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Distribution Network Reconfiguration: Review of Challenges and Techniques

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Abstract: Distribution networks have to be upgraded and has to be operated with better planning and need to incorporate smart technologies. Increasing integration of renewable energy source based distributed generation posses several threats for the network stability and reliability. Therefore, there is utmost need to reconfigure the present distribution systems. This paper presents review on problems faced by recent distribution systems and possible ways for distribution network reconfiguration.

Introduction

Generation, transmission and distribution system are ensured for power can be transmitted from the generation to the distribution system or demand via the transmission line. The majority of today's distribution systems are being stressed and operated at heavy loading conditions due to the rapid increase in electricity demand as well as certain economic and environmental constraints as well as drastically changing nature of power network users [1].

Utility distribution systems are at the centre of the smart grid revolution and also are challenged by an aging infrastructure, legacy systems that must be integrated with new technologies, changing load characteristics (such as electric vehicles), and the requirement for integration of widespread distributed resources. Given these challenges, electricity distribution companies are under pressure to improve reliability and system performance, build the necessary infrastructure for integration of distributed resources, and deal with changing load characteristics, usually under severe budget constraints. The reliability and efficiency of the distribution system operation continues to increase in importance, and, of course, safety always takes the highest priority.

According to, global energy demand is expected to increase 37% by 2040. The annual growth rate for electricity consumption in residential and commercial sectors will be 0.5% and 0.8% from 2013 through 2040, respectively. Therefore, this increasing load demand may overload the distribution feeders and may complicate the system operation.

Thus, to meet load demands, distribution networks have to be upgraded, maintained and operated with better planning and incorporate smart technologies. Nowadays, there is a global consensus that integrating renewable energy sources (RESs)/ Distributed Generations (DG) is highly needed to meet the increasing electricity demand and reduce the overall carbon dioxide footprint of energy production. Moreover, distributed generation (DG) is/may be playing an important role in electrical systems like:

- Power losses minimization at the distribution network.
- Enhance performance on voltage profile.
- Improve stability index and security of the distribution system.
- Help in improving the efficiency and reliability of the system.
- Help in saving costs due to fewer expansion plans on generation and transmission lines.
- Increase the power quality in the distribution system.
- Relieve the transmission line due to peak saving [2].

However, large-scale integration of RES-based DGs often poses several technical challenges in the system, from stability, reliability and power quality perspectives as distribution networks has changed from passive to active network which will result in a paradigm shift in the operation of these networks [1],[2].

The conventional power distribution systems have radial networks with unidirectional power flows for simple operation and protection constraint but with the advent of DGs, power distribution systems would have locally looped networks with bidirectional power flows [3].

Furthermore, DGs have to be optimally integrated in the system. The non-optimal DG placement may increase power losses, and consequently, it lowers the voltage profile below the allowable limit [1],[5].

The Distribution system reconfiguration (DSR) is one of the facile, cheapest and most powerful ways to reduce operational losses and enhance voltage profile [4].

Table: 1 Problems faced by Recent distribution systems operation and planning in Indian Contexts

ISSUES	REMEDIES	REQUIRED NETWORK RECONFIGURATION FOR [19]
Feasibility for Large integration of Renewable Energy Sources-DGs, Energy Storage, Electrical Vehicles integration in existing distribution systems	improve / upgrade the entire system performance with lower cost of investments	• Power loss reduction, • Voltage Profile Improvement, • Load profile index improvement, • Grid upgrade cost reduction, • Transmitted power cost reduction, • Reliability cost reduction,
Problem of bidirectional power flows		
Load unbalance: no matching of local generation and demand, in developing nations, meeting the energy demand is a major challenge	requires load balancing with lower cost of investments	• Power loss reduction, • Voltage Profile Improvement, • Load profile index improvement • Energy losses cost reduction
Non-optimal DG placement may increase power losses, and consequently, it lowers the voltage profile below the allowable limit.	To upgrade performance with lower cost of investments for over power /energy production handling.	• Optimal PMU placement. • Power loss reduction, • Voltage Profile Improvement, • Load profile index improvement, • Grid upgrade cost reduction,
Unscheduled/ unreliable power supply culminates to economic losses	To introduce flexibility for increasing customer RES investment payback.	• Power loss reduction, • Voltage Profile Improvement, • Grid upgrade cost reduction, • Energy losses cost reduction • Reliability cost reduction,

Reconfiguration of radial distribution networks is becoming a viable solution for improving the performance of distribution networks. Configurations may be varied with manual or automatic switching operations so that: all of the loads are supplied, reduce power loss, Load Balancing, Voltage Profile Improvement, enhance power quality, Service Restoration, Reliability Enhancement increase system security. Reconfiguration also relieves the overloading of the network components [3].

Distribution Network Reconfiguration

Distribution Network Reconfiguration (DNR) can be defined as the process of altering the topological structures of the distribution network by changing the open/close status of the sectionalizing and tie switches. This process can improve the performance of the system according to different particular objectives and constraints in the medium and long term.

