Algorithm optimization)

From bus	To bus	SRPL (Without compensation)	SRPL(With compensation)
1	2	12.963	5.735
1	5	11.643	7.132
2	3	9.599	6.876
2	4	5.087	3.750
2	5	2.821	2.181
3	4	0.963	0.191
4	5	1.494	1.447
4	7	1.631	1.683
4	9	1.277	1.256
5	6	5.152	6.247
6	11	0.265	0.269
6	12	0.167	0.167
6	13	0.494	0.486
7	8	1.111	1.146
7	9	1.050	1.073
9	10	0.020	0.028
9	14	0.201	0.214
10	11	0.129	0.134
12	13	0.010	0.010
13	14	0.218	0.222

Table 3
IEEE 14 bus values- comparison

Line from-to	% Compensation	SRPL before Compensation	SRPL after genetic algorithm	SRPL after PSO optimization
1-2	8.782	**12.963**	5.735	4.828
1-5	9.399	**11.643**	7.132	6.774
2-3	8.447	**9.599**	6.876	6.664

Figure 1: PV curve for different levels of compensation (before optimization)

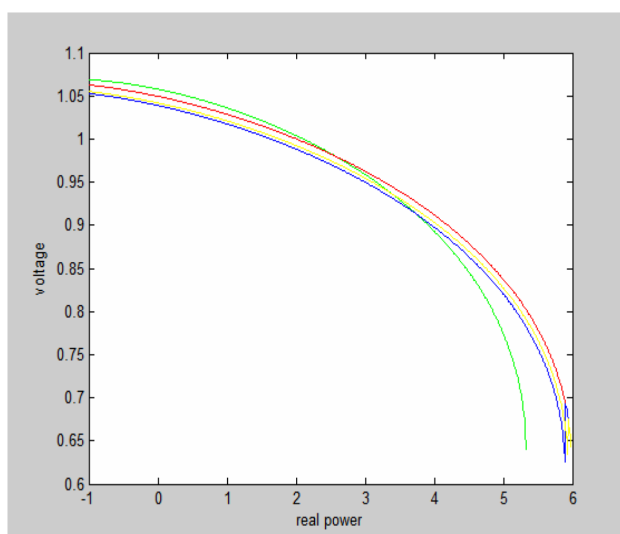

Figure 3: PV curve for different levels of compensation (Genetic Algorithm)

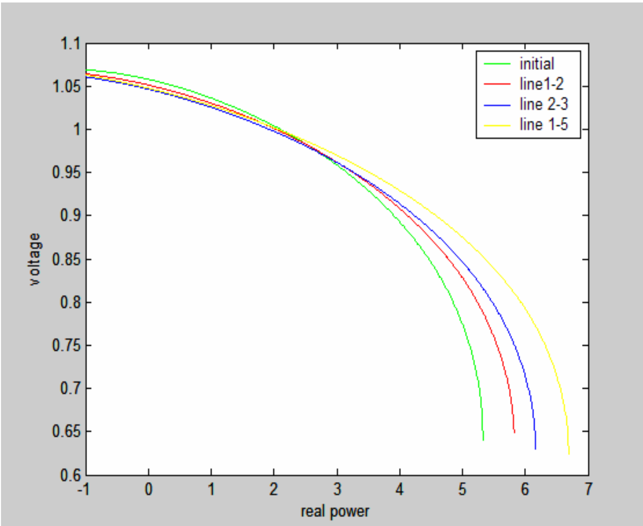

Figure 3: PV curve for different levels of compensation (PSO)

