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Reactive Power Minimization by Optimal Allocation of Statcom by Genetic Algorithm

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Abstract:
Flexible Alternating Current Transmission System (FACTS) devices are the best option to solve the voltage instability by reactive power flow and voltage control criteria. Among various FACTS controllers, in this paper we have considered Static Synchronous Compensator (STATCOM). Main objective is to find an optimal rating of STATCOM for minimization of reactive power loss and improve power system performance.We have used the Genetic Algorithm(GA) and Newton-Raphson method to find the optimal rating of STATCOM. To verify the effectiveness of algorithm, studies are carried out on IEEE-33, IEEE-30 and IEEE-9 bus systems with different loading conditions.
A program in MATLAB is developed for the purpose of calculations.

Keywords: *STATCOM, genetic algorithm, Newton Raphson method.*

1. Introduction

Modern power system has many failures due to increased loading in power transmission systems by which the operation of power system becomes complex and it will become less secure. As loading increases, it causes instability. Voltage instability is one among them, which results in major blackout of the whole power system. If these were not controlled, some lines become overloaded which leads to instability. Therefore power electronics devices like FACTS devices will be used to overcome these problems and to have reliable, secure and efficient power system.

Reactive power compensation is an important issue in power systems. FACTS controllers play important role in controlling reactive power in power network.FACTS devices also regulate active power control by their fast control characteristics and by continuous compensating capability. It reduces the flow in heavy load line and desired voltage levels are maintained. FACTS devices can also control series impedance, voltage and phase angle and can also improve both transient and small signal stability margins. They control the power flow under normal and abnormal conditions which will reduce flow in heavy loaded lines. They also result in power loss and improve stability.

Effect of FACTS devices, on power system security, reliability and loadability is studied with proper control objectives. FACTS devices are of several types like series, shunt and a combination of both series and shunt. Basically SVC and STATCOM are shunt devices and by many researches it is proved that by allocating shunt devices at the center of transmission line steady state power transfer can be increased by two times. FACTS devices which are connected in shunt provide reactive power support to transmission network system [6, 7].

2. Problem Formulation

2.1. Newton-Raphson Algorithm

1. Flat voltage profile is assumed then voltages at all buses except slack bus is assumed i.e. V_p=1.0+j0.0 for p=1,2,…….n p$\neq s, V_s$=a+j0.0
2. Next convergence ε is set such that if it becomes exceeds it, then process is repeated else it is stopped.
3. Iteration count is started k=0.
4. Bus count is taken as p=1.
5. Bus is checked for slack bus if it is slack bus then it is jumped to step 10.
6. Real and reactive powers are calculated i.eP_p, Q_p.
7. Calculate $\Delta P_p^k = P_{sp} - P_p^k$.
8. Bus p is checked whether it is a generator bus if so Q_p^k is compared with limits and if it exceeds limit, then reactive power generation is fixed to limit and bus is treated as load bus and if lower limit is violated then $Q_{sp} = Q_{pmin}$ and evaluate.

9. Calculate $\Delta Q_p^k = Q_{sp} - Q_p^k$.
10. Increment the count i.e. p=p+1
11. Determine the largest value and if largest value is less thanε then go to step 14
12. Calculate jacobian matrix elements
13. Voltage increments $\Delta e_p^k and \Delta f_p^k$ are calculated, new bus

Voltages are calculated as increment the iteration count as
k=k+1 and go to step 4.

$$e_p^{k+1} = e_p^k + \Delta e_p^k$$

$$f_p^{k+1} = f_p^k + \Delta f_p^k$$

14. Calculate bus and line powers.

2.2. Flow Chart of Ga for Case Studies

Figure 1 shows flow chart of GA for case studies. It explains the working procedure of GA when particular case studies are made.

