Reconfiguration of Radial Distribution Networks

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Abstract: The paper presents one simple heuristic method for the reconfiguration of distribution networks in order to reduce the real power loss under normal operating conditions. The proposed method is computationally very efficient because it does not require the concept of optimal power flow and require less number of switching operations. The effectiveness of the proposed method is demonstrated through one example.

1.0 Introduction

In recent years considerable research has been conducted in the area of loss minimization [1]. Distribution system reconfiguration for loss reduction was first proposed by Merlin and Back [2]. They have used a branch bound type optimization technique to determine the minimum loss configuration. All network switches are first closed to form a meshed network. The switches are then opened successively to restore the radial configuration. Based on the method of Merlin and Back [2], a heuristic algorithm has been suggested by ShirMohammadi and Hong [3]. Here also, the solution procedure starts by closing all the network switches which are then opened one after another so as to establish the optimum flow pattern in the network. Many approximations of the method of Merlin and Back have been overcome in this algorithm. Civanlar et al [4] made use solely of heuristics to determine a distribution system configuration which would reduce line losses. Civanlar et al made use of what is known as a ‘branch exchange’ operation for switching operations: the opening of any switch was required to correspond to the closure of another switch, ensuring that the radial nature of the distribution system would be preserved. The main disadvantages of this method are that only one pair of switching operations could be considered at a time and the method assured only a reduction in losses and not a minimization of losses. Baran and Wu [5] have made an attempt to improve the method of Civanlar et al [4] by introducing two approximation formulas for power flow in the transfer of system loads. The power flow equations used by Baran and Wu [5] were defined by recursive approximation of \( P, Q \) and \( V \) at each bus. Goswami and Basu [6] have introduced an algorithm similar to that of Merlin and Back [2] differing in that the distribution network considered one tie-switch at a time. In the method proposed by Goswami and Basu [6] any switch closure is determined by the opening of another switch to ensure a radial network. Chen and Cho [7] have performed an analysis of an hourly reconfiguration schedule. They have studied the hourly load patterns over an interval of a year in order to define the hourly load conditions for each season. They have used branch and bound technique for obtaining minimum loss configuration. Nara et al [8] have proposed a method of distribution system reconfiguration for reduction of real power loss using genetic algorithm. Although they have demonstrated the effectiveness of genetic algorithm for network reconfiguration but solution time is highly prohibitive. Researchers have also attempted for obtaining minimum loss reconfiguration using artificial neural networks (ANNs) approach [9]. However, this approach is not suitable for real time application because considerable amount of time is required for training and training must be performed for each utility’s network and accurate training data must be acquired to ensure that ANN offers meaningful results. Lin and Chin [10] have presented an algorithm for distribution feeder reconfiguration. They have used voltage index, ohmic index and decision index to determining the switching operation. Borozan et al [11] have presented a network reconfiguration technique similar to that of ShirMohammadi and Hong [3]. However, their methodology contains three main parts: real time load estimation, effective determination of power loss configuration and cost/benefit evaluation.

However, the optimal switching strategies for network reconfiguration proposed by most papers need to consider every candidate switch to evaluate the effectiveness of loss reduction and extensive numerical computation is often required. In the present paper one heuristic algorithm is proposed which minimize the number of switching operation and does not require the concept of optimal power flow.

2.0 Proposed Method

In the proposed method, two heuristics rules are considered. The heuristics rules are:

1.0 If the voltage drop across the open-tie switch is large, then close this tie-switch. It is expected that because of the largest voltage drop, this switching will cause maximum reduction in loss.

2.0 If the voltage drop across the open-tie switch is negligible, then that option is discarded. It is expected that because of smallest voltage drop, this switching may not cause reduction in loss.

The advantage of this technique is that it minimizes the number of switching operations and hence faster than the methods proposed by ShirMohammadi and Hong [3] and Goswami and Basu [6].

3.0 Explanation of the Proposed Techniques

For the purpose of explanation, consider the sample distribution system shown in Fig.1.

