

Dijkstra's Algorithm for Shortest Path Identification in Reconfigurable Microgrid

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Abstract: Microgrids are local distribution level networks which operate in either grid connected mode or islanded mode. It is a flexible system which supports the integration of renewable power sources such as solar, wind, etc. Reconfiguration of the microgrid occurs frequently. Due to the bidirectional power flow, traditional protection methods are not applicable to microgrids. This study discusses the use of Hybrid-Dijkstra's algorithm which finds out the shortest path from a faulted point to the nearest operating source which may lead to minimum user disconnection. The proposed algorithm is tested and validated on a standard 43-bus microgrid network and an IEEE 7-bus distribution network.

Key words: Hybrid algorithm, microgrid protection, Dijkstra's algorithm, microgrid, frequently, validated

INTRODUCTION

Microgrid is a system of Distributed Generators (DG) and loads with respect to the main grid. They are designed to operate in two modes: grid connected and islanded mode. During the grid connected mode, the utility grid caters to the load requirements of the distribution network (Bakar *et al.*, 2014; Gupta *et al.*, 2015; Mortazavi *et al.*, 2015; Swathika *et al.*, 2015; Swathika and Hemamalini, 2015). But when any fault is encountered in the network, microgrid transits itself into islanded mode, during which the DGs (Distributed Generators) installed at various sites cater to the load requirements. Also, due to the fluctuating load demand, the DGs (Distributed Generators) are connected or disconnected to the microgrid. These are the prominent reasons which trigger the reconfiguration of microgrid. The condition is more challenging due to the bidirectional power flow.

Distributed generators also cause issues like sympathetic tripping, false tripping, blind zone, varying fault levels and unnecessary islanding. Communication assisted protection schemes are used to protect the microgrid (Swathika and Hemamalini, 2015a, b, 2016a, b; Swathika *et al.*, 2015a, b, 2016a, b).

This study proposes a solution through Hybrid-Dijkstra's algorithm. The current topology of the microgrid is identified using hybrid graph algorithms. When the fault occurs, Dijkstra's algorithm finds the shortest path from fault to the nearest operating source, thereby ensuring quick fault clearance.

Shortest path identification problem: The objective is to identify the distance from the fault to the nearest

operating source with minimum part of the load being disconnected. This can be analysed as a minimization problem:

$$\text{Min}(D) = \text{min}(P) \quad (1)$$

Where:

D = Distance between faulted point to the point of common coupling

P = Paths that exist between faulted point to the point of common coupling

This is subjected to the constraint that the shortest path identified from the network using the proposed algorithm should be a radial network.

MATERIALS AND METHODS

The study discusses how the hybrid algorithm is used along with Dijkstra's algorithm to identify the shortest path of traversal. The hybrid algorithm produces a database of active nodes of the system which is further utilized by Dijkstra's algorithm to produce the sequence of traversal through the network to achieve a low cost and an efficient path of traversal. The Dijkstra's algorithm utilises these results to produce the sequence of traversal to achieve an efficient data flow.

Dijkstra's algorithm:

Let N be the number of nodes, V be the faulty node, P be the number of paths for the selected node.

- 1: Initialize the cost matrix $C[][]$ from adjacency matrix $\text{adj}[][]$. $C[i][j]$ is the cost of going from vertex i to vertex j . If there is no edge between vertices i and j then $C[i][j]$ is zero.
- 2: Enter the path matrix, $\text{path}[][]$ which represents the possible paths to the faulty node.
- 3: for ($i=1$; $i \leq p$; $i++$)