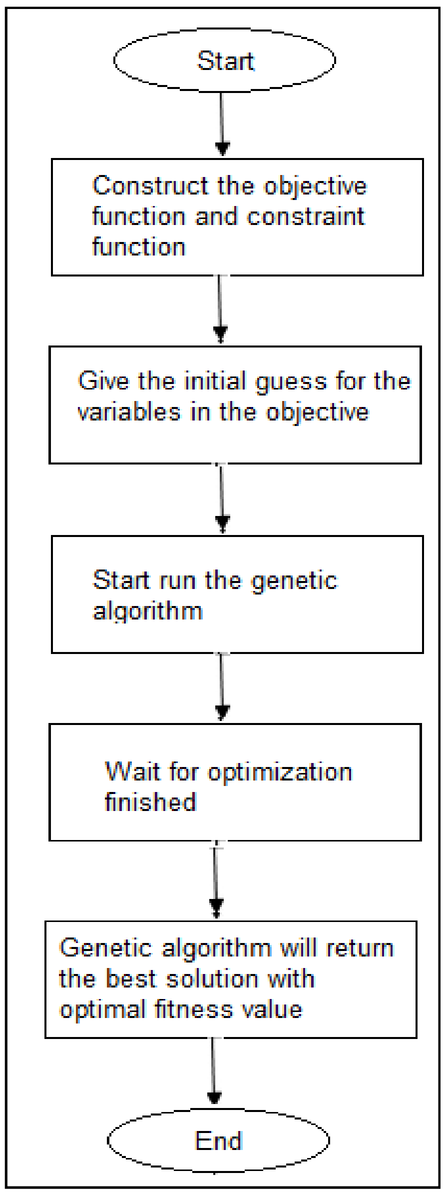

Figure 1:GA flow chart for case studies

3. Methdology and Results

3.1. Flow Chart for Proposed Work

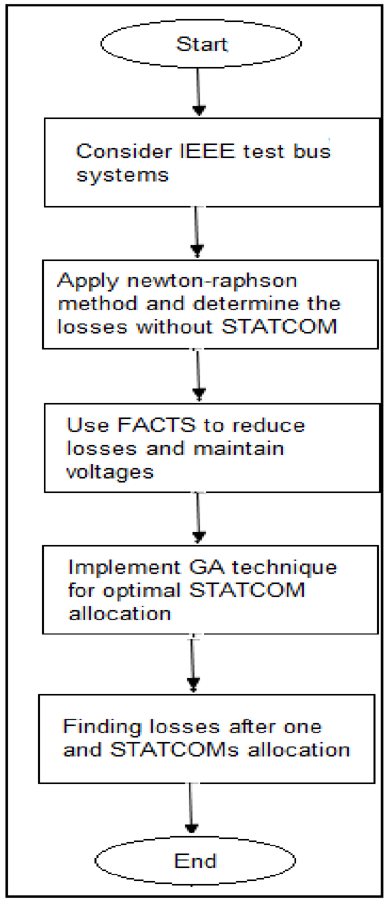

Figure 2: flow chart for proposed work

Figure 2 shows flowchart for proposed work in this flowchart it explains how the work is carried out.

3.2. Algorithm for Proposed Work

- Step1: Network data must be collected for IEEE-33 and IEEE-30 and IEEE-9.
- Step2: MATLAB program for N-R load flow is carried out from which nodal voltages, nodal angles,real power and reactive power flows and losses are obtained. Here maximum iteration is 200.
- Step3: Then MATLAB program without the STATCOM is run which uses N-R load flow values obtained in previous step and from those reactive power losses before STATCOM allocation is obtained.
- Step4: Now GA is initialized to allocate the STATCOM where
- GA population size is 10 and no of generation is 200 with crossover and mutation probability are.95 and.001.at the end of this we obtain the reactive power losses at different lines are also obtains and even we can observe the reactive power is minimized.
- Step5: Now again GA is initialized for allocating another one STATCOM in the system. By the end of this load flow we can observe that reactive power still reduced than in one STATCOM allocation.
- Step6: Above steps are repeated for different loading conditions.

4. Results

4.1. IEEE-33 Bus System

Below table 1 shows the reactive power loss in IEEE-33 bus system at various loading conditions.

