Network Reconfiguration using Boruvka Algorithm

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***Abstract*---Most of the distribution networks are connected in a closed loop consisting multiple branches with multiple nodes or open and close contacts which makes the overall structure of the distribution network very complex and also increasing the efficiency and reliability of the network is challenging, so there is a need for Network Reconfiguration. In order to address the difficulties associated with network reconfiguration, this study proposed a technique of graph theory called Boruvka algorithm. Tie and sectionalizing switches are crucial in Network Reconfiguration. The network topology framework can be evolved by modifying the sectionalising switches' opening and closing status. In this paper, standard IEEE 6-Bus system is executed using the Boruvka algorithm. Results indicate that the IEEE 6-Bus system benefits significantly from using the graph theory called Boruvka algorithm, leading to an optimal radial network configuration.**

Keywords---Boruvka algorithm; Distribution network; Network Reconfiguration; graph theory; minimum spanning tree.

I. INTRODUCTION

Reconfiguration of distribution network is a method to tackle issues with the distribution network, such as improving the voltage profile and mitigating the active power loss in the overall system. Various optimization technique, including both numerical and heuristic methods, has been employed to address Network Reconfiguration. Tie and sectionalizing switches are vital, not only in protecting the network from faults but also help in network reconfiguration. To reconfigure the distribution network there were several techniques based on either graph theory or optimization technique or a combination of both which is called hybrid. This paper represents a graph theory called Boruvka algorithm which is the oldest form of spanning tree algorithm to solve the distribution network problem of minimizing power losses by simply changing the topology structure of the sectionalizing switches.

[1] There has been a numerous study that has been investigated the research area. This study aims to restructured the distribution network by reducing actual power loss. Similarly, the alternative way of handling the distribution network reconfiguration is that by using graph theory to determine the optimal path from the meshed structure altering the structure of switches of the selected branches, which minimize the active power loss and also reducing overload on the feeder by transferring the extra load to the nearby feeder lines [1]. In this paper, to obtained the best radial network from the complex meshed structure and to minimize power loss of the network, a Graph Theory was used. Kruskal's Maximal Spanning Tree, Dijkstra's Shortest Path

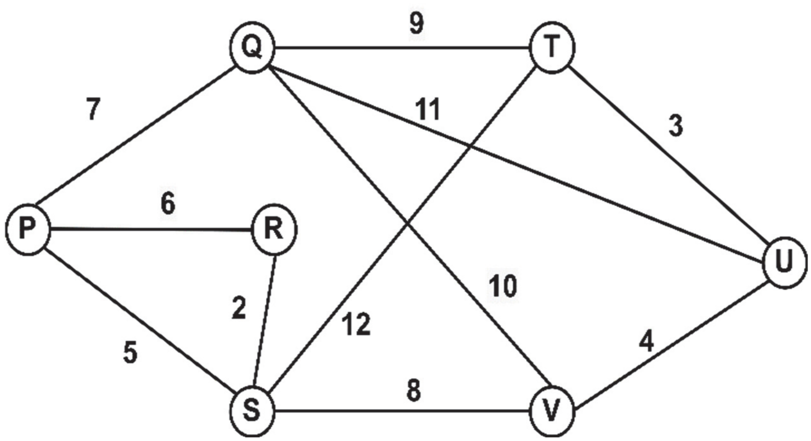
Algorithm and Prim's Minimal Spanning Tree are also presented [2]-[4]. Restructured of the distribution network to solved the problem of the feeder lines such us reducing active power loss are presented [5]. This paper introduces the application of graph theory which changes the complex meshed distribution network consisting several branches and switch into an optimal radial system [6]. In this paper, graph theory was used as an instrument to minimize the interruption time during which the utility experience power shortage due to system faults, and also to determine the radial distribution network [7]. The minimum spanning tree algorithm is used to solve the distribution network problem that is to reduce power loss and also it suggested a dynamic network reconfiguration for load fluctuation [8-10]. Prim's algorithm can be used to identify the most efficient path for a power distribution network. In this paper, using the proposed algorithm it is possible to find the optimal path between each node of the distribution network [11]. The main responsibilities of the central protection centre are supervising the microgrid, detecting any faults, determining the shortest using the combination of Boruvka and Dijkstra algorithm [12]. This paper represents a Kruskal's algorithm-based graph theory to solve reconfiguration problem that is to determine the minimum power loss of the distribution network. This algorithm has been tested on the actual radial distribution system [13].