Distribution automation is becoming increasingly important in recent years. Electric utilities are paying more attention to distribution-level reliability and quality of customer service at low operational cost [8]. Among all distribution automation functions, feeder reconfiguration (FRC) is a planning process and also a real-time operational control process. A distribution system is designed to operate economically and reliably.

FRC changes the distribution network topology through modifying the switch statues, thus redirects the power flow within the network, in order to achieve system-level objectives while satisfying the operational constraints of the system. Moreover, the reconfiguration should guarantee that the network topology is radial.

Tie switches are normally open, providing separation between feeders. Closing tie switches allows customers to be transferred to adjacent feeders in situations such as planned maintenance, service interruption and overloading.

Sectionalizing switches, which are normally closed, can be opened to isolate areas in emergencies such as fault situation. Some sectionalizing switches are open to maintain the radial topology of the distribution network.

For a manual FRC system, the reconfiguration is on seasonal basis. In automated mode, dispatcher controls FRC remotely.

In normal conditions, FRC operation once in a few hours is sufficient. Power system operators initiate system reconfiguration plan to restore the isolated loads as soon as practical. Circuit breakers, sectionalizers, and open tie-switches are the main tools for reconfiguration process. The distribution system usually reverts to its original configuration upon the repair/replacement of the failed component.

Table: 2			
	DG Technology	Capacitor Placement	Feeder Reconfiguration
Nature of injected power	Active or reactive Depends on the type of the DG	Only Reactive Power	No power is injected from any source
Installation Cost	Depends on the size and type of the DG	Comparatively less than DG	Depends on the bus system
Loss minimization	Best method for loss minimization	Moderate	Combination with DG or Capacitor makes it more efficient
Protection from fault	Need high protection from overcurrent	Need protection From surges	Highly protected Due switching arrangement

Classically, the reconfiguration problem is done manually by experienced engineers who decide the feeder/feeders that will supply the isolated portion of the system during a fault. They also decide which load/loads should be shed if necessary. In most cases, this arrangement doesn't give fast or optimum solution.

In the era of smart grids, the reconfiguration process needs to be done automatically as a step forward towards the self-healing concept of the smart grid. Moreover, newly installed equipment such as distributed generators (DGs) and automatic switches should be wisely used for better reconfiguration solutions.

Distribution System Reconfiguration

A static DSR (SDSR) approach (i.e., distribution system topology and load are considered to be fixed during specific timeframes) was formulated as a mixed-integer nonlinear optimization problem and solved by using a discrete branch-and-bound technique. Improving the SDSR approach a dynamic (multi-period) concept for the DSR solution (DDSR) Differently from SDSR, in DDSR, the load is not constant and network topology frequently changes with the real-time operational conditions using automatic (smart) switches. In this approach, features such as load fluctuations, generation variability, the uncertainty of renewable sources, market behaviour, switching time, and climate changes can be taken into account, which leads to a more accurate and realistic assessment of the network. Nevertheless, the adoption of the DDSR increases the complexity and requires higher computational effort when compared.

The feasible search space in DSR is typically large, nonconvex, and hard to explore. Hence, determining good-quality solutions for the DSR problem is always a challenging task. In order to cope with this issue, distribution system researchers have dedicated their efforts to develop efficient methodologies to find the best possible solution for the DSR. In this regard, classical optimization, heuristic, and metaheuristic methods have played prominent roles in the DSR solution.

Optimization Methods for DSR

The most crucial point is how to use the specific knowledge of the problem domain and how it is modelled and implemented [7]. The reconfiguration approach is different in normal conditions and in fault conditions. In normal conditions, optimal results are evaluated for either the existing situation of the system or taking in to account forecasted, future situations. Various conventional and heuristic methods can efficiently handle this reconfiguration problem. On the contrary, in fault conditions rapid action for service restoration is needed.

Numerous optimization methods have been developed to solve the reconfiguration problem, although a comparative analysis of their performances is still a challenging task due to the nature of the methods, differences in their implementation, and used computational equipment. To fulfill that gap, this paper discusses classical models along with metaheuristics already applied in the specialized literature considering the reported losses and computational effort.

To eliminate differences due to implementation and equipment, two proposed metrics are to eliminate differences due to implementation and equipment, two proposed metrics are assessed using a reference specialized power flow: 'equivalent time' and 'equivalent number of power flows. The quality of the solutions was compared for standard test systems (33, 136, and 417 buses) and a ranking of the methods was produced.

It was concluded that linear and conic programming models find the optimal solution for low and medium-size systems; moreover, the linear model requires lower computational effort than the conic and the nonlinear programming formulations.

On the other hand, it was verified that metaheuristics need lower computational effort and provide better solutions for large-size systems compared to classical optimization.

Different methods for solving Reconfiguration Problems are developed with significant variations of solution methods, characterization of objective functions: single or multi objectives. They are Soft Computing and mathematical optimization methods.

The heuristic methods are based on problem partitioning and using experience-based techniques for problem solving [8-10]. These methods cannot guarantee the optimal solution, but can often find acceptable solutions rapidly. Heuristic methods use mental shortcuts to help finding the solution quickly.