Loading Conditions	Before Statcom	After One Statcom	After Two Statcoms
10%	1.5038	0.1497	0.1493
20%	1.5056	0.1497	0.1476
30%	1.5087	0.1497	0.1495
40%	1.6004	0.1499	0.1442
50%	1.59092	0.1497	0.1483
60%	1.5049	0.1497	0.1486
70%	1.5134	0.1497	0.145
80%	1.3953	0.15	0.1482
90%	1.465	0.1497	0.1458
100%	1.508	0.1497	0.1495
110%	1.5103	0.1497	0.1475
120%	1.5075	0.1497	0.1449

Table 1: shows q loss variation

Below Figure 3 and Figure 4 are the graphs of reactive power losses in the system for 80% and 90% loading conditions.

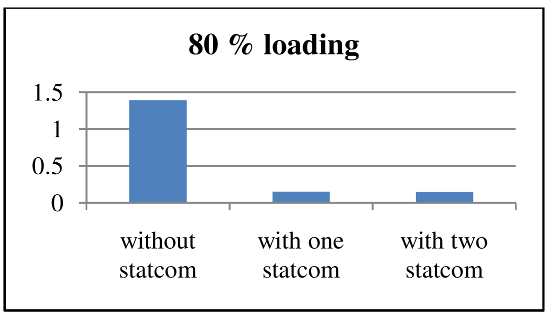

Figure 3: Reactive power loss without STATCOM, with one STATCOM and with two STATCOMS at 80 % loading condition

Above Figure 3 graph shows reactive power losses without STATCOM, with one STATCOM and with two STATCOMs. Reactive power loss without STATCOM is 1.3953p.u and after STATCOM allocation with one STATCOM reactive power loss is.15p.u and with two STATCOM it is 0.1482 p.u. q loss is reduced by 1.2453p.u after one STATCOM allocation and it is still reduced by 1.2471 p.u after two STATCOM allocations.

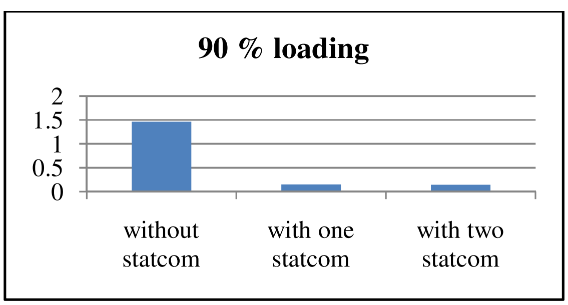

Figure 4: Reactive power loss without STATCOM,with one STATCOM and with two STATCOMS at 90 % loading condition

Above Figure 4 graph shows reactive power losses without STATCOM, with one STATCOM and with two STATCOMs. Reactive power loss without STATCOM is 1.465p.u and after STATCOM allocation with one STATCOM reactive power loss is.1497p.u and with two STATCOM it is 0.1458p.u. q loss is reduced by 1.3153p.u after one STATCOM allocation and it is still reduced by 1.3192 p.u after two STATCOM allocations.

Similarly graphs are obtained for other loading conditions.

4.2. IEEE-30 Bus System

Below table 2 shows the reactive power loss in IEEE-30 bus system at various loading conditions.

Loading conditions	Before statcom	After one statcom	After two statcoms
10%	35.6975	17.4696	17.4374
20%	36.2375	17.4696	17.4284
30%	36.089	17.4696	17.4438
40%	39.717	17.4708	17.4265
50%	33.3009	17.4704	17.4413
60%	36.7359	17.4696	17.4357
70%	36.0733	17.4696	17.4297
80%	36.4304	17.4696	17.4284
90%	33.3667	17.4704	17.4663
110%	25.3704	17.481	17.4272
120%	36.0315	17.4696	17.4342
Normal loading	37.3925	17.497	17.4427

Table 2: shows q loss variation

Below there are graphs of reactive power losses in the system for some selected loading conditions.