II. PRESENTED METHODOLOGY

Reducing power loss is one of the key features of restructuring of distribution network. Hence, it is essential to assess the active power loss using a network reconfiguration technique. Most of the distribution network are made up of complex meshed structure but it is expected to run in a simple radial network with minimal active power loss. All lines are assumed to have sectionalizing or tie switches for network reconfiguration.

A. Boruvka algorithm

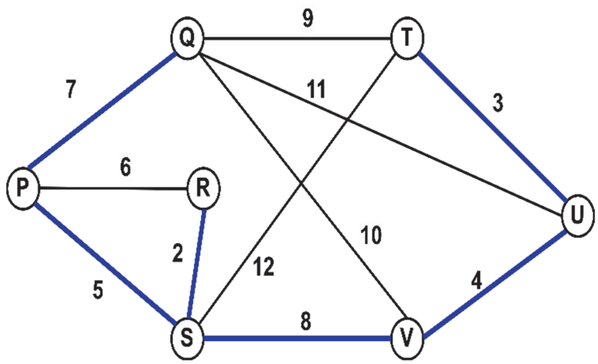
It is a greedy algorithm for finding an optimal path in a graph. It was developed by Otakar Boruvka in 1926 [14-15]. In this algorithm it begins with finding the minimum weight (W). consider the single line diagram consisting P, Q, R, S, T, U and V as vertex shown in figure.1 with their corresponding weight between P-Q, P-R, P-S, R-S, Q-T, Q-U, Q-V, S-T, S-V, V-U and T-U are 7, 6, 5, 2, 9, 11, 10, 12, 8, 4, and 3.



[2] Fig. 1 Meshed structure for seven nodes system

[3]

Let start with node P, node P has three nearby edges P-Q, P-R and P-S. From these three, the edges which has the minimum weight is P-S, which is equal 5 and marked by blue colour. Similarly, node Q has four adjacent side Q-P, Q-T, Q-U, Q-V with Q-P as minimum weight and marked blue. Similarly, rest of the node minimum weight can be found out as shown in figure 2.



[4] Fig. 2 Determination of radial system

Fig.3 represent the radial structure obtained from the given seven nodes meshed structure using Boruvka minimum spanning tree algorithm. The total minimum weight given structure is 29 for the given meshed structure.

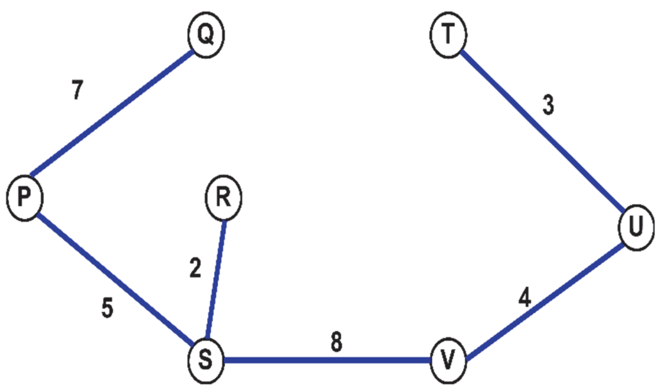


Fig. 3 Radial structured from Meshed structure for given seven nodes system

The weight of the edges represents the real power between the nodes and it is called Load Carrying Capability of the feeder lines and can be determined by the following relation.

$$LC_i = \frac{V_u V_v}{X_i} Sin\ (\theta_u - \theta_v) \tag{1}$$

Where,

LC_i = Load Carrying Capability of Feeder lines

V_u *and* V_v = node voltage at bus i and j

ISBN : 978-81-978522-2-0

$\theta_u - \theta_v$ = phase angle between node voltage at bus i and j.

