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Reverse Delete Aided Dijkstra's Algorithm for Shortest Path Identification in Microgrids

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Abstract: Microgrid plays an efficient and necessary role in consumer provision of reliable power supply by alleviating grid disturbances to boost grid resilience. In addition, to utility grid which is the main source of power supply, integration of growing employment of renewable energy sources such as solar and wind into the microgrids support a flexible and efficient electric grid. The conventional approach to designing a protective scheme may not be applicable for fault clearance in a dynamic microgrid. In this study, reverse delete algorithm aided Dijkstra's algorithm is proposed to recognize the shortest path to clear the fault from a faulted point to the utility grid or point of common coupling. The reverse delete algorithm is utilized to find the list of active nodes in the microgrid network. Whenever, a fault occurs in the microgrid, the Djikstra's algorithm is employed on the list of active nodes to identify the shortest path to clear the fault in the network. The proposed algorithm is tested on a standard129-bus microgrid test system.

Key words: Microgrid protection, Djikstra's algorithm, reverse delete algorithm, netwok, system

INTRODUCTION

Due to increasing population throughout the world there is an increasing demand for power supply. The conventional sources which account for most of the generated power are on the verge of complete depletion. Implementation of renewable energy resources as sources for distributed generation in the microgrid is a solution to meet the soaring power demand. Microgrid is a localized grid that consists of generators, loads and stationary batteries. The microgrid is capable of operating in two modes:

- Grid connected
- Islanded mode

Under normal operating conditions, the microgrid is connected to the utility grid through the point of common coupling. This mode of operation is called grid connected mode. Whenever there is a fault in the utility grid, the microgrid isolates itself from the utility grid and transits itself into islanded mode. In islanded mode, the distributed energy sources are used to supply the load requirements in the system. The conventional protective schemes may fail due to bidirectional power flow due to distribution end sources (Salam *et al*., 2008). Programmable Logic Controller (PLC) based microgrid monitoring (Swathika *et al*., 2015a-c), adaptive intelligent controller for providing suitable relay-coordination in microgrid (Swathika and Hemamalini, 2016; Swathika *et al*., 2015a, b), optimization techniques based overcurrent relay coordination (Swathika *et al*., 2015a-c; Mishra *et al*., 2015) are solutions that popularly used for microgrid protection. Also, digital relay schemes based on communication are commonly used. It aids in detection and clearing all faults including faults due to high impedance with current setting of at least 10-15% of preset value at the feeders (Sortomme *et al*., 2010). IEC61850-7-420 communication protocol (Ustun *et al*., 2012) and some data maps are employed for protection of microgrid. Other than this, microprocessor based relaying is deployed for low voltage microgrids. This protection strategy does not make use of communication devices (Swathika and Hemamalini, 2015). In order to overcome the issue of selectivity which arise due to increasing number of DGs in a microgrid which cause issues such as false tripping and unwanted islanding, an approach using graph theory algorithm is proposed in this study (Swathika and Hemamalini, 2015). This study proposes reverse delete aided Djikstra's algorithm which is capable of clearing the fault in the microgrid network by opting the shortest path from the faulted point to the Point of Common Coupling (PCC) or Utility Grid (UG). The algorithm ensures that only minimum portion of the network is disconnected during fault isolation. Reverse delete algorithm aids in finding the number of active

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nodes of dynamic microgrid network. Djikstra's algorithm recognizes the shortest path to clear the fault in the network identified by reverse delete algorithm.

Problem formulation: Microgrid is dynamic in nature and is susceptible to constant reconfiguration. It is necessary to find the current topology of the microgrid at any instant of time. The shortest path for faulted isolation in microgrid is essential. The minimization problem is:

$$\text{Min}(F) = \text{Min}(N)$$

Where:

F = Distance between faulted point to nearest source node
N = Distance between each pair of nodes in the entire graph

The shortest path from fault to operating source is found using the proposed algorithm subjected to the constraint that each vertical of microgrid is a radial network.

MATERIALS AND METHODS

Reverse delete algorithm is a greedy graphical algorithm. It is used to find the minimum spanning tree in a graph. This algorithm considers all weighted edges of the graph. It will compare the edges and find out the shortest path for a given node. Using this we can find the minimum spanning tree for the graph and identify the smallest path between the faulted node and source node without disconnecting it from the main system.