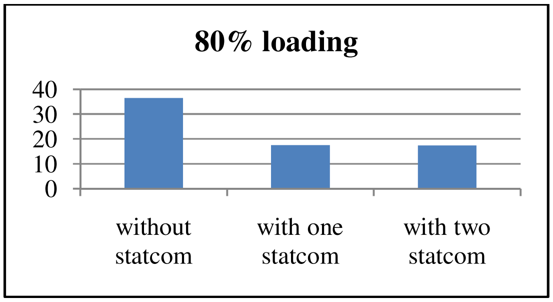

Figure 5: Reactive power loss without STATCOM, with one STATCOM and with two STATCOMS at 80 % loading condition

Above Figure 5 graph shows reactive power losses without STATCOM, with one STATCOM and with two STATCOMs. Reactive power loss without STATCOM is 36.4304 p.u and after STATCOM allocation with one STATCOM reactive power loss is 17.4696p.u and with two STATCOM it is 17.4284 p.u. q loss is reduced by 18.9608p.u after one STATCOM allocation and it is still reduced by 19.002 p.u after two STATCOM allocation.

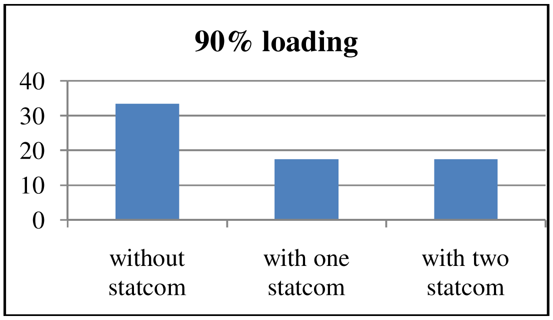

Figure 6:Reactive power loss without STATCOM,with one STATCOM and with two STATCOMS at 90 % loading condition

Above Figure 6 graph shows reactive power losses without STATCOM, with one STATCOM and with two STATCOMs. Reactive reactive power loss without STATCOM is 33.3667 p.u and after STATCOM allocation with one STATCOM reactive power loss is 17.4704p.u and with two STATCOM it is 17.4663p.u. q loss is reduced by 15.8963p.u after one STATCOM allocation and it is still reduced by 15.9004 p.u after two STATCOM allocation.

Similarly graphs are obtained for other loading conditions.

4.3. IEEE-9 Bus System

Below table 3 shows the reactive power loss in IEEE-9 bus system at various loading conditions.

Loading Conditions	Before Statcom	After One Statcom	After Two Statcoms
10%	4.1279	1.2874	0.8525
20%	7.3517	1.4647	0.8533
30%	3.6482	3.7499	0.7674
40%	4.7987	1.9382	0.8846
50%	2.0613	2.0903	0.8742
60%	9.8686	1.508	1.1737
70%	2.2286	2.1791	1.3541
80%	5.398	2.0773	0.8552
90%	3.2056	2.4857	1.1667
100%	1.4986	1.0489	0.5993
110%	5.6487	1.8229	0.9972
120%	2.2701	0.8072	0.3573

Table 3: shows q loss variation

Below there are graphs of reactive power losses in the system for some selected loading conditions.

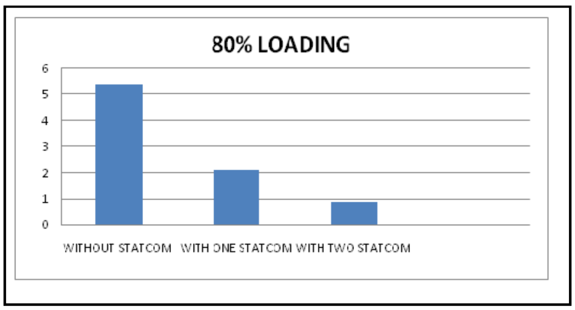

Figure 7:Reactive power loss without STATCOM,with one STATCOM and with two STATCOMS at 80 % loading condition