X_i = Reactance between feeder lines

B. The flowchart of the presented model

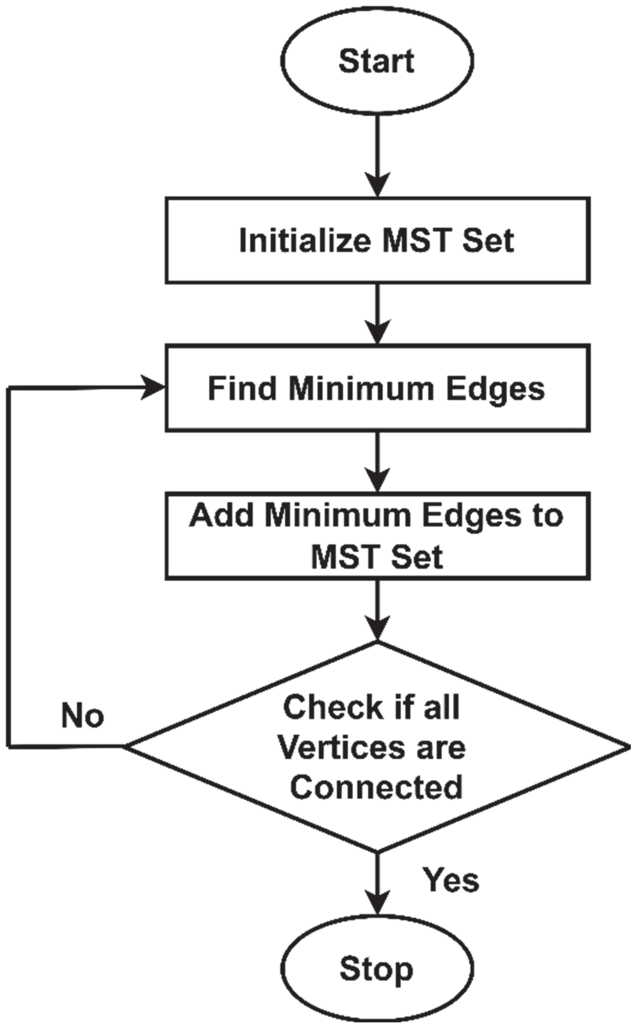
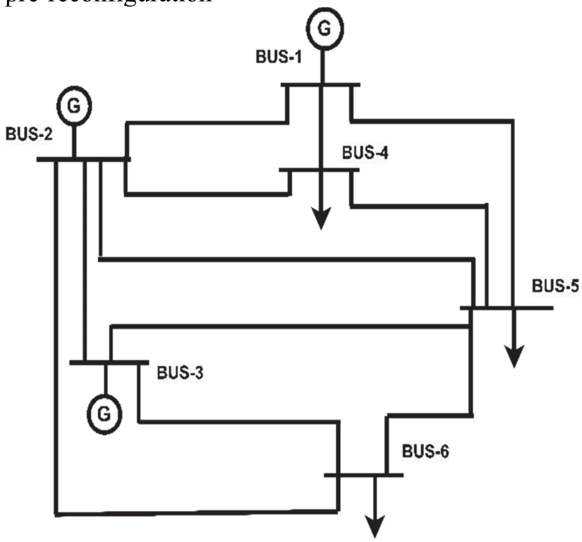


Fig. 4 The flowchart of the presented model

III. Result

The standard IEEE 6-bus system before reconfiguration is given in the Fig.5 below consisting of 6 bus and 11 feeders. And Fig.6 represent the IEEE 6-bus system after reconfiguration. The dotted line in the fig.6 denotes the line is open by a sectionalizing switch and the meshed structure of IEEE 6 bus system is transformed into radial structured. The comparative analysis of the minimum real power loss is presented in Fig.7.

