# Hybrid Prims-Viterbi's Algorithm for Protecting Multiple Utility Grids Interfaced Microgrid

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***Abstract*—With globalisation occupying the space, there has been a subsequent growth in the demand for power supply, which can be met by bringing microgrid into the scenario. Microgrid paves the way to integrate various other energy sources (along with the conventional source of energy) like Renewable Energy Systems (RES) and Distribution Grids (DG). The microgrid can be reconfigured by RES, load or utility grid connection or disconnection. The RES enables the bi-directional flow of power. Hence, it will be challenging for the protection engineers to clear the fault, if any, through conventional energy protection techniques. This paper proposes hybrid Prims-Viterbi's algorithm, which helps in identifying the shortest path from a faulted point to the point of common coupling point. This algorithm may attain a minimum portion of network disconnection during the clearance of fault. The proposed algorithm is tested and validated on a real-time 16-bus microgrid network with multiple utility grids.**

***Index Terms*—Prims Algorithm; Microgrid Protection; Viterbi Algorithm.**

## I. INTRODUCTION

A microgrid is a group of interconnected load and Distributed Energy Resources (DERs) within a defined electrical boundary, and acts as a single controllable entity concerning grid [1]-[4]. It can be connected and disconnected from the main grid so that it can operate in both grid-connected or islanded mode. Hence, it can function autonomously (i.e. when connected to the main grid) and non-autonomously (i.e. when disconnected from the main grid). In grid-connected mode, the utility grid (UG) takes care of the load demands of the distribution lines. If the fault is in the transmission line, microgrid switches to the islanded-mode, where DGs handle the loads in distribution network [5][6]. The connection or disconnection of DG is decided by the varying load demands, hence, causing the topology of the microgrid to be dynamic in nature. The bi-directional flow of power challenges the protection engineers for the clearance of the fault, as the conventional protection techniques cannot be employed in the microgrid.

The Central Protection Centre monitors the status of DG, loads and utility grids. The following indicates the constraints that must be met by the microgrid protection scheme [7][8]:

i. For low fault current levels, external and internal fault identification is possible.
ii. If fault prevails in the utility grid, the microgrid instantly operates in islanded mode.
iii. If faults exist within the microgrid, the utility side consumers are unaffected.
iv. Primary and backup protection is available for both grid-connected mode and islanded modes of operation.
v. Selectivity and speed should be in acceptable levels.

Some of the common concerns, like sympathetic tripping, false tripping, blind zone, variation in fault levels and unwanted islanding, are caused by the influence of distributed generations. The graph theory-based algorithm may be employed here to identify the shortest path in the microgrid.

This paper proposes a novel hybrid Prims-Viterbi's algorithm that assists in protecting reconfigurable microgrids. It can be done by identifying the current topology of the network. If a fault ever ensues on this network, the Viterbi algorithm detects the shortest path to insulate the fault. This system ensures that minimum network disconnection is sustained in the process of protecting the microgrid.

## II. SHORTEST PATH IDENTIFICATION PROBLEM

The aim is to identify the shortest path from the faulted point to the point of common coupling (or, to the nearest operating source), with a minimum quota of load cessation[12]. This can be articulated as a minimisation problem:

$$Min\,(d) = min\,(P)$$

where,
d = distance between the faulted point to the point of common coupling.
P = number of paths that exist between the faulted point and the point of common coupling.

This minimisation problem is subjected to a constraint that the network should be a radial network for identifying the shortest path using the proposed algorithm. The proposed hybrid Prims-Viterbi algorithm is an exploratory algorithm based on non-mathematical rules. It is subjected to a grid-connected microgrid system.

## III. METHODOLOGY

Prims algorithm is a graph theory concept to produce a minimum spanning tree for a network. Prims algorithm falls under Greedy algorithm (the greedy algorithm is an algorithmic archetype that follows the exploratory way of problem-solving by making the locally optimal choice at each stage of the network with anticipation of finding a global optimum. The favourable outcomes of Prims algorithm are a network with low-cost contemplation and quick data transfer as one of the major constraint. The main aim of the algorithm is to identify a path whose sum of weights of all the edges in the tree is of the minimum value. It has a time complexity that is O ((V+E) log V),

where,
V = number of vertices
E = number of edges connecting the vertices

Time complexity can be defined as the time taken by an algorithm to run as a function of the length of the string represented as an input.

