Chapter 6
Conclusion and Future Scope
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6.1 CONCLUSION

The main function of a power system is to feed industrial and consumer loads as economically as possible and with a reasonable level of reliability and quality. Distribution system is the bridge between the high voltage transmission system and the consumer. The important requirement of a distribution system is that it should have less losses, good power factor and better voltage profile. The power supplied to a distribution utility does not reach the end consumers fully. A substantial amount of power is lost in the distribution system in the form of losses. Technical losses are mainly the power dissipation in the electrical system. The minimization of losses is important because it will determine the economic operation of the power system. It has been observed that when a system operates at a lower power-factor, then voltage is also reduced at local end. Low-voltage increases the current flow in the system which results in more losses and may damage or reduce the life of the equipment. It is in the best interest of both the electrical utility and consumers to maintain a high power factor. It has also been concluded that the reactive power transferred over a line is directly proportional to the difference between sending end voltage and receiving end voltage i.e. voltage drop along the line and is independent of power angle. This means that the main cause of voltage drop on the line is the transfer of reactive power over the line. Thus, to maintain a good voltage profile, the control of reactive power is necessary. Hence, it is necessary to maintain reactive power balances between sources of generation and points
of demand on a zonal basis. The reactive power balances need reactive power compensation. It has also been observed that the reactive power compensation by shunt capacitors placement is simplest, cheapest and effective method to reduce the technical losses. This results in improvement in voltage profile and power factor. The installation of shunt capacitors in distribution networks need optimum location and optimal sizing so that the technical losses of the system get reduced which in turn minimizes the total annual cost (which consists of cost of losses and cost of capacitor placement) while satisfying the technical constraints like voltage levels, power flow limits etc.

The main objective of the thesis is to develop a realistic, “easy-to-implement methodology” of optimal capacitor placement in distribution system to minimize the losses. In the thesis, losses have been calculated by using Newton Raphson load flow method. This method needs less number of iteration to reach convergence, takes less computer time and hence computation cost is less and the convergence is certain. The NR method is more accurate and the number of iteration requires is almost independent of the system size. By Newton Raphson method, we have calculated voltages at various buses, losses in the system and effective active / reactive load at various buses. This algorithm of this method has been coded in MATLAB. Now, a sensitivity analysis is employed to select the candidate buses locations for placing capacitors in the radial distribution system to reduce the technical losses. The estimation of these candidate nodes basically help in the reduction of the search space for the optimization procedure. We have also calculated the Loss Sensitivity Factors \( \frac{\partial P_{\text{line loss}}}{\partial Q_{\text{eff}}} \) from the load flow analysis and the values were arranged in descending order which
decided the sequence in which the buses were to be considered for the compensation. The buses where the normalized voltage magnitude is less than 1.01 were considered as the candidate buses where the capacitor placement was needed to be done. The coding of Loss Sensitivity Factor has also been done in MATLAB. A random search algorithm for the optimization purpose has been used in the thesis. The purpose is to reduce the losses while minimizing the total annual cost (investment cost of capacitor plus the cost of losses) should be minimum while selecting the capacitors for the loss reduction. This solution will be optimum if the constraints are also satisfied. Plant Growth Simulation Algorithm (PGSA) for the optimal sizing of the capacitors is used in the present thesis. It is a bionic random algorithm which occurs in the nature. PGSA is an artificial growth model in which the algorithm follows both growth and probability rules which are based on actual plant phototropism theory. PGSA model is easily compatible with the distribution system. The environment of a plant has been considered as the proposed objective function. Root has been taken as the initial value of the function. Preferential growth node was considered as a new capacitor size on candidate buses. Branch has been consider as the possible values of functions to the corresponding capacitor sizes which has given the better values than initial value of the function. The algorithm of this method has also been coded in MATLAB. The effectiveness of the proposed method for loss reduction by capacitor placement has been tested on 9-bus, 15 bus and 34-bus test radial distribution systems and results have also been compared with other approaches. We have further found that our results are better than other approaches.
The first case is 9-bus, single feeder, radial distribution system. The rated line voltage of this system is 23 kV and total reactive load is 4186 kVAR. Buses 6, 5, 9 and 10 have been selected as the candidate buses for the capacitor placement using loss sensitivity analysis. On applying Newton Raphson Load flows method, the initial power loss was 783.77 kW and after capacitor placement using the proposed method it is reduced to 686.90 kW. Annual cost for uncompensated system was $1,31,674 and after applying PGSA method the cost has been reduced to $1,17,240 and hence 10.96% saving has been achieved. By placing the optimal size of capacitors at optimal locations, the voltages at buses have also improved. Bus number 10 has lowest voltage of 0.8375 p.u. which has been improved to 0.8802 p.u. For the uncompensated system, the power factor was 0.94 and after compensation power factor has been improved to 0.99.

