Research Journal of Applied Sciences, Engineering and Technology 5(16): 4149-4154, 2013
DOI:10.19026/rjaset.5.4641
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: July 31, 2012 Accepted: September 08, 2012 Published: April 30, 2013

**Research Article**

# Algorithm Acceleration and Data Storage Volume Reduction in Reliability Modeling Within Distribution Network

Esmail limouzade
Department of Electronic, Dezful Branch, Islamic Azad University, Dezful, Iran

**Abstract:** Investigation and assessment of a system performance was complex. So Equipment reliability modeling may be a proper solution to easier it. Electricity distribution network is among systems reliability of which is of great importance. They are highly complex due to their large size and hence their modeling takes a long time. This study offers a simple algorithm for Electricity distribution networks modeling which enjoys algorithm high speed and data low volume. It is based on a graph search method called coloring. In this innovative method, it is suggested to search minimal path from the beginning of the feeder to the sink points. Also it is applied by saving paths in terms of switches and through logical operations of symmetric difference without searching paths from each input to estimate minimal path between all inputs and outputs. In so doing there will be no need for explicitly defining the source node, as it is easily recognizable via junction matrix composition. This kind of network modeling is so flexible and it is simply applicable to bidirectional or non-planar graphs.

**Keywords:** Acceleration, data volume reduction, graph theory, reliability, modeling

## INTRODUCTION

In general, Reliability is as much as systems performance. The more is a system size and complexity, the more its unreliable behavior and costs will be Chen *et al*. (2011). In the past research, the main objective of "spares and reliability optimization problem" in systems is often to maximize total reliability under such constraints as budget and space. As far as components multiple-choice is concerned, mathematical methods were not effective and heuristic and meta-heuristic methods must be applied (Genç *et al*., 2012). Many methods for reliability optimization assume that systems components are parallel or series, different plans are available and various methods have been applied to solve this problem (Patelli *et al*., 2011). Reliability is referred to as a system capability in realizing its required performance under environmental and functional circumstances and within a certain time span. In the other words, reliability is as much as systems performance (Arya *et al*., 2012a). To maximize the system total reliability, the required space and costs and the weight of costs pertaining to maintenance, hiring and firing operator, equipment substitution in different work shifts must be minimized (Yingkui and Jing, 2012). In the last decade, researchers have studied reliability optimization problem consisting of Redundancy Allocation Problem and Reliability Assignment Problem. Solving these 2 problems simultaneously is further more difficult comparing with solving them separately as 2 different kinds of decision-making variables must simultaneously be determined (Wang and Li, 2012). Since considering these objectives or constraints in the problem makes it closer to the reality and further complicates its solving, it is necessary to provide an innovative and mixed solution. Two types of modeling of multiple-objective reliability problem are as following.

**Type 1:** Maximize system reliability, Rs
Minimize system cost, $C_s$
Minimize system weight, $W_s$
Subject to:
$R_{s\,min} \leq Rs \leq 1$, $Cs_{\,min} \leq C_s \leq C_{s\,max}$
$W_{s\,min} \leq W_s \leq W_{s\,max}$ , $R_{i\,min,}$ $R_{i\,min} \leq R_i \leq 1$

**Type 2:** Maximize system reliability, $R_s$
Minimize system cost, $C_s$
Subject to:
$R_{s\,min} \leq R_s \leq 1$, $C_{s\,min} \leq C_s \leq C_{s\,max}$
$W_{s\,min} \leq W_s \leq W_{s\,max}$ , $V_{s\,min} \leq V_s \leq W_{s\,max} \leq$
$R_{i\,min,} \leq R_i \leq 1$

The 1$^{st}$ model is a multiple-objective one which aims at maximizing the system reliability and minimizing the system costs and weight. The 2$^{nd}$ model is a binary-objective one whose objectives are maximizing system reliability and minimizing system costs with regard to constraints of cost, weight, volume and reliability low limit for subsystems components and the whole system. System reliability depends upon its components decoration. It means that system reliability with parallel components differs from a system with series components and a system comprising of these two decorations (Khalili-Damghani and Amiri, 2012). So:

* If the system is constituted of series components, then the total reliability equals to:

$$R_s(n)=\prod_{i-1}^{s} R_i(n_i)$$

* If the system is constituted of parallel components, then the reliability equals to:

$$R_s(n)=\prod_{i-1}^{s}\left[1-(1-R_i(n_i))\right]$$

If the system comprising of series-parallel components, the reliability is calculated with respect to the system design (regular or complex) and through the mentioned relations (Zhang *et al*., 2007). In general and regardless of differences, all of the minimum cut-set and tie-set algorithms attempt to offer a model characterizing the network graph and tracing the current path between the network nodes. All tracing methods are divided in 2 general groups from mathematical modeling and graph search methods perspective. The 1st group is Breadth First Search and as the name suggests, it is a level to level graph search. It starts at the root (selecting some node as the root in the graphs or the root-less trees) and puts it in the 1st level. Then for each of those neighbor nodes in turn, it inspects their neighbor nodes which were unvisited and so on. It is stopped when all neighbors of the final level nodes have been visited.

The 2nd group is called Depth-first search and as the name suggests, it is a deeper search in the graph. It starts at the root (selecting some node as the root in the graphs or the root-less trees) and explores neighboring nodes via output edges of current node as far as possible along each branch before backtracking. Upon facing with unvisited neighbors, it is implemented recursively for that node. If all neighbors have been already visited, it backtracks and it is continued in a node from which we have come to the current node. It goes deeper and deeper as far as possible. It continues until all accessible nodes will be visited (Moslemi, 2011).

Based on the above introduction, the present study titled as "offering a quick method of modeling and assessing reliability" aims at providing a simple and quick method for network routing through using former methods. This method is based on what is called graph coloring that has not yet been applied in graph search studies.

## LITERATURE REVIEW

Emphasizing on the effect of the system components location, Karbasian *et al*. (2009) have provided a model to keep balance between the system reliability and costs of positioning, maintenance and repair and have solved it via lingo software. Zhao *et al*. (2007) applied penalty function and local search for solving reliability optimization in series-parallel systems. Yadav *et al*. (2009) combined two approaches of reliability-based design and robust design and optimized it via Taguchi quality loss function. Wang *et al*. (2009) addressed uncertainty of likely events of failure in spare systems based on Cross Entropy Approach. Gupta *et al*. (2009) solved the problem of spare allocation in series systems or interval values through unconstrained integer programming and formulated interval coefficients (high and low limits for reliability) and via penalty function and advanced genetic algorithm. Also Ferreira and Bretas (2012) used nonlinear binary programming model aiming to minimize the SAIDI and SAIFI reliability indices of a distribution feeder based on the branch-and-bound algorithm by identifying types and locations of protection devices and sectionalizing switches. Arya *et al*. (2012b) optimized distribution Reliability with respect to failure rate and repair time of each section of the distribution. Differential Evolution (DE), Particle Swarm Optimization (PSO) and Co-ordinate Aggregation based PSO (CAPSO) has been used to develop computational algorithms.

## METHODOLOGY

In fact, the routing algorithm presented here, is part of a comprehensive algorithm developed for modeling and predicting the reliability [1]www. math. uaa. alaska. edu/~afkjm/cs411/handouts /graphs. The purpose of its implementation is to produce the required data for the reliability prediction algorithm. Network data including minimal path matrix of each sink point to the source and minimal path matrix of maneuver points are required in order to calculate reliability in open ring networks. It enjoys node/branches concept and constitutes network nodes junction through using raw data of matrix network. Then by examining splits, from each node it extracts the current paths between the source node and each sink point. Figure 1 shows the overall framework of the algorithm.

The raw data of nodes junction is applied in constituting network junctions matrix. These data are actually the inputs of the network modeling algorithm comprising of: node number, parent node number, element code, branch code, element status (closed status = one and open status = zero). Hence nodes junction matrix is obtained for each feeders branched from secondary grid substation.