Analogous to the tree concepts in data structures, a map is being framed by the Prims algorithm from a selected node to the negotiating to intend by iteratively adding a child node until the destination is reached. We observe an edge addition for each node of the system.

Consider a system having 'n' members (assuming all the connected nodes are functional). A network is developed connecting the active nodes if only first 'x' nodes are functional at any instance. These active nodes form a web that connects each node to the other participating nodes, directly or indirectly, for the communication between them.

The loads (L), utility grid (UG), DG sources and the common point of coupling (PCC) are assumed to be the active nodes, for an electric grid. The edge weight is also assumed as '1'. A dimension matrix of N X N is built for 'N' number of active nodes in the network. For a node connected or disconnected, the shortest distance is updated accordingly.

For our problem, we consider the utility grid as our base node, and for any alterations in the grid, the change is directed to and from the base node.

For the problem, the following properties must hold true:

i. For all vertices, $a,b \in V$, 'p' can be considered as the shortest path for traversal from a to b using its weight function w, only if it holds true for w^ as well; where,

$$w^\wedge(a, b) = w(a, b) + Dist[a] – Dist[b]$$

ii. For all edges (a, b), the new calculated weights must be non-negative.

Viterbi's algorithm is a dynamic programming algorithm to find the sequence of hidden states called 'Viterbi Path' ideally employed in sparse, edge weighted, directed graphs. All the negative weights from input graph are removed using Bellman-ford algorithm. The shortest path is then identified using Dijkstra's algorithm.

**VITERBI'S ALGORITHM:**

The Viterbi algorithm seen as finding the shortest route through a graph is:

**Step 1- Input**

$\mathbf{Z}=z_1,z_2,...,z_n$ the input observed sequence

**Step 2- Initialization**

$k=1$ time index
$S(c_1)=c_1$
$L(c_1)=0$ this is a variable that accumulate the lengths, the initial length is 0

**Step 3- Recursion:**

For all transitions $t_k=(c_k,c_{k+1})$
compute: $L(c_k,c_{k+1}) = L(c_k) + l\,[t_k = (c_k,c_{k+1})]$ among all $c_k$.
Find $L(c_{k+1}) = \min L(c_k,c_{k+1})$
For each $c_{k+1}$
store $L(c_{k+1})$ and the corresponding survivor $S(c_{k+1})$

$k=k+1$
Repeat until $k=n$

With finite state sequences, **C** the algorithm terminates at time n with the shortest complete path stored as the survivor $S(c_K)$.
The complexity of the algorithm is easily estimated:

1. Memory: the algorithm requires M storage locations, one for each state, where each location must be capable of storing a length L(m) and a truncated survivor listing S(m) of the symbols.
2. Computation: in each unit of time the algorithm must make $M^2$ additions at most, one for each existing transition, and M comparisons among the $M^2$ results.

Thus, the amount of storage is proportional to the number of states, and the amount of computation to the number of transitions.

## IV. SIMULATION RESULTS

The 16-bus real-time microgrid network is considered for the analysis as shown in Figure 1. This test system contains two utility grids namely: UG1 and UG2 at bus 1 and bus 2 respectively.

*Case 1: UG1 connected and UG2 disconnected*

If there is a fault closer to bus 16, the possible paths are given as follows:

16-13-6-5-1 (weight=4)
16-15-13-6-5-1 (weight=5)

The shortest path is identified using the proposed hybrid Prim's-Viterbi's algorithm as 16-13-6-5-,1 which involves five nodes and the total weight is 4 as shown in Figure 2.

*Case 2: UG2 connected and UG1 disconnected*

If there is a fault closer to bus 16, the possible paths are given as follows:

16-13-6-2 (weight=3)
16-15-13-6-2 (weight=4)

The shortest path is identified using the proposed hybrid Prim's-Viterbi's algorithm as 16-13-6-2, which involves four nodes, and the total weight is 3 as shown in Figure 3.

