Literature Survey on Loss Reduction Methods for Three Phase Unbalanced Radial Distribution Network

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ABSTRACT
The large network of power system ends at distribution system, where voltage is low and current is high. For primary distribution, three phase ac line parameters are considered. Mutual coupling and unbalanced loading makes unsymmetrical current flow and irregular voltage drop in the network, consequently branch losses are different in each phase. This paper has brief description about loss minimization approaches like Distributed generator (DG), capacitor placement and feeder reconfiguration for unbalanced radial distribution network.

Keywords - Unbalanced radial distribution, Distributed generator, Capacitor placement, Feeder reconfiguration.

1. INTRODUCTION
In this competitive power distribution market, it is essential that bulk power must be provided properly to the consumers. Power quantity and quality have become benchmarks for the power distribution companies. Power demand is uncertain and that’s the reason more attention is required on the distribution side of any power system. Power distribution is mainly categorized into primary and secondary. The arrangement of the feeders from substation and the voltage range are different in each case. Feeder with low voltage and high current suffers more from active and reactive power loss. In three phase line model with unbalanced loading condition have certain different parameters which influence the load flow solution of the distribution structure, Hence it necessary to understand the complete model and power flow of three phase system.

1.1 Load Flow Techniques for Three Phase Unbalanced Radial Network
There are several load flow techniques for radial distribution network. Every three phase network has single line representation, for which the basic parameters like voltage, impedance, current and power are evaluated in per unit. Unlike three phase balanced radial network, unbalanced network is not transposed and the power demand for each phase is not same. Mutual coupling effect and ground effect are the crucial phenomena for three phase analysis. Depending on the number of buses and the line parameters, different researchers have followed different methods to express their power flow solution. Rajan [20] et al. has presented load flow on backward/forward sweep power flow technique, in which three-phase mathematical model with mutual coupling has been developed. Samal and Ganguly [22] have represented backward/forward sweep in modified way to get an efficient and quick load flow solution. Ciric et al [19] have showed a four line model for three phase network and considered the ground connection for solution. The effect of ground current has been demonstrated using backward/forward approach. Zimmerman and Chiang [17] have performed power flow using fast decoupled method. Yang and Le [23] propounded a new technique which has involved loop frame instead of bus frame. A current injection technique has been used to build the coefficient matrix and to calculate shunt capacitor harmonic current. Teng and Chang [18] proposed a unique load flow for unbalanced radial system which was based on classical approach of Newton Raphson (NR) load flow in
which branch voltage was taken as state variable. Lower- upper triangular (LU) factorization of Jacobian matrix has reduced the computation time of load flow analysis. Mahmoud and Akher [21] represented an efficient method to solve multi-phase unbalanced network using backward/forward load flow technique in which new transformer model has been introduced. Proposed method has given better solution for singularity problem of nodal admittance sub matrices formed by transformer configuration.

2. LOSS REDUCTION TECHNIQUES

When we discuss about losses, we include active power loss and reactive power loss. A distribution system is said to be reliable when its branch losses are minimum. Losses in the branches are mainly reduced, either by external power injection method or by distribution automation technology. There are several other sub systems which come under such methods for loss compensation, but in this paper distributed generator, capacitor placement and feeder reconfiguration technologies are discussed in details. These subsystems have certain design parameters which deals with its power generating or absorbing capability and the nature of the power for which the net power loss of the line could be reduced.

2.1 Distributed Generation Technology

Distributed generation (commonly known as DG) is a small scale power generation technology which is free from centralized power generation. The ownership of the distributed generation could be managed by individual or power distribution companies. The power range for the distributed generation has been defined by several International standards. Some of them are mentioned below:

The IEEE standard 1547 [1] has defined that DG is an independent source of generation. Single or combined DG systems should have power rating less than 10 MW.

The Electric Power Research Institute [2] defines that distributed generator has power rating of few kilowatts up to 50 MW.

The International Conference on Large High Voltage Electric Systems (CIGRE)[3] defines DG range between 50-100 MW.

The classifications of the Distributed generation have been presented by several different authors, but mostly have categorized them on the basis of their power, nature and capacity. Ackermann et al. [4] have defined Distributed generation, using several references and divided the power range of the generator as per their standards. The generators have been distinguished as micro, small and medium type of DG. Pyassi et al. [7] have organized DG into four categories as per their nature. Type-1 has been selected for real power generators, type-2 for the reactive power generators, type-3 for the synchronous generators and type-4 for the induction type of generators. Singh et al. [5] have represented the renewable and non-renewable sources of energy used as distributed generator. The cost and the benefits using generators have been highlighted in this research paper.