The second test case for the proposed method is a 15 bus radial distribution system. The rated line voltage of the system is 11 kV and total reactive load is 1251 kVAR. Buses 6, 3, 11 and 4 can be selected as the candidate buses for the capacitor placement using loss sensitivity analysis. On applying Newton Raphson Load flow method, the initial power loss was 61.8 kW and after capacitor placement using the proposed method it is reduced to 30.6 kW. Annual cost for uncompensated system was $10,381 and after applying PGSA method the cost has been reduced to $6514.5 and hence 37.24% saving has been achieved. By placing the optimal capacity of capacitors at optimal locations, the voltages at buses have also improved. Bus number 13 has lowest voltage of 0.944517 p.u. which has been improved to...
improved to 0.9709 p.u. For the uncompensated system, the power factor was 0.70 and after compensation power factor has been improved to 0.99.

The third test case for the proposed method is a 34 bus radial distribution system. The rated line voltage of the system is 11 kV and total reactive load is 2873 kVAr. Buses 19, 22, 20 have been selected as the candidate buses for the capacitor placement using loss sensitivity analysis. On applying Newton Raphson Load flow method, the initial power loss is 221.67 kW and after capacitor placement using the proposed method it is reduced to 168.8 kW. Total annual cost for uncompensated system was $37,182 and after applying PGSA method the cost has been reduced to $29,778 and hence 19.91% saving has been achieved. By placing the optimal capacity of capacitors at optimal locations, the voltages at buses have also improved. Bus number 27 has lowest voltage of 0.9417 p.u. which has been improved to 0.9493 p.u. For the uncompensated system, the power factor was 0.85 and after compensation power factor has been improved to 0.98.

The advantages of the proposed method are:

(i) It handles the objective function and the constraints separately, avoiding the trouble to determine the barrier factors.

(ii) The proposed approach does not require any external parameters.

(iii) The proposed approach has a guiding search direction that continuously changes as the change of the objective function. This method places the capacitors at less number of locations with optimum size and offers net annual saving in initial investment.
(iv) The number of sensitive nodes is relatively small compared to the total number of nodes in the distribution system; therefore, the size of the problem is considerably reduced. This makes this method very attractive when dealing with large distribution systems.

(v) Realistic sizes and locations for shunt capacitors are considered in this algorithm.

(vi) No voltage violation due to the addition of capacitors is allowed by the algorithm.

(vii) This method can easily be implemented on non linear loads if the data of load is given for specific interval of time.

(viii) This method can also be implemented with FACTS devices and switched capacitors.

6.2 FUTURE SCOPE

From the future scope point of view, following points may also be considered to apply this proposed method.

(i) Application of this PGSA method to ring distribution system.

(ii) Implementation of PGSA on transmission system.

(iii) PGSA can be implemented on non linear load patterns.

(iv) PGSA can be used with distributed generation sources.

(v) With this methodology, switched capacitors can also be used to reduce losses.

(vi) Further harmonic distortion can also be considered in the analysis.
6.3 PRACTICAL FEASIBILITY:

(i) The proposed method can be implemented easily on practical distribution system and transmission lines.

(ii) This method can also be used in industries to improve the power factor and voltage profile at receiving end.

(iii) The proposed method can also be used to connect small and large distributed generation sources with practical feeders coming from grid sub stations.