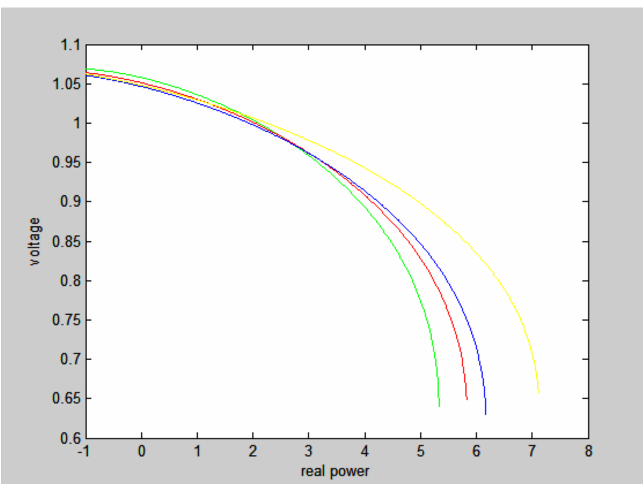

Figure4: V vs. loading parameter before optimization for bus -14

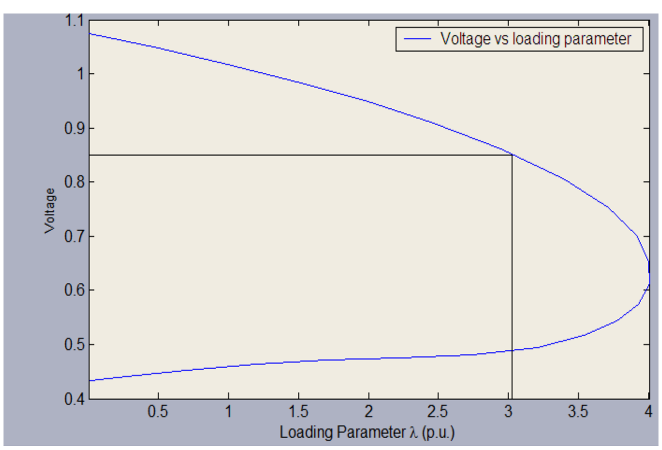

Figure5: V vs loading parameter for PSO optimization bus -14

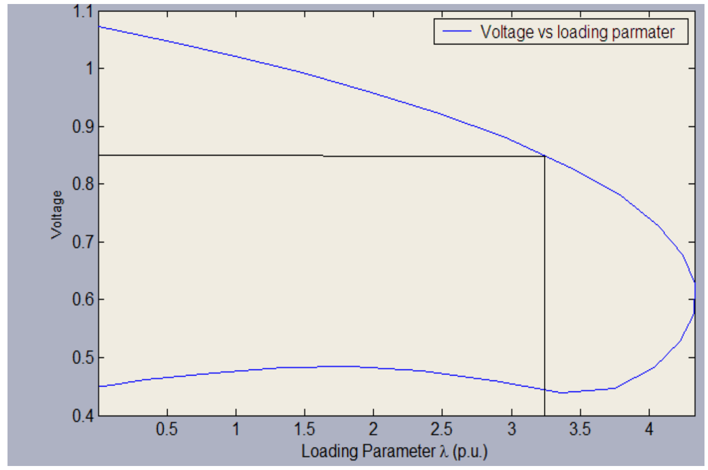

Table 3
IEEE -30 bus system

Series Reactive Power Loss in IEEE 30 Bus System (PSO implementation)

From bus	To bus	SRPL (Without compensation)	SRPL(With compensation)
1	**2**	**16.362**	**4.4329**
1	**3**	**11.506**	**5.5006**
2	4	3.3718	3.2245
2	**5**	**62.044**	**57.089**
2	6	5.7961	5.7890
3	4	0.481	0.6741
4	6	2.102	2.2117
4	12	9.203	9.7453
5	7	0.563	0.5015
6	7	2.252	2.4501
6	8	0.079	0.0820
6	9	0.809	0.8879
6	10	3.812	3.9844
6	28	0.124	0.1264
8	28	0.0006	0.0006

9	10	0.635	0.6443
9	11	0.306	0.4328
10	17	0.022	0.0202
10	20	0.185	0.1825
10	21	0.048	0.0494
10	22	0.086	0.0887
12	13	0.068	0.1182
12	14	0.303	0.3129
12	15	0.826	0.8608
12	16	0.1072	0.1183
14	15	0.025	0.0281
15	18	0.236	0.2496
15	23	0.085	0.0955
16	17	0.211	0.2446
18	19	0.006	0.0071
19	20	0.011	0.0110
21	22	0.0007	0.0001
22	24	0.0385	0.0403
23	24	0.0074	0.0097
24	25	0.0224	0.0276
25	26	0.0923	0.0945
25	27	0.0245	0.022
27	28	0.6362	0.639
27	29	0.1485	0.151
27	30	1.0663	1.087
29	30	0.566	0.577