It is assumed that every branch has a sectionalizing switch. This system has four tie-lines and four tie-switches (Fig.1). Initially run the ac load flow program for radial networks. Now detect the open tie-switch across which the voltage...
drop is maximum. Say out of these four tie-switches, voltage drop across the open tie-switch, tie-4 (Fig.1), is maximum. Now check whether this voltage drop is greater than some specified value (say $\varepsilon$) or not. Say this voltage drop is greater than $\varepsilon$, then close this tie-switch and a mesh is formed (Fig.2) in the system and comes back to the radial configuration by opening the same or a different switch of the loop depending upon the result of the mesh distribution load flow through the switches of the same loop. In order to find the radial system which will supply all of the loads with minimal losses, one switch in the loop must be opened. In order to disturb the system least amount, the switch in the section with the lowest current is opened.

Fig.1: Sample distribution system with four tie lines

Fig.2: Distribution system with single loop (tie-4 is closed) (assuming that the switch forms part of a loop feed).

Say, branch (12-13) is carrying minimum current and hence this branch is opened to restore the radial structure and ac load flow program for radial networks is repeated. Fig.3 shows the configuration after closing the tie-switch (tie-4) and opening the branch (12-13).

Fig.3: Radial configuration after first switching operation

Fig.4: Distribution system with single loop

Fig.5: Radial configuration after second switching operation

Again, voltage drop across the open tie-switches, tie-1, tie-2 and tie-3 are computed and say voltage drop across tie-1 is maximum. Now check whether the voltage drop across this open tie-switch (tie-1) is greater than $\varepsilon$ or not. Say this is greater than $\varepsilon$ and this tie-switch is closed to
Step-4: Identify the open tie-switch across which the voltage drop is maximum and its code, $k$, i.e. $\Delta V_{tie, max} = \Delta V_{tie}(k)$.

Step-5: Check whether $\Delta V_{tie, max} > \varepsilon$ or not. If answer is YES go to Step-6 Otherwise go to Step-9.

Step-6: Close the tie-switch $k$ and a mesh is formed in the system. Run mesh distribution load flow.

Step-7: Open the switch in the loop carrying the lowest current and radial structure is restored.

Step-8: Set $ntie = ntie - 1$ and rearrange the coding of the rest of the tie switches and go to Step-2.

Step-9: Print output results.

Step-10: Stop.

4.0 Example

In this section, effectiveness of the proposed method is demonstrated through one example. Proposed method has also been compared with the methods of Shirmohamadi and Hong [3] and Goswami and Basu [6].

A 69 node radial distribution network [12] is considered (Fig.7). This system has five tie-lines. Data for this system are given in [5, 12, 16]. Before reconfiguration total real power loss of this system is 224.96 KW.

In the case of Shirmohamadi and Hong’s method [3], opening branches are (64 – 65), (13 – 14), (21 – 20), (10 – 11), and (57 – 58). Total real power loss after reconfiguration is 118.50 KW. This method needs to consider all the five switches. Reduction in real power loss is 106.46 KW. Minimum voltage is occurring at node 64, i.e. $V_{64}=0.93818$.

In the case of Goswami and Basu’s method [6], opening branches are (10 – 11), (17 – 18), (12 – 13), (58 – 59), and (61 – 62). Total real power loss after reconfiguration is 108.63 KW. This method also requires switching operation of all the five switches. Reduction in real power loss is 116.33 KW. Minimum voltage is occurring at node 61, i.e. $V_{61}=0.94948$.

For the proposed method opening branches are (11 – 12), (56 – 57), and (61 – 62), and require only three switching operations. Total real power loss after reconfiguration is 104.93 KW. Reduction in real power loss is 120.03 KW. In this, case minimum voltage is also occurring at node 61, i.e. $V_{61}=0.94948$.

From the above discussion it is clear that the proposed method give maximum reduction of real power loss and it requires only three switching operations where as other two methods [3,6] require all the switching operations. Proposed method is 1.5 times faster than the method proposed in ref. [3] and 1.74 times faster than the method proposed in ref.[6].

5.0 Conclusions

In this paper, one heuristic algorithm has been presented for the reconfiguration of distribution feeders. The proposed algorithm does not require the concept of optimal flow pattern. The advantage of the proposed algorithm is that it minimizes the number of switching operations. The effectiveness of the proposed method has been demonstrated through one example. It was found that the proposed method is faster than the methods proposed by Shirmohamadi and Hong[3] and Goswami and Basu[6].
Fig.7: Initial configuration of 69 node radial distribution network.

6.0 References