Reverse deletion algorithm to find minimum spanning tree:

- Step 1: To begin the operation we require a connected and weighted graph
- Step 2: Identify all the nodes and edges individually.
- Step 3: Ensure that each node is connected to the other node directly or indirectly
- Step 4: First choose the highest value edge, check if the two nodes are connected to that particular node.
- Step 5: Then remove that selected edge from graph and go for the next highest value edge .If more than one edge having the same value are present than go for them one by one
- Step 6: For multiple vertices and edges repeat Step 4 and 5, until we get the minimum spanning tree

The algorithm runs with time complexity of:

$$O\,(E \log V\,(\log \log V)^3)\ \text{time}$$

Where:

E = Number of edges
V = Number of vertices

Dijkstra's algorithm for finding the shortest path to clear the fault:

- Step 1: Mark the beginning node as zero and encircle it
- Step 2: Compare the values of all the nodes which are connected to the beginning node and identify the edge with the least value
- Step 3: Mark the values to each connected nodes according to the values of the edges from the beginning nodes temporarily
- Step 4: Select the temporary mark of lowest value and encircle it
- Step 5: Repeat the above two steps until we reach the final node with its permanent value
- Step 6: After getting the permanent value of the final node, the shortest path from the beginning node is found
- Step 7: To verify whether our path is shortest or not, we can interchange our beginning node and final node and continue with the above following steps. If both the path and distance matches then our result would be correct

RESULTS AND DISCUSSION

A 129-bus standard microgrid network is considered as shown in Fig. 1. Distributed Generators (DGs) and loads maybe connected at any bus in the network. In grid connected mode, the utility grid is considered as base node. In islanded mode, the nearest operating source is considered as base node. The reverse delete algorithm assists in generating the list of active nodes in the network. The Dijkstra's algorithm identifies shortest path from faulted point to the utility grid. In Fig. 1, the following are the node equivalences: 152 or 31; 450 or 115; 300 or 116; 250 or 117; 251 or 118; 149 or 119; 151 or 120; 610 or 121; 451 or 123; 197 or 124; 195 or 125; 135 or 10; 160 or 122. The remaining nodes are considered as such. Let all the nodes be active in microgrid at this instant of time and act in grid connected mode. Let utility grid be connected at bus 33. Let the weight of all edges be '1'. Let a fault be triggered between node 117 and node 30. The shortest path identified by the proposed algorithm is indicated in Fig. 2 as follows: 117-30-29-28-25-26-27-33. The shortest path involves 8 nodes and 7 edges.