In general, heuristic algorithms have the advantage of quickly providing results and requiring low computational effort. However, especially for more complex large systems, they often suffer from some limitations related to low-quality solutions and, in some cases, provide unfeasible solutions.

A heuristic or heuristic technique is any approach to problem solving or self-discovery that employs a practical method that is not guaranteed to be optimal, perfect, or rational, but is nevertheless sufficient for reaching an immediate, short-term goal or approximation.

Where finding an optimal solution is impossible or impractical, heuristic methods can be used to speed up the process of finding a satisfactory solution.

Heuristics can be mental shortcuts that ease the cognitive load of making a decision. The heuristics technique where network reconfiguration is formulated into an optimization problem and solved iteratively without derivative in formation is known as meta-heuristic. In general, employing Metaheuristics (MHs) to solve the RDSs has advantages due to their more flexible strategies and straight-forward implementations that do not require having an explicit mathematical formulation. Therefore, they can be easily adapted to the characteristics of the optimization problem. Another advantage is that they adopt search strategies to escape local optimum solutions by exploring multiple paths or regions in the search for the global optimum.

Despite those positive points, a disadvantage of using MHs is that they do not guarantee optimality and do not provide information about the gap between the obtained solution and the global optimum.

Similar to MHs, mathematical optimization models have benefits and weaknesses. Theoretically, they can reach the global optimum. On the other hand, their main disadvantage is the relatively high computational effort when compared to MHs. When applied to the RDS, a large number of interconnection switches increases the size of the optimization problem, requiring more computational time to solve the complete mathematical model.

Distribution network reconfiguration is a process to find radial operating structure while satisfying operational constraint. To guarantee fast & reliable operation, reconfiguration of network can be done for following objectives:

1. Load Balancing by Implementation optimal network reconfiguration by exhaustive search
2. Power Loss Reduction in distribution network through optimal reconfiguration.
3. Voltage Profile Improvement in distribution network through optimal reconfiguration.
4. Reliability Improvement in distribution network through optimal reconfiguration.

Conclusion

In order to incorporate distributed generation, distribution networks have to be reconfigured. The efficient distribution system operation as power loss can be reduced to operate with high quality and reliability. Life of distribution system components can be improved as voltage profile can be improved to operate with high quality and reliability. Load supplying /Load ability of distribution system can be increased by load balancing for optimal utilization of Distribution network. Continuity of Electrical energy supply during maintenance, fault and other contingency situation is feasible which makes distribution system more reliable, stable and secure.

Bibliography

1. Y. K. Wu, C. Y. Lee, L. C. Liu and S. H. Tsai, Study of reconfiguration for the distribution system with distributed generators," IEEE Trans. Power Deliv., vol. 25, no. 3, pp. 1678–1685, 2010, doi: 10.1109/TPWRD.2010.2046339.
2. Mohapatra A. QIP course on "Smart Grid Technology Distribution Management System", Assistant Professor, Department of Electrical Engineering, IIT Kanpur.
3. B. Sultana, M. W. Mustafa, U. Sultana and A. R. Bhatti, Review on reliability improvement and power loss reduction in distribution system via network reconfiguration," Renew. Sustain. Energy Rev., vol. 66, pp. 297–310, 2016, doi: 10.1016/j.rser.2016.08.011.
4. R. N. Smarajit Ghosh, "Literature Survey on Loss Reduction Methods for Three Phase Unbalanced Radial Distribution Network," Int. J. Sci. Res. Educ., no. July 2016, doi: 10.18535/ijsre/v4i07.18.
5. S. Ma, H. Zhang, and G. Xu, "Distribution Network Reconfiguration with Wind," no. 12, pp. 1–4, 2012.
6. L. Tang, F. Yang, and J. Ma, "A survey on distribution system feeder reconfiguration: Objectives and solutions," 2014 IEEE Innov. Smart Grid Technol. - Asia, ISGT ASIA 2014, pp. 62–67, 2014, doi: 10.1109/ISGT-Asia.2014.6873765.
7. M. R. M. Cruz, D. Z. Fitiwi, S. F. Santos, and J. P. S. Catalão, "Flexibilizing distribution network systems via dynamic reconfiguration to support large-scale integration of variable energy sources using a genetic algorithm," IFIP Adv. Inf. Commun. Technol., vol. 499, pp. 72–80, 2017, doi: 10.1007/978-3-319-56077-9_6.
8. J. Xiao et al., "Flexible distribution network: Definition, configuration, operation, and pilot project," IET Gener. Transm. Distrib., vol. 12, no. 20, pp. 4492–4498, 2018, doi: 10.1049/iet-gtd.2018.5641.
9. J. Jose and A. Kowli, "Reliability constrained distribution feeder reconfiguration for power loss minimization," 2016 Natl. Power Syst. Conf. NPSC 2016, 2017, doi: 10.1109/NPSC.2016.7858938.
10. S. Elsaiah, M. Benidris, and J. Mitra, "Reliability improvement of power distribution system through feeder reconfiguration," 2014 Int. Conf. Probabilistic Methods Appl. to Power Syst. PMAPS 2014 - Conf. Proc., 2014, doi: 10.1109/PMAPS.2014.6960676.