SOME ASPECTS OF NETWORK RECONFIGURATION IN ELECTRICAL DISTRIBUTION SYSTEMS

by

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CERTIFICATE

This is to certify that the thesis entitled, "SOME ASPECTS OF NETWORK RECONFIGURATION IN ELECTRICAL DISTRIBUTION SYSTEMS", which is being submitted by Nuthalapati D. R. Sarma. to the Department of Electrical Engineering, Indian Institute of Technology. Delhi. India, for the award of degree of Doctor of Philosophy, is a bonafide research work carried out under the guidance of Late Prof. K. S. Prakasa Rao, of Department of Electrical Engineering, Indian Institute of Technology, Delhi.

The results contained in this thesis have not been submitted to any other University or Institute for award of any degree or diploma.

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THIS THESIS

IS DEDICATED

TO

MY BELOVED PARENTS

SHRI NUTHALAPATI HANUMANTHA RAO

AND

SMT. NUTHALAPATI KAMALA DEVI

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(Nuthalapati D. R. Sarma)

ABSTRACT

The phenomenal advancements in computer, control and communication technologies have made the automation of power distribution systems a viable option. Several utilities in developed countries have already implemented many Distribution Automation Systems (DAS). Developing countries like India are also exploring DAS. Network Reconfiguration is one of the important features of DAS. It deals with change of feeder configurations through remotely controlling the switches on a real-time basis. Network reconfiguration needs to be done for the following reasons in day-to-day distribution system operations:

- Service restoration
- Loss minimization
- Load balancing

This thesis investigates into these aspects of network reconfiguration and explores some new ideas and approaches to solve them in an efficient way.

Network Reconfiguration for Service Restoration

A distribution system can be easily represented by a graph. In this thesis a reduced graph representation of the system is suggested so that enumeration of alternate strategies for service restoration will be simple and efficient. The network is reduced by suitably coalescing certain set of nodes together and the reduced network is then

analyzed for finding alternate paths from source points to affected load points. This involves finding all the 'interested trees' of the network. Service restoration strategies should also meet some important operational considerations viz., satisfying voltage and current constraints, minimum switchings, minimum losses etc.. Chapter III presents a new and efficient method of network reconfiguration for service restoration based on the above ideas. A simple scheme is presented for determination of affected load points, non-restorable affected load points on the occurance of a fault. A new scheme for load shedding is proposed which helps to keep the disruption to a minimum level in a situation where load shedding is inevitable.

The problem of generating all interested trees referred above is solved in Chapter II. It considers a noninterested node, say, 'N', and then enumerates all possible combinations of building up of trees to include this node 'N' and to exclude this node 'N'. In order to include a noninterested node 'N', atleast two edges incident at 'N' are to be included in the tree. This approach would directly give all interested trees without repetition.

Network Reconfiguration for Loss Minimization

Another important aspect of feeder reconfiguration in distribution systems is loss minimization. Most of the existing methods are based on either heuristics or successive approximation methods in which they consider one feeder pair at a time to reconfigure the network to reduce losses thus restricting the search area for optimization. In this thesis some new ideas are explored to consider all feeder pairs simultaneously which helps in seeking the solution with a global perspective.

While reconfiguring the network, some loads (nodes) are to be transferred from one circuit to another. So a particular load at a node is either connected to a circuit or not connected to a circuit (but connected to neighboring circuit). It is convenient to assign a 0-1 integer variable to a node which may have to be transferred to the other circuit. Power loss function is formulated in terms of these 0-1 integer variables. This objective function has to be minimized to identify the switchings required to reduce losses. Based on this idea, a new method is proposed in Chapter IV, for loss minimization using 0-1 integer programming method. This solves the problem using discrete variables and the solution is obtained in a few iterations. Generalized procedure is also given to formulate the problem.

In Chapter V, another method is proposed using quadratic programming method. Here, the problem is formulated in terms of continious variables (current variables). The objective function formulated in terms of these current variables is minimized to directly determine the switching operations required to reduce the losses. This gives the solution in a single iteration. Whenever it is required to reconfigure the network to reduce losses, one has to just calculate only some coefficients of the objective function. Generalized procedure is also given to easily determine the coefficients of the objective function.

Network Reconfiguration for Load Balancing

Another aspect of network reconfiguration in distribution systems is for load balancing. Based on the ideas presented in Chapters IV and V, two new methods are proposed to solve the problem of load balancing of transformers. These methods consider all feeder pairs simultaneously so as to seek the solution with a global perspective.

To achieve load balancing, it is required to load all the transformers equally in

proportion to their capacities. For a given loading condition, one can determine the desirable loading of each transformer to get load balancing. If i_a, i_b, ..., i_t represent loads of transformers and i_{Da}, i_{Db}, ... , i_{Dt} represent their desirable loadings to achieve load balancing, then the objective function that is required to be minimized can be obtained as $F = (i_a - i_{Da})^2 + (i_b - i_{Db})^2 + ... + (i_t - i_{Dt})^2$. In Chapter VI, based on the ideas presented in Chatpers IV and V, load balancing problem is also solved using 0-1 integer programming method and quadratic programming method.

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