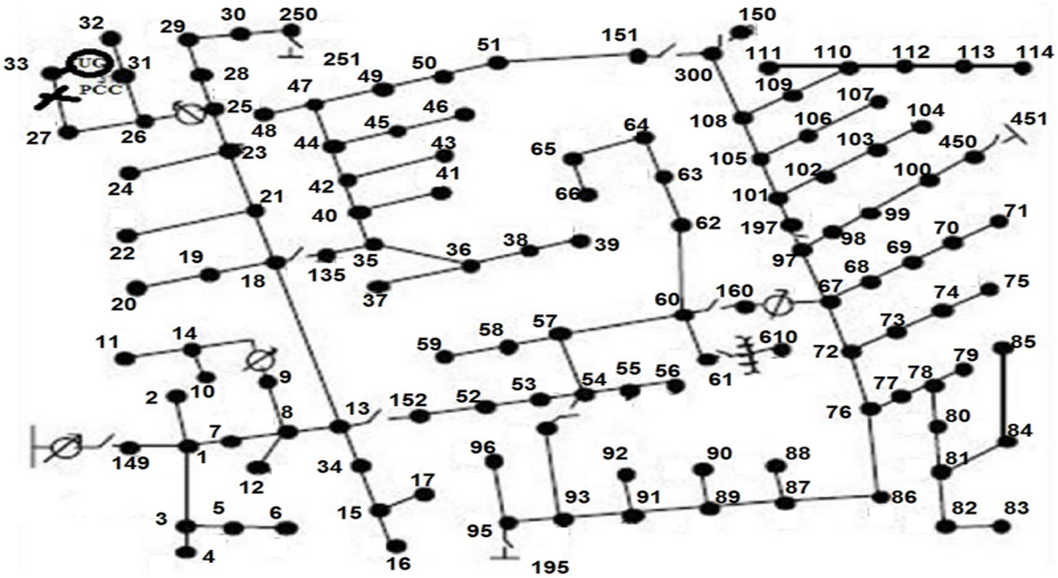

Fig. 1: About 129 bus microgrid network

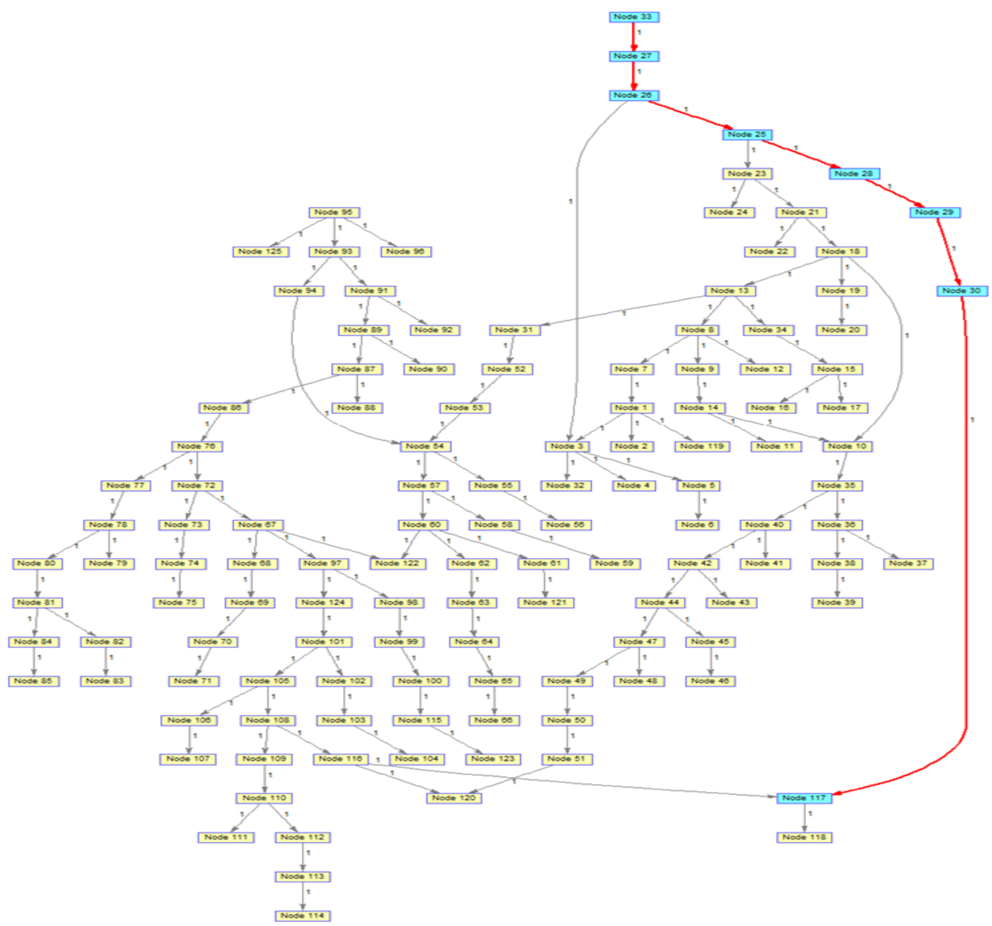

Fig. 2: Shortest path identification for a fault between node 117 and 30 in 129 bus microgrid network

Table 1: Shortest path identification using reverse delete aided Dijkstra's algorithm

Node closer to faulted point	Distance	Path
250	7	250-30-29-28-25-26-27-PCC
61	14	61-60-57-54-53-52-152-13-18-21-3-25-26-27-PCC
114	23	114-113-112-110-109-108-300-151-51-50-49-47-44-42-40-35-135-18-21-23-25-26-27-PCC
85	23	85-84-81-80-78-77-76-72-67-160-60-57-54-53-52-152-13-18-21-23-25-26-27-PCC
610	15	610-61-60-57-54-53-52-152-13-18-21-23-25-26-27-PCC

Table 2: Run time in AMD E-2 1800 APU processor

Error nodes	Run time (sec)
57	0.029751
119	0.036981
65	0.040129
118	0.034532
21	0.029929
45	0.051725
124	0.032257

Table 3: Run time in AMD E-2 1800 APU Processor

Error node	Run time (sec)
57	0.029461
119	0.027910
65	0.028716
118	0.028100
21	0.029076
45	0.028869
124	0.028474

If the microgrid acts in islanded mode, then the shortest path from faulted point to the point of common coupling maybe tabulated as indicated in Table 1. Hence, the proposed algorithm is tested and validated on 129-bus microgrid network. It is witnessed that unlike the conventional protection schemes, this algorithm ensures that only the smallest portion of network is disconnected when a fault occurs so that not many consumers are affected. A generic code was developed for the algorithm and executed on two different processors. Few faults were introduced at various locations as indicated in Table 2 and 3.

CONCLUSION

Due to bidirectional power flow, dynamic nature of network topology and fault current variations in the system, conventional protection schemes are not suitable for microgrid in both grid connected and islanded mode. This study proposes Reverse delete-Djikstra's algorithm that identifies active nodes in the network. These nodes include active buses, loads, DGs and utility grid. The algorithm also clears the fault in the microgrid network by identifying the shortest path from the faulted point to the Utility grid or Point of common coupling with the intention that only a minimum portion of the network gets disconnected during fault isolation. Thereby effective segregation of faulted segment from the healthy portion of network is attained. The proposed algorithm is tested and authenticated on a 129-bus standard microgrid network in both grid connected and islanded modes of operation.

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