Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 117 (2017) 1078–1084

Energy Procedia

www.elsevier.com/locate/procedia

1st International Conference on Power Engineering, Computing and CONtrol, PECCON-2017, 2-4 March 2017, VIT University, Chennai Campus

Fuzzy Decision and Graph Algorithms Aided Adaptive Protection of Microgrid

Dr. O.V. Gnana Swathika[a], S. Angalaeswari[a], V. Anantha Krishnan[a], Dr. K. Jamuna[a], Dr. J.L. Febin Daya[a,*]

[a]*VIT University, Chennai-127, India*

Abstract

Consumer power demand is an ever increasing component in distribution networks. A solution to meet this bridge between conventional source availability and load demands is using microgrids. The microgrid is an assortment of loads and distributed generators (DGs). The dynamicity of microgrids is a key challenge for protection engineers. The purpose of this paper is to develop a central protection system (CPS) for a microgrid with fuzzy based monitoring and graph algorithms based protection control features. Hence the CPS provides suitable overcurrent relay coordination to the microgrid which may cause minimum portion of the network disconnection.

Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.

Keywords: Microgrid; Adaptive Protection; Graph algorithms; Fuzzy

1. Introduction

Microgrids are the conglomeration of generating sources and consumers in the distribution level. The microgrid operates in grid-connected mode with a fully operational utility grid. When a fault prevails in the utility grid, the microgrid isolates itself into islanded mode where the DGs cater to the soaring demand of consumers [1]. The fault current magnitude varies phenomenally in the two modes of operation. Electricity market liberalization is a key reason that provokes DG penetration [2]. As more and more DGs are connected or disconnected from a system based on varying load demands, the topology of the microgrid substantially varies and it in turn makes the power flow in microgrid as bi-directional. Thus the microgrid demands a protection system that is adaptive in nature [3]. Digital relays or directional overcurrent relays need to be employed at strategic locations and they should be able to communicate with a center protection center (CPC) that is responsible for microgrid monitoring and protection [4-7]. Hence two-way communication is vital in hybrid microgrid protection system. Multilayer Perceptrons (MLPs)

1876-6102 © 2017 The Authors. Published by Elsevier Ltd.
Peer-review under responsibility of the scientific committee of the 1st International Conference on Power Engineering, Computing and CONtrol.
10.1016/j.egypro.2017.05.231

neural networks maybe employed for protecting the microgrid. Also neural network based fault location algorithms maybe involved in designing protection schemes in microgrids. Impedance measurement based monitoring tool with fast transient detecting capability maybe employed in microgrid network. A hybrid microgrid protection system comprising of a differential and adaptive microgrid protection scheme with high accuracy and low communications cost is available in literature. A real-time analysis on the critical parameters obtained from field Intelligent Electronic Devices via IEC 61850 is performed in the central controller.

In this research article, an adaptive protection scheme with overcurrent capability is proposed for a reconfigurable microgrid. The central protection system (CPS) is responsible for monitoring and protecting the microgrid. CPS is able to identify faults in the microgrid using fuzzy logic. Once a fault is identified in the feeder, the graph algorithms are used to predict the path with least distance from a fault to the closest active source. The relays available in this least distance path are coordinated to attain suitable fault clearance. The fuzzy logic and graph algorithm assisted CPS may trigger less network disconnection in a faulted reconfigurable dynamic microgrid.

2. Issues in protecting microgrid network

Overcurrent faults are predominant in microgrids. Possible events in utility grid fed microgrid include normal operation, resynchronization and abnormality in feeder/utility grid/bus. Relays designed for conventional distribution network fail to function effectively in microgrids due to issues like network dynamicity and fluctuation in both fault current magnitude and direction. In utility grid fed microgrid, the magnitude of fault current is 20-50 times that of the normal current. In a microgrid with Inverter interfaced Distributed Generator (IIDG), the fault current contribution is below 50% of its rated current at the fault point. 1.1 to 1.2 times the rated Distributed Energy Resources (DER) current is provided to a fault by DER. Other protection issues caused due to DG interfacing include underreach, nuisance tripping, failure in fault clearance, variation in fault current level and unintentional islanding.