## MODELING RESULTS

The algorithm initial idea stems from depth search concept, yet it is a recursive algorithm that searches

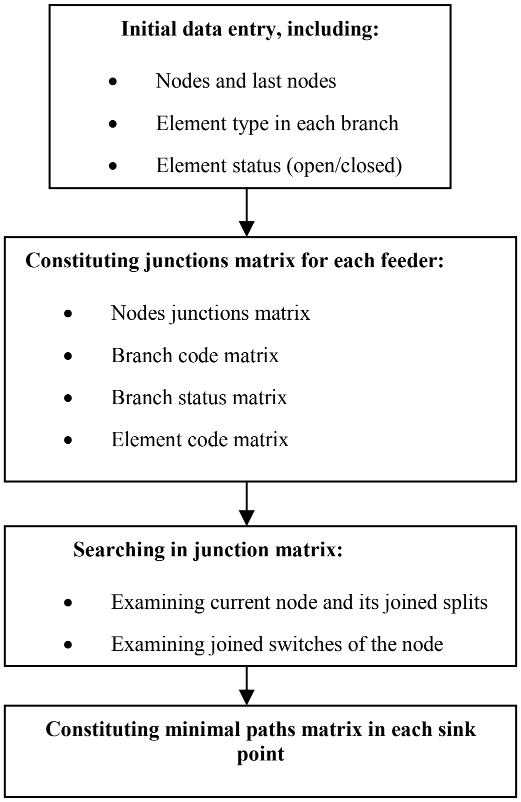


Fig. 1: Conceptual framework of the network routing algorithm

each time again from the beginning of the feeder which reduces the program speed. To overcome this problem, another idea called Graph Coloring Method has been employed. Simply, graph coloring concept is a method for recognizing ring in the graph based on a particular constraint. Graph coloring is labeling graph vertices so that the neighboring vertices do not possess a label. These labels are called colors. It is said that a graph is k-colorable if it can be colored by maximum k different colors. If a graph is not k-colorable, it has a ring. It is called vertices coloring. Similarly, in coloring the edges, each color is allocated to one edge so that two neighboring edges will not possess an identical color (Yufeng *et al*., 2009). Also to compare search speed of BFS and DFS, if we consider each branch search as a time unit, DFS method searches the whole network in 48 time units while graph coloring and BFS methods will search the whole network in only 23 time units. However in determining the minimal path, BFS method occupies 9 times more memory volume than the DFS and graph coloring methods. Consequently it can be asserted that in the real distribution networks with a lot of splits, at least 50% time saving in network search stage is brought about. To determine existing paths between all sinks and their sources, suffice it to search the switches between each sink and the related source. This is applicable to both open ring distribution feeder

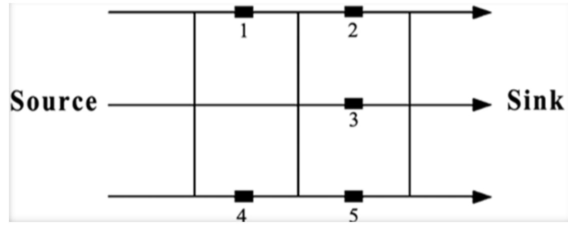


Fig. 2: Sample ring network with a few switches between 3 sources and 3 sinks

and secondary grid substation that is a ring network. Search starts at a node and it is studied whether the next node is a switch, another element in the network or a sink. If it is a switch, the node number is saved in a matrix called path matrix. In principle, path matrix is a one that demonstrates which switches exist in each path. It is a matrix (K×P) in which K denotes path matrix numbers and P denotes switch numbers. Then split node becomes the current node and the algorithm continues to search until it reaches the sink point and the path is completed. For example, simple network with 3 sources, 3 sinks and 5 switches shown in Fig. 2 is studied.

In the figure, existing paths between source 1 and sink 2 by searching corresponding switches including 9 paths are as below.

