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A Review on Distribution Feeder Reconfiguration Methods

K. K. S.V. V Prakasa Rao
SDSC SHAR, ISRO, Dept.of Space, Sriharikota
kpraoshar@gmail.com

V. C. Veera Reddy
Dept. of EEE, AITS, Tirupati, A.P, India
veerareddy_vc@yahoo.com

Abstract: Distribution Feeder Reconfiguration (DFR) is a critical analysis to optimize and control the distribution system and an important function of distribution automation system. Distribution feeders are configured radially. Their configurations may be varied with manual or automatic switching operations so that all of the loads are supplied with acceptable voltage levels, reduce power loss and enhance power quality. DFR also relieves the overloading of the network components. The change in network configuration is performed by opening sectionalizing (normally closed) and closing tie (normally open) switches of the network. These switching are performed in such a way that the radiality of the network is maintained and all of the loads are energized. This paper presents a review of Distribution Feeder Reconfiguration (DFR) methods which includes heuristic and genetic algorithm approach.

Key Words: Distribution System, Feeder Reconfiguration, Optimization Technique, Heuristic Method, Computational Effort, Loss Reduction and Genetic Algorithm Approach.

I.INTRODUCTION

The distribution networks are operated radially because of simpler protection and lower short circuit currents. Distribution losses vary for the changed configuration under same loading condition. Therefore, under normal operating conditions, distribution engineers periodically reconfigure distribution feeders by opening and closing of switches in order to increase the reliability and reduce line loss. The resulting feeders must remain radial and meet all the load requirements. There are numerous numbers of switches in the distribution system and the number of possible switching operations is tremendous.

Distribution systems consist of groups of interconnected radial circuits. The configuration may be varied via switching operations to transfer loads among the feeders through normally closed switches (sectionalizing switches) or normally open switches (tie switches). DFR is a process that consists of changing the status of the network switches in order to resupply the non-energized areas after a fault occurrence or optimize given criteria. DFR problem of radial power distribution systems may be stated as follows: given a load profile for a distribution network with a number of tie lines and switching points, find a radial configuration for the network, which minimizes the network losses, supply the critical loads at acceptable voltage levels.

DFR is a complex combinatorial optimization problem which yields the best distribution network configuration with minimal losses by optimizing an appropriate objective function and at the same time, maintaining the constraints imposed upon the network. These constraints are voltage limits at nodes, the radial topology of network and supply of power to all loads. In recent past, considerable research has been conducted for loss minimization in the area of DFR. DFR for loss reduction was first proposed by Merlin and Back. They have used a branch-and-bound-type optimization technique to determine the minimum loss configuration.

The aim of this paper is to present a review of developments on DFR methods which includes heuristic and genetic algorithm approach. This paper is organized as follows: Section II briefly summarizes goals of DFR and indicates their relationship. In section III, DFR methods are classified and presented. Concluding remarks are stated in section IV.

II.GOALS OF DFR

A distribution system is designed to operate economically and reliably. Corresponding DFR objectives reflect these goals. This section describes commonly used DFR objectives.

A. Power Loss Reduction

Power Loss reduction is a main objective of DFR because the reduction in system losses brings down the unnecessary operational cost to the profit-driven utilities. System losses are affected by many aspects, such as load imbalance, low voltages, and long distribution lines [1].

B. Load Balancing

DFR for load balancing determines an optimum radial distribution system configuration to balance loads among distribution feeders. The optimal load balancing switching operation enables appropriate transfer of loads from heavy-loaded feeders to light-loaded feeders, in order to maintain sufficient load transfer margin and consequently enhance operational efficiency [2]. Load balancing can mitigate equipment overloading to avoid unnecessary system losses and faster equipment aging that will cause even more losses.

C. Mitigation of Voltage sags

Distribution feeder emanates radially from the substation to supply the loads and thereby the voltage drops along the distribution lines from the substation. To maintain the node voltage profiles within operating limits, various control strategies have been implemented, including voltage regulators and reactive power support. In order to achieve a better voltage profile, DFR alters the network topology and therefore power flow magnitudes and directs to avoid overloads and long distribution paths that will cause a significant voltage drop.

D. Service Restoration

The goals described above are commonly targeted for normal conditions of a distribution system. Service restoration, however, is a group of objectives in emergency conditions such as fault, when switches are opened to isolate part of the system. The isolation can lead to loss of loads and/or distributed generators (DGs). DFR for service restoration redirects the power flow to regain the service to loads and DG connections to the network while considering the objectives for normal conditions and special requirements, such as minimum restoration time, maximum restored load and minimum switching operations [3].

III.DFR METHODS

DFR methods can broadly be classified as loss change estimation, sequential switch opening, quadratic programming, voltage and loss indices and artificial intelligence methods.