Above Figure 7 graph shows reactive power losses without STATCOM, with one STATCOM and with two STATCOMs. Reactive power loss without STATCOM is 5.398 p.u and after STATCOM allocation with one STATCOM reactive power loss is 2.0773p.u and with two STATCOM it is.8552 p.u. q loss is reduced by 3.3207p.u after one STATCOM allocation and it is still reduced by 4.5428 p.u after two STATCOM's allocation

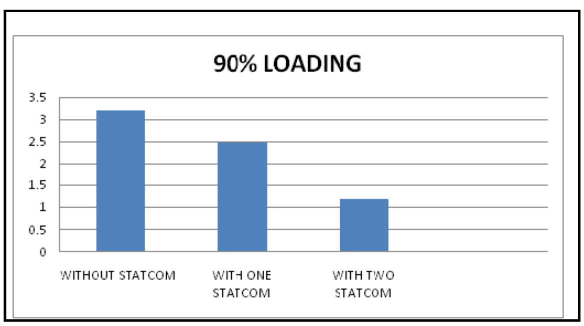

Figure 8: Reactive power loss without STATCOM, with one STATCOM and with two STATCOMS at 90 % loading condition

Above Figure 8 graph shows reactive power losses without STATCOM, with one STATCOM and with two STATCOMs. Reactive power loss without STATCOM is 3.2056 p.u and after STATCOM allocation with one STATCOM reactive power loss is 2.4857p.u and with two STATCOM it is 1.1667p.u. q loss is reduced b.7199p.u after one STATCOM allocation and it is still reduced by 2.0389 p.u after two STATCOM's allocation.

Similarly graphs are obtained for other loading conditions.

5. Discussion of Results

Below table 4 shows the reactive power loss reduction in IEEE-33, IEEE-30 and IEEE-9 bus system at various loading conditions.

Loading conditions	IEEE-33		IEEE-30		IEEE-9	
	One statcom	**Two statcoms**	**One statcom**	**Two statcoms**	**One statcom**	**Two statcoms**
10%	1.3541	1.3545	18.2279	18.260	2.8405	3.2754
20%	1.3559	1.358	18.7679	18.809	5.887	6.4984
30%	1.359	1.3592	18.9194	18.6452	-.1017	2.8808
40%	1.4505	1.4562	22.2462	22.2905	2.8605	3.9141
50%	1.4412	1.4426	15.8305	15.8596	-.029	1.1871
60%	1.3552	1.3563	19.2663	19.3002	8.3606	8.6949
70%	1.3637	1.3684	18.6037	18.6436	.0489	.8745
80%	1.2453	1.2471	18.9608	19.002	3.3207	4.5428
90%	1.3153	1.3192	15.8963	15.9004	.7199	2.0389
110%	1.3583	1.3585	19.8955	19.9498	.44961	.8993
120%	1.3606	1.3628	7.8894	7.9432	3.8258	4.6515
normal	1.3578	1.3626	18.5619	18.5973	1.4629	1.9128

Table 4: shows Reactive power loss reduction in various buses after allocating STATCOMS

6. Conclusion

In a power system due to increasing power demand the system have become less secure. It is concluded from many research works that by placing FACTS controllers the power system security is improved. This project work mainly helps in understanding the principles of STATCOM and also the basics of reactive power compensation using STATCOM. In our work we mainly analyzed the performance of the power system without STATCOM, with one STATCOM and with two STATCOM's allocation. Here we have used MATLAB coding for Newton-Raphson method to calculate the reactive power losses and Genetic Algorithm method for STATCOM allocation. First, we run the MATLAB coding without STATCOM and reactive power losses are obtained. Secondly, we allocate one STATCOM using Genetic algorithm and reactive power losses are obtained. Next another additional STATCOM is added with first one and again reactive power losses are obtained.This above procedure is carried on different IEEE buses like IEEE-33, IEEE-30 and IEEE-9 bus system and even it is carried at different loading conditions. It is concluded from the results that the reactive power loss is minimized in the system after one STATCOM allocation and it is even observed that the reactive power loss is still reduced when additional STATCOM is allocated. By this work we can improve the performance of the system as the voltage profile of the power system gets improved by the reactive power minimization.

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