{2, 3, 5, 1and 2, 1 and 3, 1 and 5, 4 and 2, 4 and 3, 4 and 5}

This kind of search increase the program speed and since the paths are merely recognized and saved via existing switches in the source and sink path, the memory calculations and data volume is reduced. Moreover, as this algorithm has been developed for calculating distribution network reliability, network utilization has been accomplished in algorithm implementation; it means that for maneuver operations, after error occurrence and/or DGs junctions to the network to retrieve some of the sinks, minimal paths between maneuver usually-open points and the sinks are required. To accomplish this part and to prevent routing algorithm reimplementation which will be time-consuming for real network dimensions, a very simple and innovative solution based on a simple principle in the graph theory has been suggested. As per Fig. 3, if we have 2 paths of AB and ACD, then BCD path is easily obtained via logical operations of symmetric difference. This idea has been employed for reducing searching operation so that through searching the path between the beginning of the feeder and all the nodes and maneuver points and by using logical operations, the path between all DGs or maneuver points and the sinks will be gained without a new searching operation and the program operation speed will significantly be modified as well. Because searching methods is further ore time-consuming comparing with logical operations.

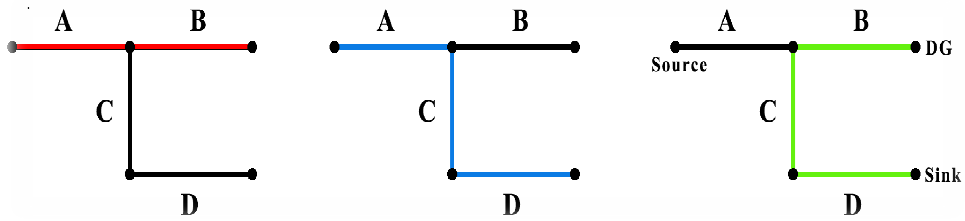


Fig. 3: Routing of symmetric difference logical operations between 2 paths

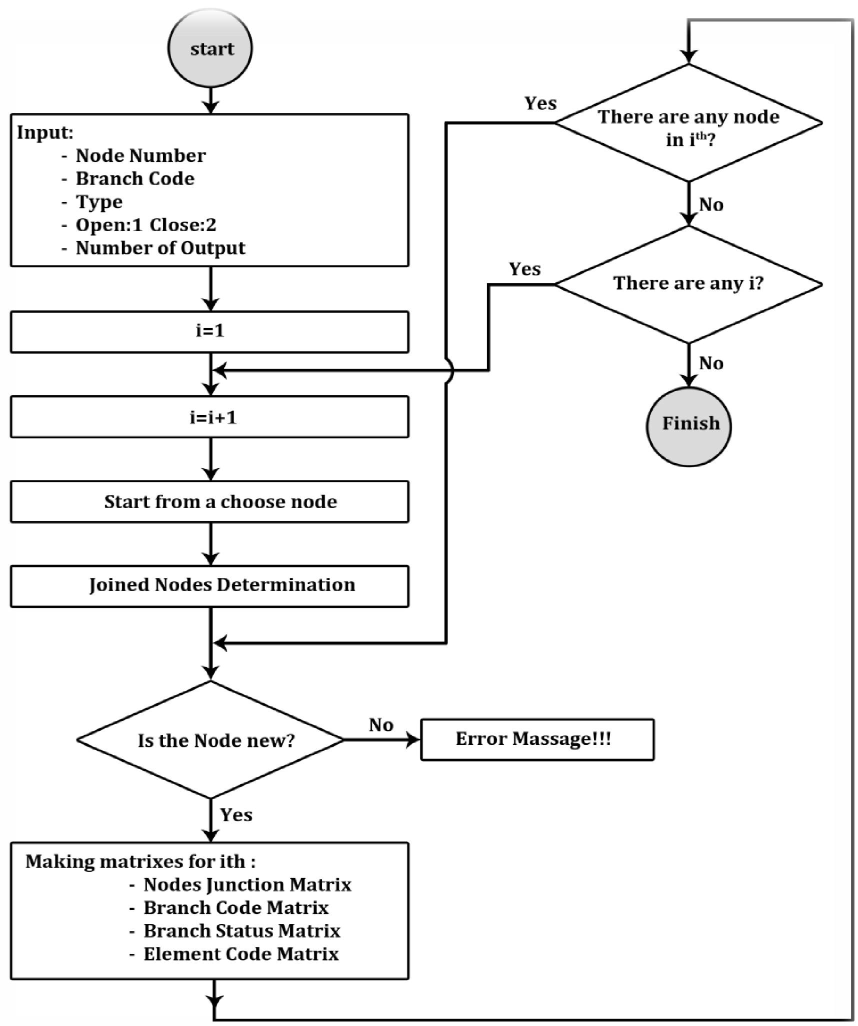


Fig. 4: The 1st block of modeling algorithm

The algorithm flowcharts have been shown in Fig. 4 and 5.