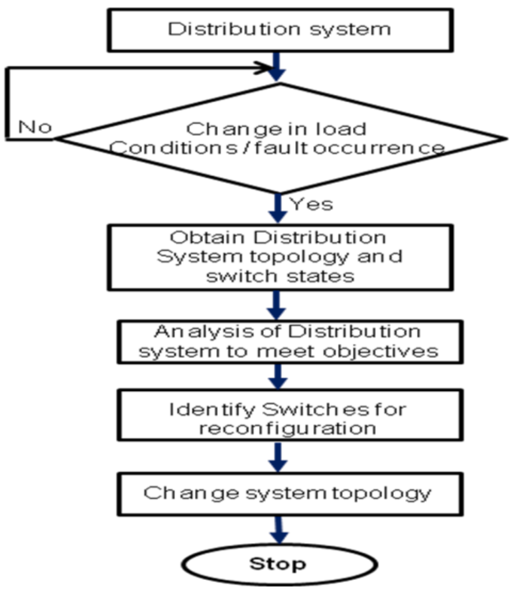

Fig. 1 DFR Flow Chart

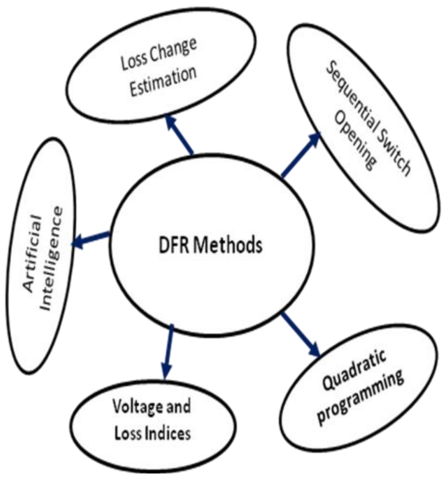

Fig.2 DFR Methods Classification

A. Loss change estimation method

This method is first suggested by Civanlar, Grainger, yin and Lee [4], uses an expression in the real power losses to know if a switching option produces an increase/reduction in losses. In this, the expression filters out those switching options that would not yield loss reduction. A switch exchange operation corresponds to the selection of a pair of switches, one for opening and the other for closing. The switch exchange operation becomes very time consuming and it does not ensure near an optimum solution.

Baran and Felix F. Wu [5] presented an alternate branch exchange algorithm with a filtering mechanism applying two approximate power flow methods with varying degree of accuracy viz., simplified method and backward & forward update of distribution flow. The methods are computationally attractive and in general, give a conservative estimation of loss reduction.

Qiuyu Peng and Steven H. Low [6] proposed an optimal branch exchange algorithm where some loads are transferred from one feeder to another feeder while maintaining the radial structure of the network. It uses an AC power flow model and is based on the recently developed convex relaxation of optimal power flow. This algorithm gives an optimal solution when the voltage magnitudes are the same on all buses.

Carlos et. al., [7] reported an efficient reconfiguration algorithm based on loss change estimation method proposed by Civanlar [4]. The algorithm establishes switching operations to reduce power loss with minimum computational effort. The results obtained show that the method is very robust, in spite of its simplicity.

B. Sequential switch opening

Merlin and Back [8] proposed a search technique with load flow on a meshed power system, opening the links with the lowest flow and finally by applying branch-bond procedure. If the nodal current injection vector, I, at the nodes of a meshed network is known, then the branch current vector, Ib, for an optimal flow pattern to give minimum resistive losses can be determined to solve the following problem:

Minimize $\sum r_b I_b^2$ subject to: $[A] J = I$

Where r_b is the branch resistance

A is the branch-node incidence matrix.

The solution of the problem is $\sum r_b J_b = 0$

Shrimohammadi and Wayne Hong [9] used a robust heuristic method developed based on the idea presented in [8], (Merlin Back). This method uses an optimal power flow and converges to the near-optimum solution and the final solution is independent of the initial status of the network switches.

Goswami and Basu [10] reported a power flow based heuristic algorithm for determining the minimum loss configuration. The algorithm is based on the concept of optimum flow pattern which is determined by solving the KVL and KCL (Kirchhoff's voltage and current laws) equations of the network. The optimum flow pattern of a single loop formed by closing a normally open switch is found out and the flow pattern is established in the radial network by opening a closed switch. This process is repeated till the minimum loss configuration is obtained.

Mortaza Afsari [11] developed a method based on sequential switch opening. In his thesis a power-based method is used where there is no need to convert the nodal powers to currents at different stages, thus saving a few power flow runs. The switch carrying minimum active power is opened to convert the loop into a radial form. This is continued till all the switches are exhausted and the system comes to minimum loss radial configuration.