Fig. 5. IEEE 6-bus system pre-reconfiguration



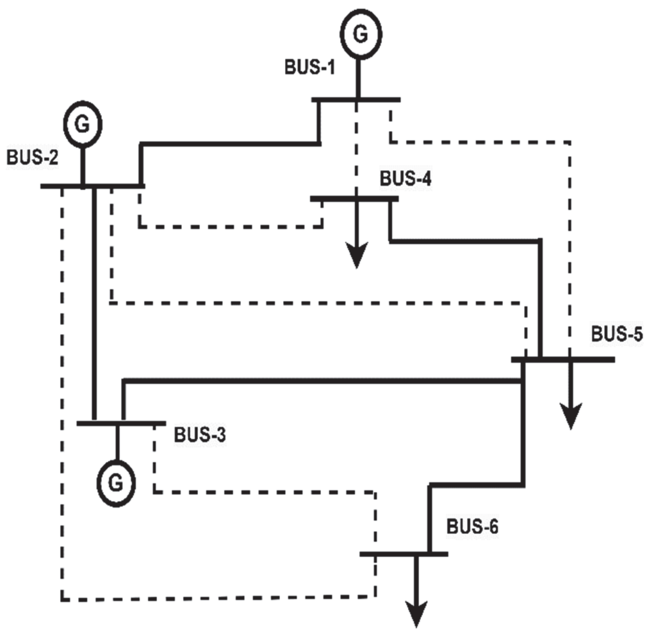


Fig.6. IEEE 6-bus system post-reconfiguration

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TABLE.2 COMPARISON TABLE FOR DIFFERENT METHODS

Sl. No.	Method	Minimum Ploss in p.u
1	Boruvka's	0.10872
2	Prim's	0.4097
3	Dijkstra's	2.2014
4	Kruskal's	1.99342
5	Edmunds'	1.8698

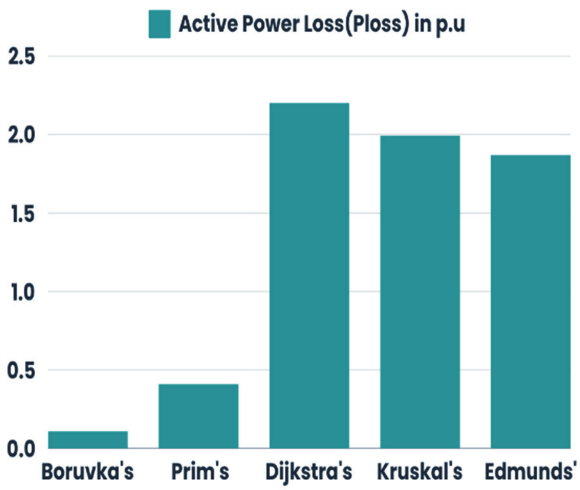

Fig.7.Showing comparison analysis for different methods.

TABLE.3 OPTIMIZED VALUE OF VOLTAGE AND PHASE ANGLE

Bus number	Voltage in per unit (pu)	Phase angle in degrees
1	0.98	25.12
2	0.999	25.00
3	0.96	25.15
4	0.992	25.20
5	0.98	25.27
6	0.972	25.32

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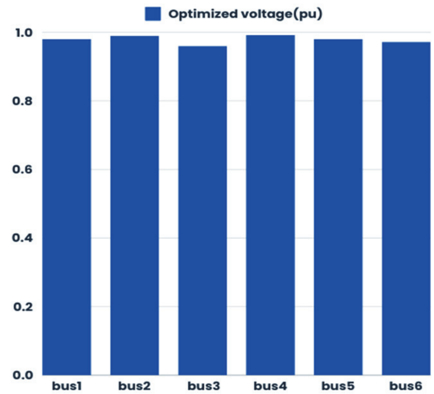

Fig.8. Graphical representation of Optimized value of voltage and phase angle.

Table.1 represent the comparison analysis of minimal real power loss for standard IEEE 6-Bus system [3]. The proposed model shown a significant reduction in active power loss as compared to another graphical methods. Table.2 represent the optimized value of voltage in per unit and phase angle in degrees after performing Boruvka Algorithm. And the graphical representation for IEEE 6 bus system after developing Boruvka Minimum Spanning Tree Algorithm is given in Fig.6. The least voltage 0.96 per unit and it is at bus number 3.

IV. Conclusion

A Boruvka Minimum Spanning Tree Algorithm for IEEE 6-bus system is introduced to find the best optimal radial path for the presented model to improve the voltage profile and reduce power loss of the distribution network. Distribution network reconfiguration is accomplished by adjusting the status of sectionalizing switches to achieve optimal operating condition for standard IEEE 6-bus system. The result shows that the presented model achieved the minimal active power loss for the specified distribution network.

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