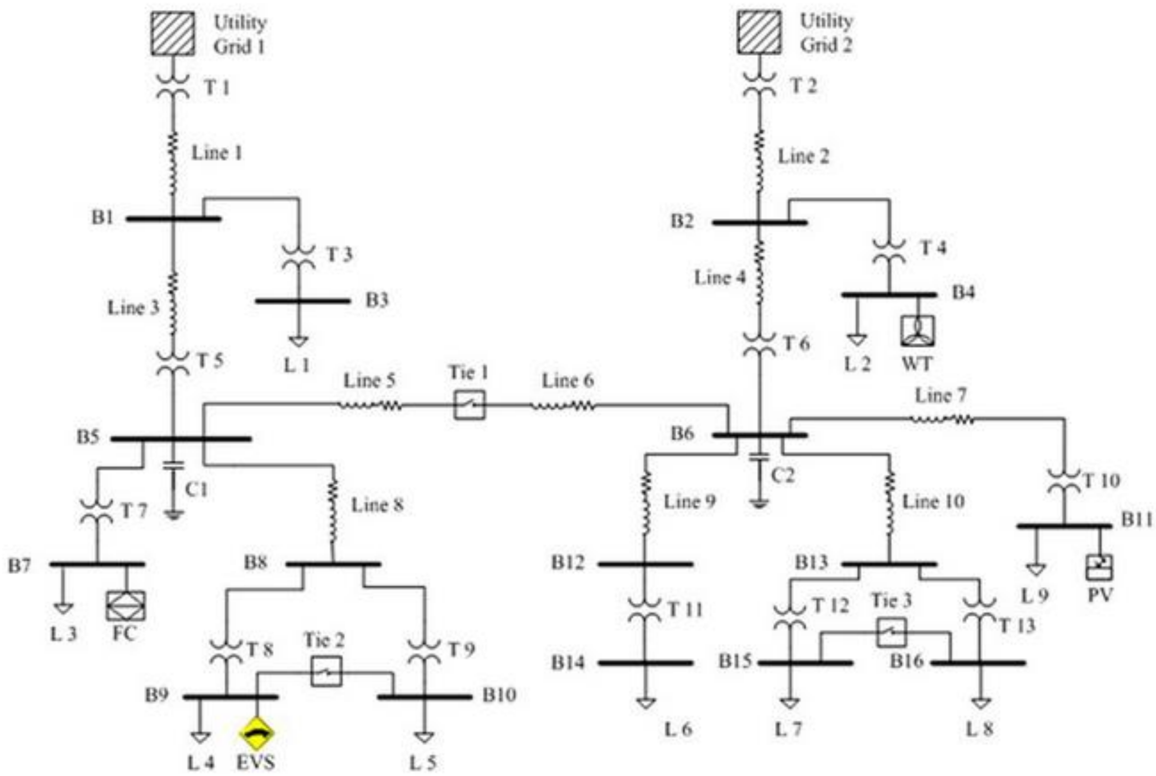


Figure 1: Real-Time 16-bus microgrid network with multiple utility grids

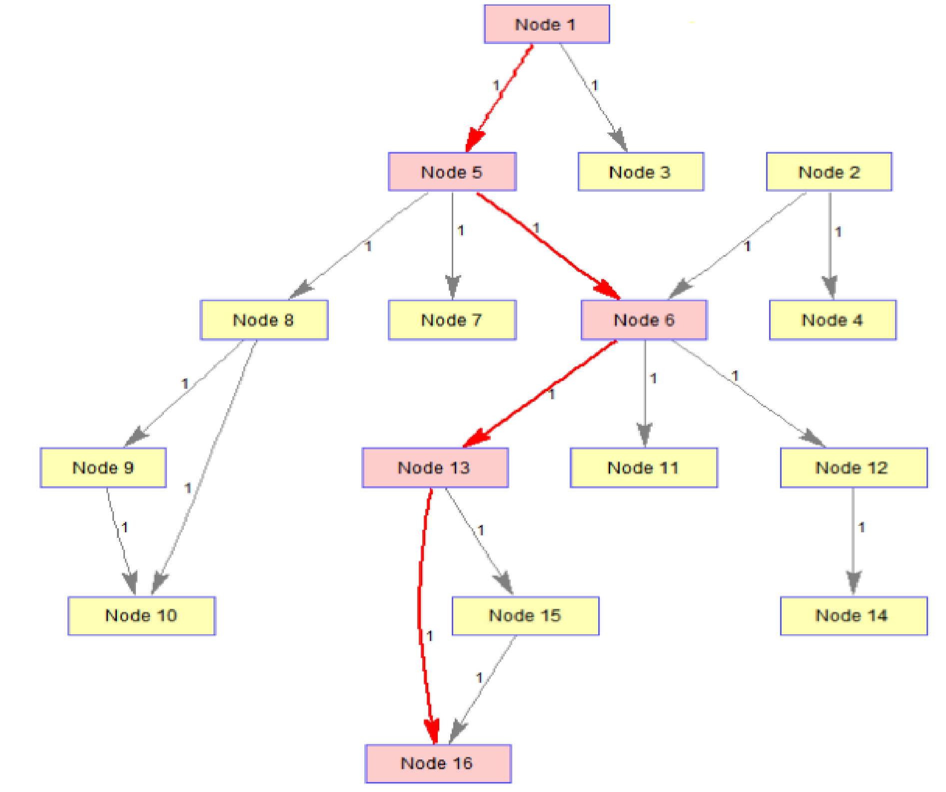


Figure 2: Shortest path from faulted point to Utility Grid 1

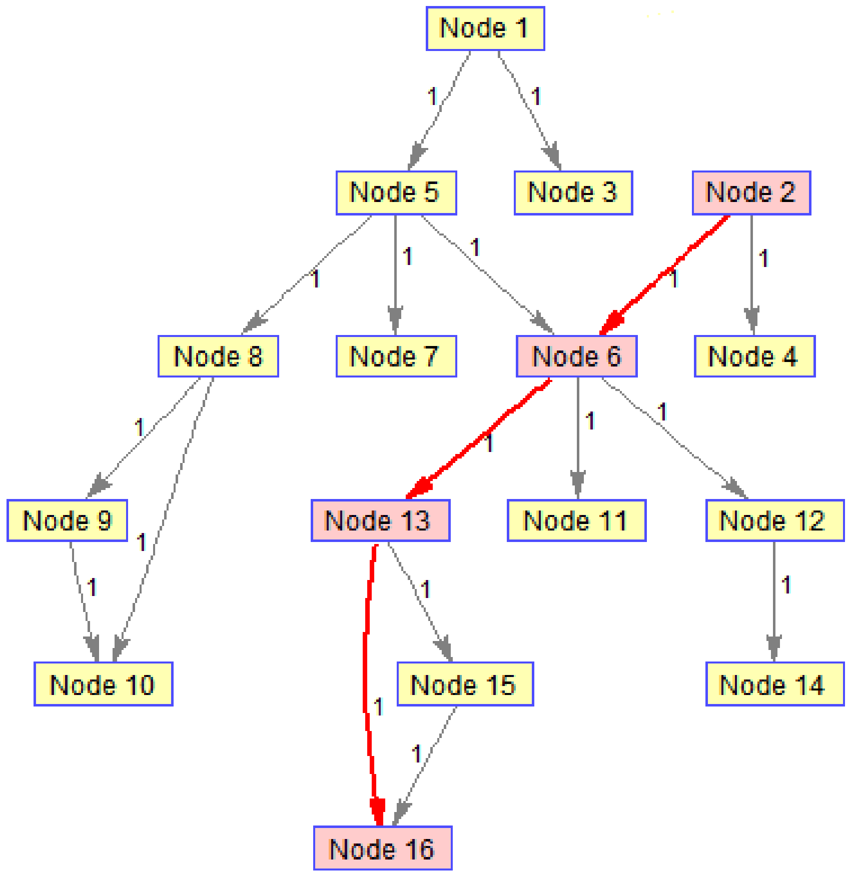


Figure 3: Shortest path from faulted point to Utility Grid 2

## V. CONCLUSION

Due to the changing topology of the network, it is a challenge for the protection engineers to clear the fault (if any) in the network using conventional protection techniques. This paper proposes a hybrid Prims-Viterbi's algorithm, which aids in identifying the DGs, Load, Utility grids (UG) in the network. If there is a fault in the network, the proposed algorithm aids in finding the shortest path between the faulted point and the point of common coupling (PCC) to clear the fault quickly. The results are validated in real-time microgrid network with two utility grids. This algorithm may attain a minimum portion of network disconnection during fault clearance. Thus, this novel hybrid Prims Viterbi's algorithm may be extended to larger microgrids conveniently.

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