Adaptive protection based on Modbus and IEC61850 communication protocols is a solution with minimum outage time but requires high initial investment. Adaptive directional interlock is a scheme wherein the tripping time maybe set at fixed value for all circuit breakers inside the island and minimum value of short circuit current is dynamically modified or reduced.

3. Proposed Fuzzy Decision Based Adaptive Protection of Microgrid

For analysis, a standard IEEE 21-bus grid-connected Microgrid test system as indicated in Fig. 1 is chosen. The test system is modeled in PSCAD software. The distribution feeder utilized in the study is a 13.8 kV three phase system. There are four sub-feeders connected to the distribution feeder further consisting of three phase transformers, three phase loads and distributed generators. The utility is represented as a 69 kV, 1000 MVA, and 50 Hz voltage source. The transformers are represented using two winding delta star transformer with the specified ratings and are considered in their ideal form. Loads with the specified power are connected. The test system consists of 3 distributed generation sources with different voltage levels. Various topological configurations of the microgrid are modeled in PSCAD and simulated. The test system is considered in both normal and faulted modes. The normal and fault current values in all the branches are noted for each topology.

Central protection system (CPS) is responsible for monitoring and protecting the microgrid test system. In CPS a fuzzy logic [8-11] is executed continuously, which is responsible for identifying the fault in the network. Once a fault is detected, the CPS protects the microgrid by tripping appropriate sequence of circuit breakers. After clearing the fault the central protection system again starts monitoring the post fault network.

