A NEW NONLINEAR CONSTRUCTIVE METHOD FOR LOSS REDUCTION AND LOAD BALANCING IN RADIAL DISTRIBUTION NETWORK RECONFIGURATION

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Abstract

Ineffective utilization of power is one of the reasons of power crisis faced by developing countries. Network reconfiguration is a combinatorial optimization problem to dwindle the power losses by keeping into account the various operational constraints in distribution systems.

We propose an improved algorithm to determine the optimal topology among a various alternatives, to reduce the loss reduction and to balance the load. The solution for loss reduction through network reconfiguration involves a guiding search over the relevant configurations, and the load balancing indexes are defined for formulation of objective function of load balancing problem. As a test case this method has been applied on a real network having 20 nodes radial distribution system for loss minimization and load balancing. Our propose system has the advantage that it does not require external parameters, such as barrier factors or crossover rate as contrast to most prevailing systems.

Keywords: Optimization, Topology, Network reconfiguration, Load balancing, loss reduction

Introduction

Investments in power distribution systems constitute a significant part of the utilities’ expenses (H. L. Willis et al., 1995). For this reason, efficient planning tools are needed to allow the planners to reduce costs. Computer optimization algorithms improve cost reduction compared with systems designed by hand. In recent years, a lot of mathematical models and algorithms have been developed. The authors in (H. K. Temraz 1993; S. K.

Khator 1997 & H. L. Willis 1996) focus on selection and application of optimization methods for distribution design.

The electric power distribution system usually operates in a radial configuration, with tie switches between circuits to provide alternate feeds. Reconfiguration is the process of operating on remote elements (*e.g.* switches) to change the circuit topology. As we know that the loads vary with time of day, day of the week, and season, and each type of load, *i.e.* residential, commercial, and industrial has a different time profile, and each feeder serves a different mix of loads. Therefore, the load pattern on each feeder varies constantly, and with a different variation on each feeder. This creates an opportunity to constantly keep losses at a minimum by reconfiguring the feeders during the day. Automatic switches and control systems are installed to perform this distribution automatically (Williams B.R., Walden D.G 1994; Hayashi Y, Iwamoto S., Furuya S., Liu C 1996).

Optimal distribution planning involves network reconfiguration for distribution loss minimization, load balancing under normal operating conditions and fast service restoration minimizing the zones without power under failure conditions.

Boardman (Boardman, J. T. and C. C. Meckiff 1985) proposed an optimal reconfiguration known as “branch and bound”. This technique goes for an exhaustive search, except that a search direction will be terminated when it becomes obvious that its end result will be less optimal than a previously found solution. Branch and bound also benefits from breaking the problem into sub-problems, each of which can be optimized separately. Even so, branch and bound is a combinatorial method and hence too slow for practical use.

A general formulation of the feeder reconfiguration problem for loss reduction and load balancing is introduced in (M. E. Baran and F. F. Wu, 1989). The solution employs a search over different radial configurations created by considering branch exchange type switching. Edelmiro and others (Edelmiro et el 2002) presented a branch exchange method and derived a simple formula to estimate the loss reduction. In (D. Das, 2006), the authors proposed an algorithm based on fuzzy multi-objective approach for network reconfiguration.

This paper presents an improved algorithm that remarkably decreases the dimension of the variables in the model employing algorithm for radial distribution network reconfiguration. This approach minimizes the total system loss and keep load balancing while satisfying its constraints. The proposed method handles objective function and constraints separately, which averts the trouble to determine the barrier factors. The algorithm implements a guiding search direction that changes dynamically as the change of the objective function and does not require any external parameters. This technique has the advantages of better searching performance over the previously published algorithms in literature.

The rest of the paper is organized as follow: The proposed algorithm is discussed in section-II. A case study on the proposed problem is laid down in section-III. Conclusion is given in Section-IV.

The proposed Algorithm

The network reconfiguration in distribution systems is usually done for loss reduction or load balancing. In this paper, we propose a new technique to overcome these two problems. The loss-minimum problem can be formulated as follows (Jing Ye, Yichang and F. Z. wang 2009)

$$Min_{P_{T,loss}} = \sum_{i=1}^{N_{br}} R_i |I_i|^2 \qquad (1)$$

where $P_{T,loss}$ is the total real loss of the distributed system, R_i and I_i are the resistance and the current magnitude of the feeder section i respectively, and N_{br} is the total number of branches in whole system.

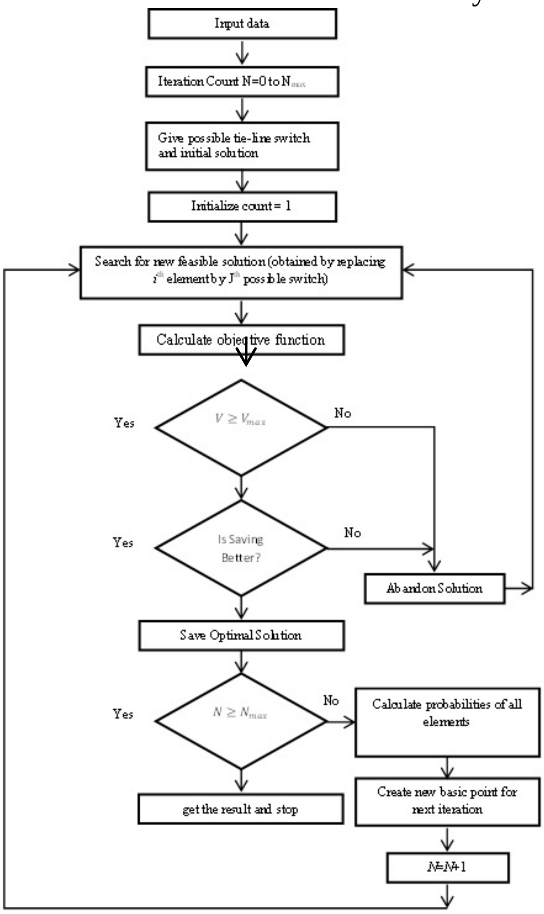

Figure 1 Flow Chart for network reconfiguration under proposed algorithm

Equation (1) is subject to the following constraints

Current Capacity Constraint

$$I_i \leq I_i^{max} \quad , \quad i \in N_{br} \tag{2}$$

where I_i^{max} is the upper limit of the current magnitude in feeder section i.