The algorithm 1$^{st}$ block (Fig. 4) relates to constituting the network junctions matrix and determining network topology. In the input, such data as the process has been expressed. The algorithm starts from a choose node and while determining the joined nodes, it always investigates whether there is a ring or not and if any, an error massage will be appeared. The 2$^{nd}$ block (Fig. 5) constitutes flowcharts of developing minimal paths on the basis of searching all switches between the source and sink points. In this stage, a code corresponding with a color is allocated to each network branch. Whenever a new switch is found, it is added to a matrix called MP matrix and if it reaches a sink, the corresponding row has been developed in the matrix.

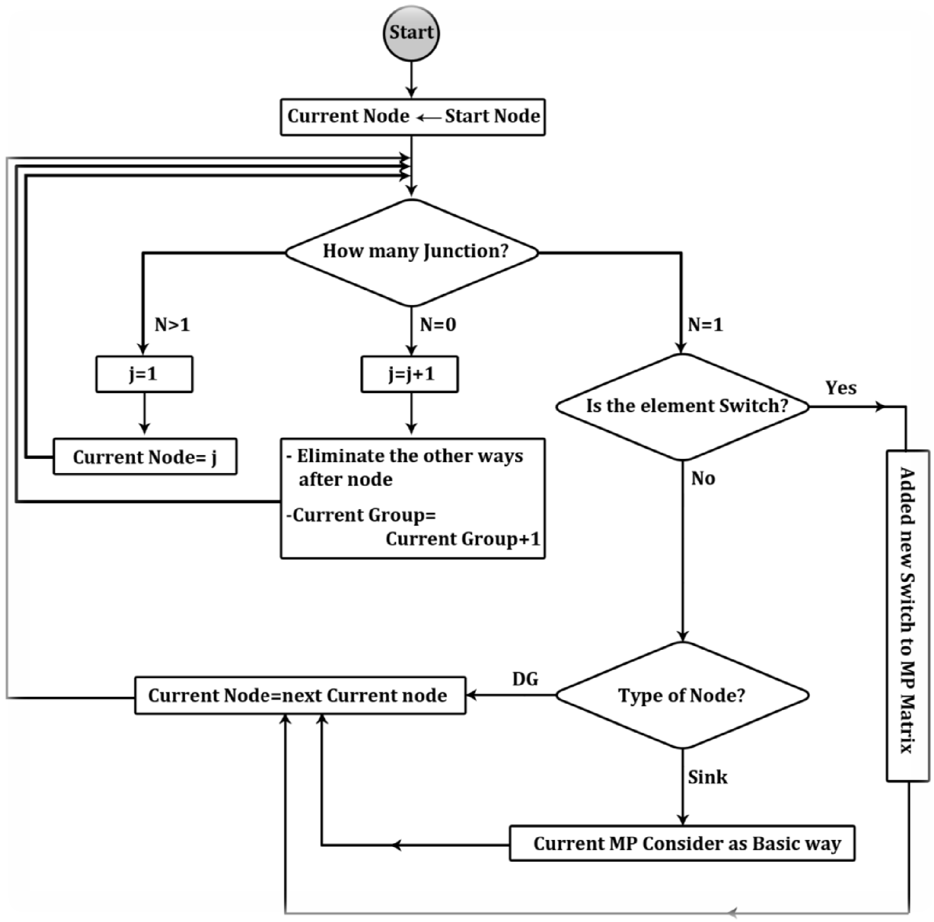


Fig. 5: The 2nd block of modeling algorithm

## CONCLUSION

In this study, a simple and innovative algorithm based on the graph coloring method has been offered for network graph modeling and path searching in the distribution network. In this method, in order to reduce data processing volume and accelerate the algorithm, only the switches existing in the paths are searched rather than the whole elements. In fact, the network is equated based on its switches. In this model, minimal paths with graph searching are calculated directly for ring networks and radial networks. Also it is applied by saving paths in terms of switches and through logical operations of symmetric difference without searching paths from each input to estimate minimal path between all inputs and outputs. In so doing there will be no need for explicitly defining the source node, as it is easily recognizable via junction matrix composition. This kind of network modeling is so flexible and it is simply applicable to bidirectional or non-planar graphs. Besides, there is no constraint in the number of source nodes or final nodes. These may be considered among the offered algorithm advantages.