Table 1. Technical Specification of the microgrid

Utility voltage (kV)	69
$(MVA)_b$	1000
f	50Hz
X/R ratio of Utility source	22.2

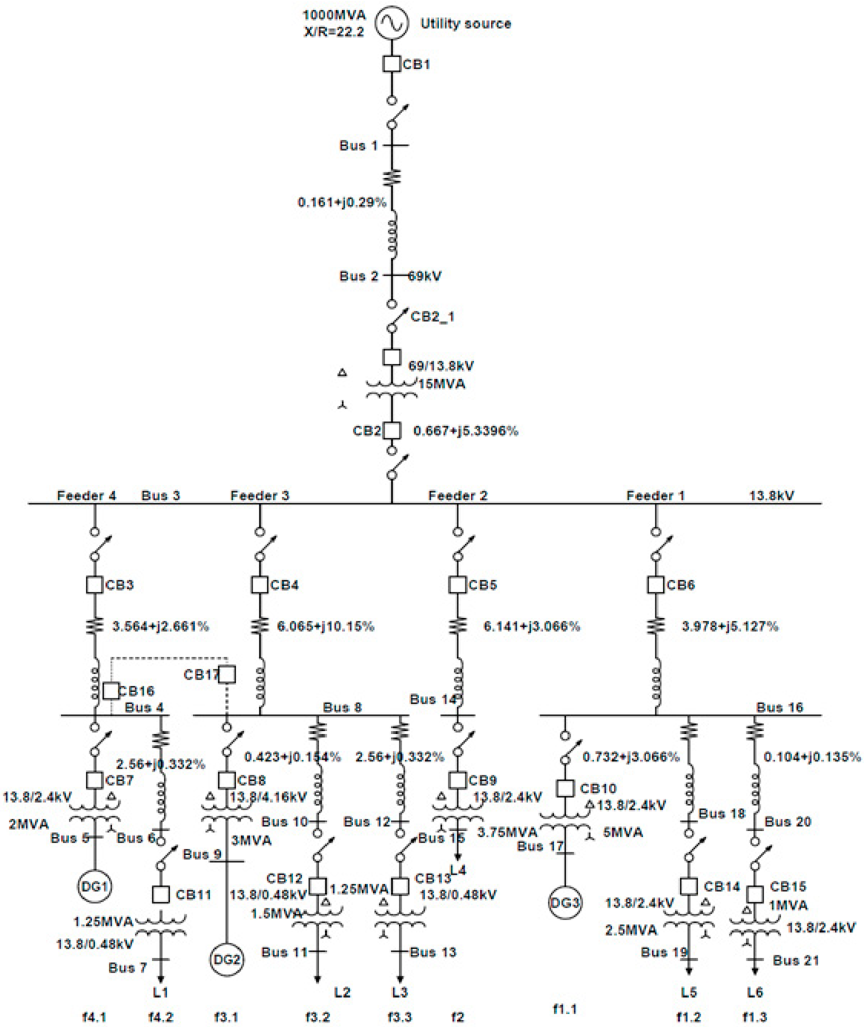

Fig. 1. IEEE 21-bus microgrid network

3.1 Fuzzy logic based Fault Detection

The basic structure of the fuzzy logic is given in Fig. 2. The feeder current $i(k)$ and feeder voltage $v(k)$ are the input variables. In the proposed work, feeder 3.1 is taken as a test case. The fuzzy logic block gives the fault value *f(t)* as output which is used to identify the fault. At the initial stage, input variables $i(k)$ and $v(k)$ are converted into fuzzy variables $I(k)$ and $V(k)$. The membership functions used is shown Fig. 3. The input variables are divided into three fuzzy sets: L (Low), M (Medium) and H (High). In the next stage of the fuzzy logic, the fuzzy variables $i(k)$and $v(k)$ are processed by an inference engine using control rules contained in a 3×3 rule bases. The fuzzy rule matrices used for the proposed work is given in Table 2. The fuzzy rules were designed based on the dynamic behaviour of the feeder current and voltage during normal and faulty condition. The rules are expressed in the form

Rule : If x is A and y is B then z is C.

There are many inference algorithms available in the literature, which can be used to space the fuzzy set values. In this work, the max-min inference algorithm is used, where in the membership degree must be equal to the maximum of the product of current and voltage.