2.1.1 Important Parameters for DG placement on Multi Phase Radial Network.

There are mainly two parameters for which the effect of DG could be efficient. First the location at which DG must inject its power and second the maximum amount of power that can be supplied by the generator. In simple, siting and sizing jargons can be used for such phenomena. This is the area where several researches are still going on. Some of the past and ongoing projects related to DG size and its placements are mentioned in the next section.

2.1.2 Some Proposed methods related to DG site and size.

Dahal and Salehfar [10] have developed a program for unbalanced distribution model in which the favourable locations and the estimation of the DGs have been performed by Particle swarm optimization (PSO) techniques. Othman et al. [8] have redefined the big bang -big crunch algorithm for getting appropriate node locations and the effective power range of the DGs for multiple DG placement on three phase unbalanced distribution network. Hong [14] has suggested about Loss sensitivity index, which plays
an important role in identifying the node locations for best DG placement. A mathematical expression has been described to determine the sensitivity index for three phase unbalanced radial network. Subrahmanyam and Radhakrishna have mentioned a simple method in their paper [6]. This method determines the location and the size of the Distributed generator for which the net power loss in minimum. The overall performance is based on unbalanced radial distribution network. The voltage sensitivity index has a vital role in this method. Kumar and Ganesh [9] have chosen Genetic algorithm (GA) to decide the location and the size of the DG for betterment of voltage in unbalanced radial network.

2.2 Efficient Capacitor Placement

Capacitor placement is one of those cheapest methods for loss compensation. Loss compensators like FACT devices mainly have capacitors in their circuit. Capacitor has energy storing capability which absorbs and injects reactive power in the circuit. Loss reduction and voltage improvement are some positive effects due to capacitor placement. Like distributed generation, its effectiveness also depends on the location and the size. For three phase model, capacitor banks could be in star or delta connection.

2.2.1 Some proposed methods on Capacitor placement

Ravichandrudu et al. [21] have presented Artificial Bee colony (ABC) method to find the size of the capacitor for proper placement at certain location in unbalanced radial distribution system. Eajal and Hawary have developed a technique based on hybrid Particle swarm optimization (HPSO) in their paper [12]. This technique identifies the site and the size of the capacitor for unbalanced radial distribution network under presence of harmonics. Murty and Kumar [13] have identified optimal size and site of capacitor using Index Vector method for unbalanced radial distribution network. In this project different types of load unbalances and various loading conditions have been evaluated. Subrahmanyam [11] has presented a unique algorithm to find the best node location for capacitor placement in unbalanced radial networks and simple Genetic algorithm (GA) has been used to find the size of the capacitor bank.

2.3 Feeder Reconfiguration

Feeder reconfiguration (often called as network reconfiguration) is a process of alternating the network’s path with the help of switches. This is the simplest way of loss reduction. The overall concept of network reconfiguration is based on distribution automation. The branches with least power losses are mainly preferred as alternate path for power flow.

2.3.1 Some proposed methods on Feeder Reconfiguration

Goswami and Chatterji [16] have investigated the influence of feeder reconfiguration on power quality of distribution system. The situation of network reconfiguration is reformed with a motive to enhance the quality of the distribution system. Vulasala et al. [14] have performed the network reconfiguration to reduce the power losses and to improve the voltage level in three-phase unbalanced radial distribution system. Genetic Algorithm (GA) has been applied to get the optimum solution from reconfiguration of distribution network to decrease the total loss. Taher and Karimi [15] investigated network reconfiguration of balanced and unbalanced radial distribution network. This method has an efficient approach of simultaneous use of network reconfiguration as well as Distributed generation (DG) allocation. A Multi-objective approach has been implemented to resolve distribution network problems like power losses, voltage profile, voltage unbalance and current unbalance. Genetic algorithm (GA) was used to get optimum solution.

Comparison

The key features of each loss minimization technique is given in the table 1
<table>
<thead>
<tr>
<th></th>
<th>DG Technology</th>
<th>Capacitor Placement</th>
<th>Feeder Reconfig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nature of injected power</td>
<td>Active or reactive depends on the type of the DG</td>
<td>Only Reactive Power</td>
<td>No power is injected from any source</td>
</tr>
<tr>
<td>Installati-on Cost</td>
<td>Depends on the size and type of the DG</td>
<td>Comparatively less than DG</td>
<td>Depends on the bus system</td>
</tr>
<tr>
<td>Loss minimizati-on</td>
<td>Best method for loss minimization</td>
<td>Moderate</td>
<td>Combinatio-n with DG or Capacitor makes it more efficient</td>
</tr>
<tr>
<td>Protection from fault</td>
<td>Need high protection from overcurrent</td>
<td>Need protection from surges</td>
<td>Highly protected due switching arrangement</td>
</tr>
</tbody>
</table>

CONCLUSION
This paper has briefly described about different loss minimization techniques used in power flow solution for three phase unbalanced radial distribution network. Some standard parameters, easy definitions and key differences have been explained in this paper.

REFERENCES
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