## REFERENCES

Arya, L.D., S.C. Choube, R. Arya and A. Tiwary, 2012a. Evaluation of reliability indices accounting omission of random repair time for distribution systems using monte carlo simulation. Int. J. Elec. Power, 42(1): 533-541.

Arya, R., S.C. Choube and L.D. Arya, 2012b. Reliability evaluation and enhancement of distribution systems in the presence of distributed generation based on standby mode. Int. J. Elec. Power, 43(1): 607-616.

Chen, B.Y., W. Lam, A. Sumalee and H. Shao, 2011. An efficient solution algorithm for solving multi-class reliability-based traffic assignment problem. Math. Comput. Model., 54(5-6): 1428-1439.

Ferreira, G.D. and A.S. Bretas, 2012. A nonlinear binary programming model for electric distribution systems reliability optimization. Int. J. Elec. Power, 43(1): 384-392.

Genç, H.M., O.K. Erol, I. Eksin, M.F. Berber and B.O. Güleryüz, 2012. A stochastic neighborhood search approach for airport gate assignment problem. Expert Syst. Appl., 39(1): 316-327.

Gupta, R.K., A.K. Bhunia and D. Roy, 2009. A GA based penalty function technique for solving constrained redundancy allocation problem of series system with interval valued reliability of components. Comput. Appl. Math., 232(2): 275-284.

Karbasian, *et al*., 2009. Modifying maintenance and repair on the basis of system reliability as per costs and reliability associated with its components location. The 1st Conference of Aerospace Systems Reliability Engineering.

Khalili-Damghani, K. and M. Amiri, 2012. Solving binary-state multi-objective reliability redundancy allocation series-parallel problem using efficient epsilon-constraint, multi-start partial bound enumeration algorithm and DEA. Reliab. Eng. Syst. Safe., 103: 35-44.

Moslemi, N., 2011. Predicting Electricity Distribution Networks Reliability: Network Modeling and Reliability Indices Calculation. Niroo Research Center, Network Studies Center.

Patelli, E., H.J. Pradlwarter and G.I. Schuëller, 2011. On multinormal integrals by importance sampling for parallel system reliability. Struct. Saf., 33(1): 1-7.

Wang, L. and L. Li, 2012. A coevolutionary differential evolution with harmony search for reliability-redundancy optimization. Expert Syst. Appl., 39(5): 5271-5278.

Wang, Z., M. Gerstein and M. Snyder, 2009. RNA-Seq: A revolutionary tool for transcriptomics. Nat. Rev. Genet., 10: 57-63.

Yadav, O.P., S.S. Bhamare and A. Rathore, 2009. Reliability-based robust design optimization: A multi-objective framework using hybrid quality loss function. Quail. Reliab. Eng. Int., 26(1): 27-41.

Yingkui, G. and L. Jing, 2012. Multi-state system reliability: A new and systematic review. Procedia Eng., 29: 531-536.

Yufeng, H., L. Zongqi, L. Wenxia and Z. Jianhua, 2009. Design and implementation of reliability evaluation module for medium voltage distribution networks by objectarx technology. 8th International Conference on Advances in Power System Control, Operation and Management, (APSCOM), North China Electric Power University, Beijing, China, Nov. 8-11, pp: 1-6.

Zhang, J., S.F. Jones, J. Wang and S. Helal, 2007. DPQ: Using a distributed priority queue to improve Ad hoc TCP performance. Proceedings of the 4th International Conference on Information Technology (ITNG), Las Vegas, Nevada, USA, April 2-4.

Zhao, J.H., Z. Liu and M.T. Dao, 2007. Reliability optimization using multiobjective ant colony. Reliab. Eng. Syst. Safe., 92: 109-120.