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{ distance[i] = 0
  Row = 1
  { for (j=1 ; j <= n; j++)
    If (row is not equal to V)
      Column = path[i][j+1]
      Distance [i] = distance[i] + cost[row][column]
    }
  Row = column
}

```

4: Now find out the minimum distance from the distance matrix (i.e.) distance[i].

5: Extract the shortest path from the path matrix.

For an electrical grid, Loads (L), Utility Grid (UG), DG sources and the Point of Common Coupling (PCC) are assumed to be the active nodes. Also, we assume the edge (path) weight as '1'. If 'N' is the number of active nodes in the network then a dimension matrix of size (N X N) is formed. For a node connected or disconnected the shortest path of traversal is updated accordingly. The Dijkstra's algorithm that is used for the shortest path identification is given:

The hybrid Boruvka and Prims algorithm is employed on the microgrid network for obtaining the list of active nodes. First with Boruvka's the edges of the network are reduced into half. Now, Prims methodology creates a large tree which connects the other small trees in the list. This cycle of the two algorithms is repeated until we find out the active nodes.

RESULTS AND DISCUSSION

Case 1; IEEE 7-bus microgrid network: A generic code is developed for the proposed Hybrid-Dijkstra's algorithm. Let a fault occur closer to the bus 6 in the IEEE standard 7 bus distribution network shown in Fig. 1. The shortest path for quick fault clearance is as indicated in Fig. 2. This path involves 3 nodes each with the path weight of '2'. The algorithm is executed on three different processors namely:

- Intel(R) Core TM i5-3230M, CPU@ 2.60 GHz
- Intel(R) Core TM i7-3612QM, CPU@ 2.10 GHz
- Intel(R) Core TM i7-4720MQ, CPU@ 2.20 GHz

The run time in these processors for a fault closer to bus 6 is indicated in Table 1.