C. Quadratic programming

Huddleston Charles. T, et. al.,[12] developed a quadratic loss function in which multiple switching pairs are considered simultaneously with linear current balance equations as constraints. This method has the advantage of solving multiple switching options.

McDermott et. al., [13] proposed a non-linear constructive method for reconfiguration problem of distribution networks. This reconfiguration algorithm starts with all operable switches open, and at each step, closes the switch that results in the least increase in the objective function. The objective function is defined as incremental losses divided by incremental load served. A simplified loss formula is used to screen candidate switches.

Joel Jose and Anupama Kowli [14] presented a path-based mixed integer quadratic programming (MIQP) formulation of distribution feeder reconfiguration (DFR) for loss minimization and reliability enhancement. The proposed path-to-branch incidence matrix results in linear expressions for the reliability indices and power flow equations. These linear models are suitably deployed in a flexible DFR optimization framework wherein reliability can feature in either via objectives or constraints.

D. Voltage and Loss Indices

Lin and Chin [15] suggested an algorithm which adopts a switching index to get a proper set of switching operation. This algoril.hm adopts a switching index to get a proper set of switching operations. Switching indices were derived by using branch voltage drops and line constants. In the normal operational state, switches with the largest index in each loop are considered for switching. Under service restorative state, the candidate switches with the smallest index are considered to restore disconnected load points.

E. Artificial Intelligence

The methods using Expert systems, ANN, GA, Simulated annealing, and evolutionary programming fall in this category. GA has been developed by Professor John Holland [16], his colleagues and students at the Michigan University in the middle sixties.

Nara, Shiose, Kitagawa and Ishihara [17] implemented GA for obtaining loss minimum reconfiguration. In this, the loss has been considered as an objective function with constraints such as voltage drop, line capacity, transformer capacity, power supply and feeder load connection. The GA's will give near optimum solution by searching the optimal string (solution) with the help of randomized information exchange.

Lin, Cheng, and Tsay [18] used Refined GA approach to solving the loss minimum reconfiguration of the distribution network. This method is similar to that of [16] conventional GA. The initial population is determined by optimal power flow. To avoid pre maturity the conventional crossover and mutation scheme was refined by a competition mechanism to avoid the dilemma choosing a proper probability for crossover and mutation. The RGA (Refined Genetic Algorithm) provides an overall switching decision which tends to converge to a local optimum.

Simulated Annealing was presented by Matos and Melo [19] and Chang. H. C., et al., [20]. SA is a meta-heuristic tool and the problem was defined or a multi-objective optimization problem. This methodology is very flexible regarding the evaluation of each candidate configuration allowing the inclusion of different criterion, operation and also electrical constraints.

The AI based reconfiguration methods have become popular in view of automation of distribution networks. Artificial neural network based feeder reconfiguration for loss reduction is proposed by Kim, H., et. al.,[21]. Artificial neural networks determine the appropriate system topology that reduces the power loss according to the variation of load pattern. Liu, C. C., et. al., [22] discussed an expert system based operational scheme for loss reduction and a knowledge-based distribution system analysis and reconfiguration method was proposed by G. Chang et. al., [23].

CONCLUSIONS

This paper presents a review of developments on distribution feeder reconfiguration. In this paper different feeder reconfiguration techniques have been discussed. Their objectives and constraints have also been reported. As the demand for electricity increases day by day, distribution system becomes complicated and its control becomes difficult. Several intelligence techniques are used for feeder reconfiguration to reduce power losses and improve voltage profile and reliability. Intelligent switchgear is now used in feeder reconfiguration to enhance accuracy and reliability with the advancement in the field of automation. It is difficult to select a single method/solution that could satisfy the requirement of all operational aspects, including computational efficiency and operational constraints. In the case of faulty conditions, the comprehensive off-line studies can well address the uncertainties in contingencies and operating conditions, knowledge-based heuristics are the most reliable and efficient. It is preferred to reasonably integrate some of the solution methods to make use of their merits and avoid their disadvantages for normal conditions.

REFERENCES

[1] R. J. Sarfi, M. Salama, and A. Chikhani, "A survey of the state of the art in distribution system reconfiguration for system loss reduction," *Electric Power Systems Research*, vol. 31, pp. 61-70, 1994.

[2] L. F. Ochoa, R. M. Ciric, A. Padilha-Feltrin, and G. P. Harrison, "Evaluation of distribution system losses due to load unbalance," in *Power Systems Computation Conference (PSCC)*, Liege, Belgium, 2005, pp. 1-4.

[3] S. P. Singh, G. S. Raju, G. K. Rao, and M. Afsari, "A heuristic method for feeder reconfiguration and service restoration in distribution networks," *International Journal of Electrical Power & Energy Systems*, vol. 31, pp. 309-314, 2009.