Table 5
Series Reactive Power Loss in IEEE 30 Bus System (Genetic algorithm, implementation)

From bus	To bus	SRPL (Without compensation)	SRPL(With compensation)
1	**2**	**16.362**	**6.479**
1	**3**	**11.506**	**7.056**
2	4	3.3718	3.145
2	**5**	**62.044**	**58.876**
2	6	5.7961	5.70
3	4	0.481	0.411
4	6	2.102	1.987
4	12	9.203	8.953
5	7	0.563	0.511
6	7	2.252	2.156
6	8	0.079	0.071
6	9	0.809	0.807
6	10	3.812	3.804
6	28	0.124	0.126
8	28	0.0006	0.0002
9	10	0.635	0.633
9	11	0.306	0.328
10	17	0.022	0.032
10	20	0.185	0.185
10	21	0.048	0.049
10	22	0.086	0.088
12	13	0.068	0.110
12	14	0.303	0.319
12	15	0.826	0.830
12	16	0.1072	0.108
14	15	0.025	0.028
15	18	0.236	0.246
15	23	0.085	0.0925
16	17	0.211	0.2436
18	19	0.006	0.0031

19	20	0.011	0.008
21	22	0.0007	0.0006
22	24	0.0385	0.03403
23	24	0.0074	0.00897
24	25	0.0224	0.02376
25	26	0.0923	0.095
25	27	0.0245	0.0232
27	28	0.6362	0.6309
27	29	0.1485	0.181
27	30	1.0663	1.077
29	30	0.566	0.587

Table 6
IEEE 30 bus values- comparison

Line from- to	% Compe nsation	SRPL before Compe nsation	SRPL after SRPL-Algorit hm	SRPL after genetic algorith m	SRPL after PSO optimiza tion
1-2	8.7829	**16.362**	10.485	6.479	4.43291
1-3	9.3996	**11.506**	9.3996	7.056	5.50063
2-5	8.4478	**62.044**	60.194	58.876	57.0894

6. Discussions

A software program is developed in mat lab for the maximum number of series capacitors to be included in the system to have a better compensation to enhance the voltage stability margin. The program first calculates the stability indicators for each line and selects the best one for the compensation based on the Q_{loss}. Then the selected line is compensated for the degree of compensation (K_s) to meet the system reactive requirement. The voltages are then updated .When the predefined number of lines is compensated, the program continues to iterate till all the voltages of the load buses are above stability limit. When the selected lines are compensated by 70% the iteration ends.

To have an optimal location of the series compensators with the above stability the optimization techniques are used. It is seen from the fig 1 for the line 1-5 with out optimization the stability value of the real power is 6. With the Genetic algorithm the real power is 6.7 and with the PSO the real power value is 7. (Fig 2&3).Hence PSO gives the better optimization and the best location of the series capacitors.

The enhancement of the stability margin is also analyzed with the PSAT tool box. From figure 4 the stability margin of the load bus before optimization but with the series capacitor in the line 1-5 has margin of λ = 4 with the voltage of 0.65 p.u.

Figure depicts the result of enhanced stability margin of λ=4.5 for the same voltage of 0.65 p.u. Hence PSO gives the better margin for the location of the series capacitors in the line 1-5.

7. Conclusion

In this paper the series reactive power loss minimization is achieved through the series compensation method. The exact location and the degree of compensation for the series capacitor to be installed in the transmission line is found out. The algorithm developed and the indicator $\frac{dQ_{loss}}{dK_S}$ shows the exact line for the employment of series capacitor. This reduces the effective reactance of the line and helps reduce the reactive power loss in turn providing high degree of stability to the system. Compensation in the form of series capacitors also increases the power transfer capability of the line. The results obtained are verified with the standard IEEE 14 and 30 bus systems.

Paper also deals with the optimal location of the series capacitors to minimize the reactive power loss in order to enhance the stability by obtaining the appropriate value of compensation. The optimized value for the series capacitor is found with the degree of compensation. The optimal location of the series capacitors is carried out using PSO and genetic algorithm. It is evident from the graphs obtained the margin of increases to a better value with the appropriate location of the series capacitor using the optimization techniques.

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