Case 2; IEEE 43-bus microgrid network is considered: The IEEE standard 43 bus network shown in Fig. 3 is considered for analysis. If a fault occurs closer to node 43, the possible paths are as follows:

- 1-2-15-28-39-43 (Weight = 5)
- 1-15-28-39-43 (Weight = 4)
- 1-2-6-12-43 (Weight = 4)

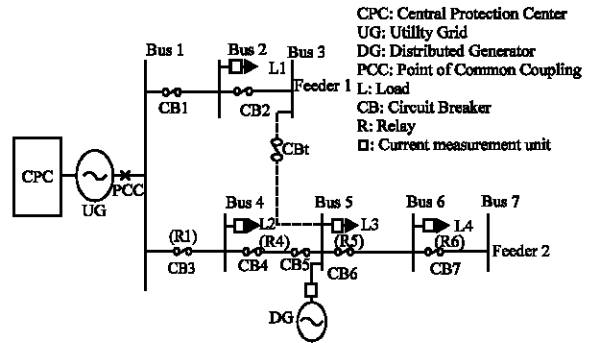


Fig. 1: IEEE standard 7-bus distribution network one line diagram

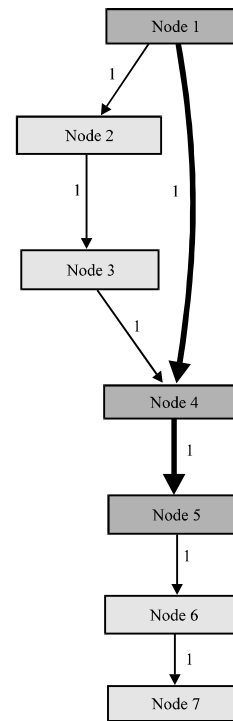


Fig. 2: IEEE standard 7-bus distribution network

Table 1: Experimental results using different processors

Error node	Processor	Run time (clocks per second)
6	Intel(R) Core TM i5-3230M CPU@ 2.60 GHz	7.153100e+004
6	Intel(R) Core TM i7-3612QM CPU@ 2.10 GHz	8.087400e+004
6	Intel(R) Core TM i7-4720MQ CPU@ 2.20 GHz	11.3820e+004

The shortest path identified using the proposed Hybrid-Dijkstra's algorithm is indicated in Fig. 4. This shortest path involves 5 nodes and its pathweight is 4. Continuity of supply is ensured by the proposed algorithm to maximum number of connected nodes.

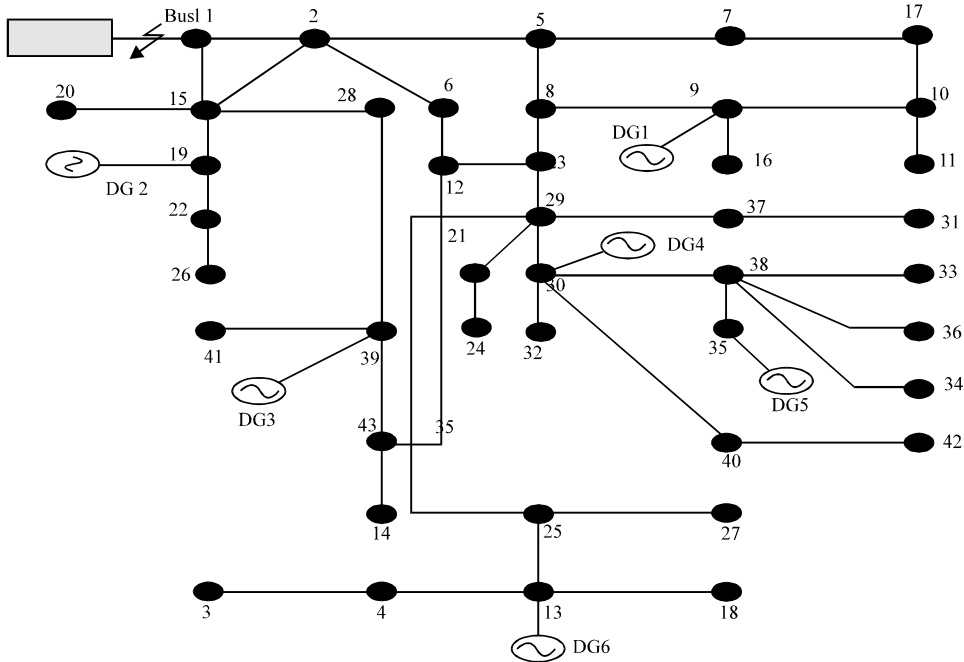


Fig. 3: IEEE standard 43-bus microgrid network

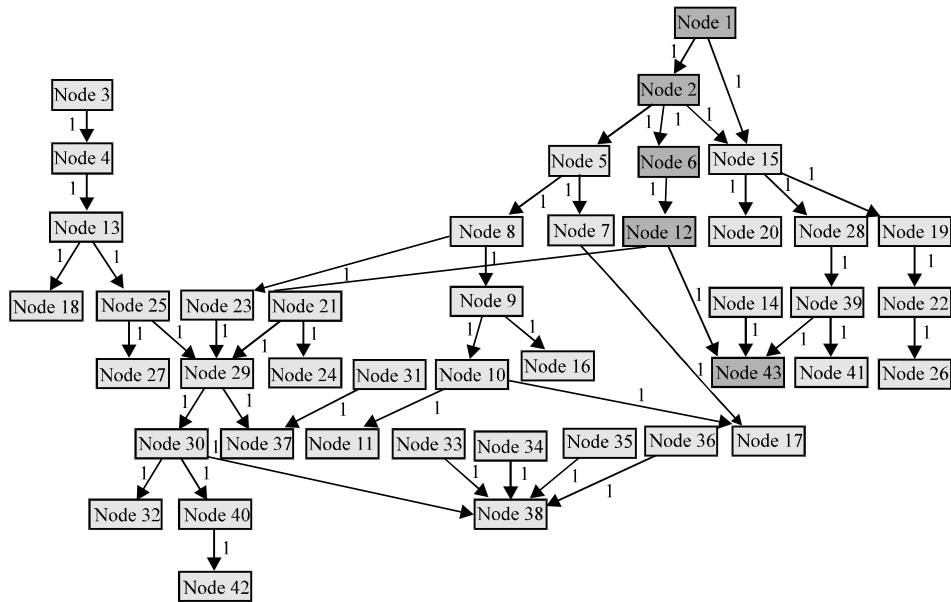


Fig. 4: Shortest pat identification in IEEE standard 43-bus microgrid network

CONCLUSION

A reconfigurable microgrid system possesses challenges for protection engineers. This study proposes Hybrid-Dijkstra's algorithm as a quick and efficient solution for the following identifying active nodes, i.e., Dgs, loads, etc., in case of a fault

occurrence, the shortest path quickly isolates the faulty from healthy portion of the network. This may ensure minimum disruption of the power supply to consumers in the network. The proposed algorithm is tested and validated on a 43-bus microgrid network and an IEEE 7-bus standard distribution system.

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