[4] S. Civanlar, J.J. Grainger, H. Yin and S.S.H. Lee, "Distribution feeder reconfiguration for loss reduction", *IEEE Trans. on Power Delivery*, Vol. PWRD-3, No. 3, 1988, pp. 1217-1223.

[5] M.E. Baran and F.F. Wu, "Network reconfiguration in distribution systems for loss reduction and load balancing", *Trans. on Power Delivery*, Vol. PWRD-4, No. 2, 1989, pp. 1401-1407.

[6] Qiuyu Peng and Steven H. Low, "Optimal branch exchange for Feeder reconfiguration in Distribution Networks", 52nd IEEE conference on Decision and Control, December 10-13, 2013. Florence, Italy.

[7] Carlos A. Castro, JR. and Andre A. Watanabe, "An efficient Reconfiguration algorithm for loss reduction of distribution systems", Electric Power Systems Research, 19 (1990), pp. 137-144.

[8] A. Merlin and H. Back, "Search for a minimum-loss operating spanning tree configuration in urban power distribution systems" *Proceedings of 5th PSCC*, Cambridge, U.K., Sept., 1-5, 1975, pp. 1-18.

[9] D. Shirmohammadi and H.W. Hong, "Reconfiguration of Electric Distribution Network for Resistive Line Losses Reduction", *IEEE Transactions on Power Delivery*, Vol. 4, No. 2, April 1989, pp. 1492-1498.

[10] S.K. Goswami and S.K. Basu, "A New Algorithm for the Reconfiguration of Distribution Feeders for Loss Minimization", *IEEE Transactions on Power Delivery*, Vol. 7, No.3, July 1992, pp. 1484-1490.

[11] Mortaza Afsari, "Improved algorithm for power flow and reconfiguration of distribution networks", *Ph.D. thesis*, Electrical Engineering Department, *I.T., B.H.U.*, Varanasi, 2000.

[12] C.T. Huddleston, R.P. Broadwater, and A. Chandrasekaran, "Reconfiguration Algorithm for Minimizing Losses in Radial Electric Distribution systems", *Electric Power Systems Research*, Vol. 18, 1990, pp. 57-66.

[13] T.E. McDermott, I. Drezga and R.P. Broadwater, "A Heuristic Nonlinear Constructive Method for Distribution System Reconfiguration", *IEEE Transactions on Power Systems*, Vol. 14, No. 2, May 1999, pp. 478-483.

[14] Joel Jose, Anupama Kowli, "Reliability constrained distribution feeder reconfiguration for power loss minimization", 2016 National Power Systems Conference (NPSC), IEEE Conference Publications.

[15] Whei-Min Lin and Hong-Chan Chin, "A New Approach for Distribution Feeder Reconfiguration for Loss Reduction and Service Restoration", *IEEE Transactions on Power Delivery*, Vol. 13, No. 3, July 1998, pp. 870-875.

[16] J.H. Holland, "Adaptation in natural and artificial systems", Univ. Michigan Press, 1975.

[17] K. Nara, A. Shiose, M. Kitagawa and T. Ishihara, "Implementation of Genetic algorithms for distribution system loss minimum re-configuration", *IEEE Trans. on Power System*, Vol. 7, No. 3; Aug. 1992, pp. 1044-1051.

[18] W.M. Lin, F.S. Cheng and M.T. Tsay, "Distribution feeder reconfiguration with refined genetic algorithm," *IEE proc. Gen., Trans., and Dist.*, Vol. 147, No. 6, Nov. 2000, pp. 349-354.

[19] M.A. Matos and Paulo Melo, "Multi objective reconfiguration for loss reduction and service restoration using simulated annealing", IEEE power Tech 99 conference, Budapest, Hungary, Aug. 29, Sept, 1999.

[20] Chang,H. C., and Kuo, C. C., "Network reconfiguration in distribution systems using simulated annealing", Electric Power System Research, 1994, 29, pp.227-238.

[21] H.Kim, Y. Ko and K.H. Jung, " Artificial neural Network based feeder reconfiguration for loss reduction in distribution systems", *IEEE Transactions on Power Delivery*, Vol. 8, No. 3, 1993, pp. 1356-1366.

[22] C.C. Liu, S.J. Lee and S.S. Venkata, "An expert system operational aid for restoration and loss reduction in distribution systems", *IEEE Transactions on Power Systems*, Vol. 3, No. 2, 1998, pp. 619-626.

[23] G. Chang, J. Zrida and J.D. Birdwell, "Knowledge-based distribution system analysis and reconfiguration", *IEEE Transactions on Power Systems*, Vol. 5, No. 3, 1990, pp. 744-749.