Voltage drop Constraint

$$V_i^{min} \leq V_i \leq V_i^{max} \ , \quad i \in N_d \tag{3}$$

where V_i is the voltage magnitude of bus i , V_i^{min} and V_i^{max} are minimum and maximum voltage limit of bus *i* respectively, and N_d is the total number of nodes in whole system.

Radial Topology

The concept of changing the topology of distribution systems for loss minimization for the first time was introduced in (A. Merlin and H. Back 1975).

Illustrative Example

The implantation is chosen on real network of *Tootak,* Quetta Electric Supply Company, Pakistan having ten generating stations and twenty consumer nods as sketched in figure 2, the distribution system with ten sources and several switching devices; *Swi*. At the initial state, all the switches are closed and the system is operating in loop configuration.

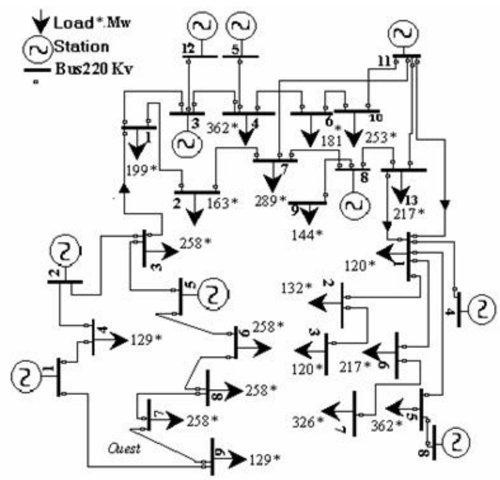

Figure 2 Electrical Topology

According to the obtained results, the main tree is an open configuration. The algorithm finds 232 alternatives. Among these alternatives, the choice of the optimal solution is made only by closing the switch $SW_{27\text{-}28}$ in step N° 49 and opening the switches $SW_{23\text{-}26}$ in step N°78. For these alternatives, the minimal cost is represented in table 1 with corresponding power transit, and a comparative overview is tabulated in table 2.

Table 1. Optimal solution from proposed algorithm

Total Alternatives Number 232	Switches States	Candidate Lines	Power Transit GW
Step N°1: N°49	On	27-28	10
Step N°1: N°78	Off	23-26	12.4
Step N°1: N°78	Off	23-26	12.56

Table 2 Benefits of proposed algorithm

	Existing system	Proposed system	Benefit
Lines losses	297 kw	242 kw	55.0 kw
Transformation losses	0.2 kw	0.2 kw	0.0 kw
Total power loess	292.2 kw	242.2 kw	55 kw
Power loss in percentage	10%	08%	19%
Annual energy loss	604020.1 kwh	492191.7 kwh	111828.4 kwh
Annual energy loss in percentage	6%	5%	19%

The figure 3 shows the simulation results before and after the proposed reconfiguration. As it can be seen from the figure that there is voluptuous improvement in voltage drop after apply the proposed reconfiguration. At node 20 the voltage is improved from 28 % to 22 %.

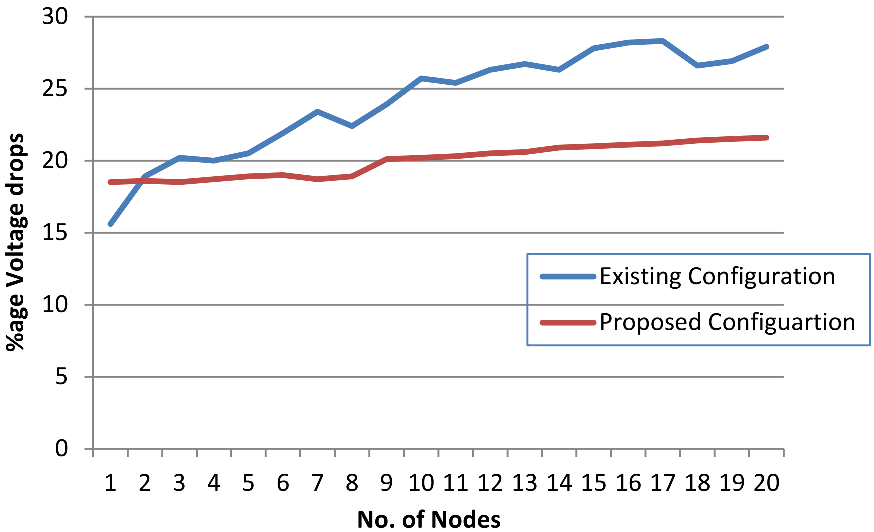

Figure 3 voltage drops before and after the proposed reconfiguration

Conclusions

This algorithm differs from most others, by constructing the system from scratch, rather than performing switch exchanges or sequential switch openings. An approximate loss formula helps to quickly screen candidate switch closings, but this method still performs more load flow calculations than other methods. Most of the load flow calculations only work with a subset of the system. The algorithm can solve load either restoration or loss minimization problems. The test case shows that this algorithm minimizes the losses from 29% to 15 % and improves the voltage drop from 59% to 29%.

Power factor is improved from 73% to 98%.

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