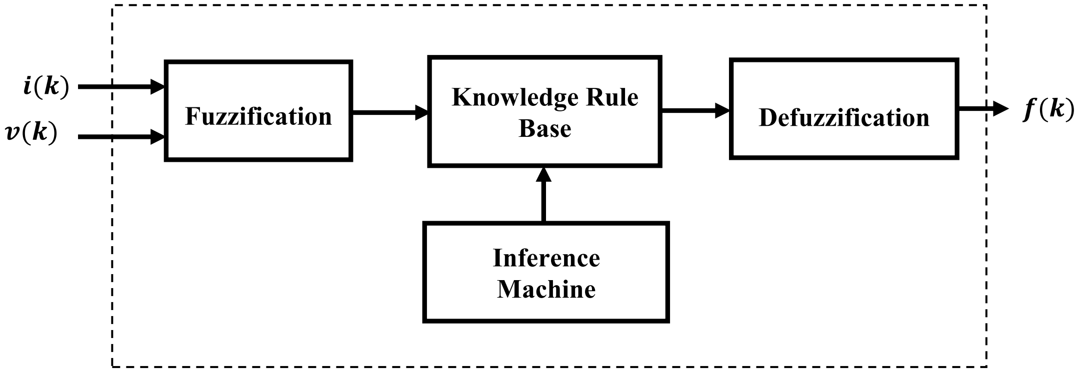

Fig. 2. Structure of Fuzzy Logic

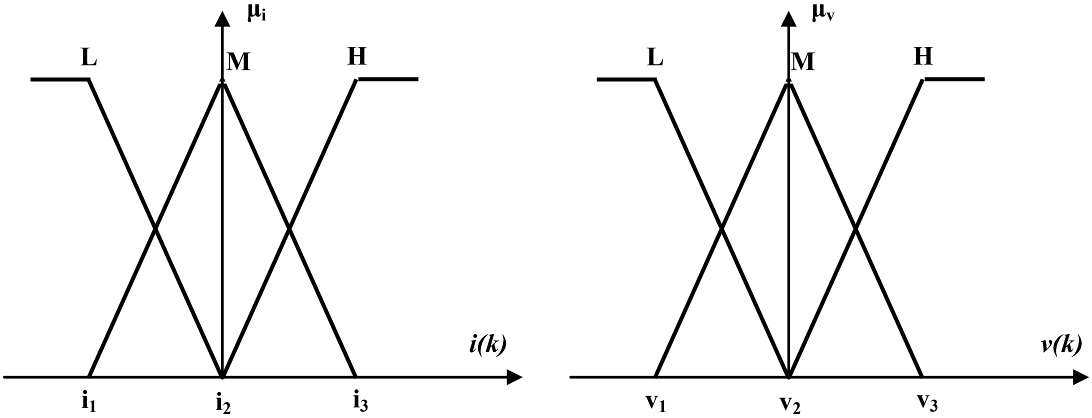

Fig. 3. Input membership function of fuzzy logic

Table 2. Fuzzy Rule Matrix

v(k) \ i(k)	**L**	**M**	**H**
L	L	M	H
M	L	M	H
H	L	L	L

The output of the inference engine is given to the defuzzification block. The defuzzification stage converts the fuzzy values in to crisp values using Centroid deffuzification algorithm. Thus the fuzzy logic block gives the crisp value of fault ranging from 0 to 1. 0 indicates the possibility of no fault and 1 indicates the possibility of fault in the feeder. A threshold value can be fixed to find the faulty feeder from the fault value given by the fuzzy logic.

4. Results and Discussion

In Section 3, the fuzzy logic based fault detection technique is discussed. After fault identification in a specific line is done using the fuzzy logic, it is important to identify the minimum weighted path using graph algorithms. In this research article, the proposed Boruvkas's aided Dijkstra's algorithm is used for this purpose. The Boruvkas algorithm is used trace the topology of the microgrid at any instant of time. With this information, the minimum weighted path from a fault location to nearest active source is found using Dijkstras algorithm. The graph algorithms facilitate quick fault isolation and also have a possibility of reduced network disconnection.

4.1 Implementation of Boruvka's aided Dijkstra's algorithm

The implementation of the graph algorithms is realized on grid-connected IEEE 21-bus network shown in Fig.1. All vertices are considered with a weight of '1'.Other than CB16 and CB18, all other breakers are critical breakers of the test system.

Case 1: Assume CB17 is in tripped state and a fault occurs near DG2. The minimum weighted path as identified by Boruvka's aided Dijkstra's algorithm is Buses: 9-8-3- 2-1 (path weight =4) as shown in Fig. 4.

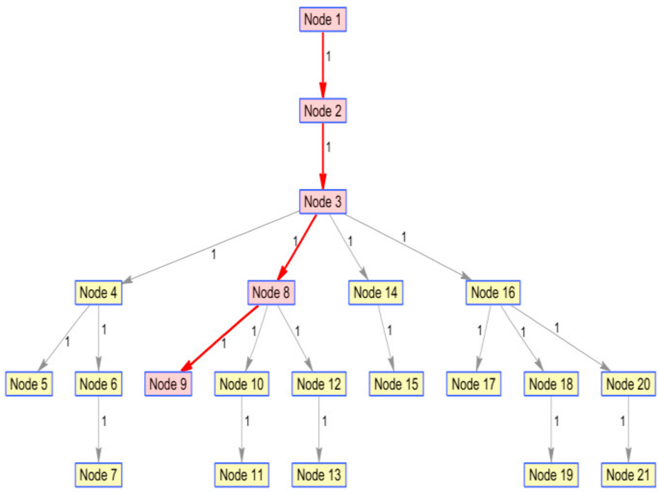

Fig. 4. Minimum weighted path for Fault between Bus8 and Bus9 in IEEE 21-bus microgrid test system

Case 2: Let unavoidable circumstance cause CB4 to trip. To attain continuous supply to consumers, CB17 is restored. If a fault is raised near DG2, the shortest path is Bus: 9-8-4-3- 2- 1 (path weight =5) as shown in Fig. 5.

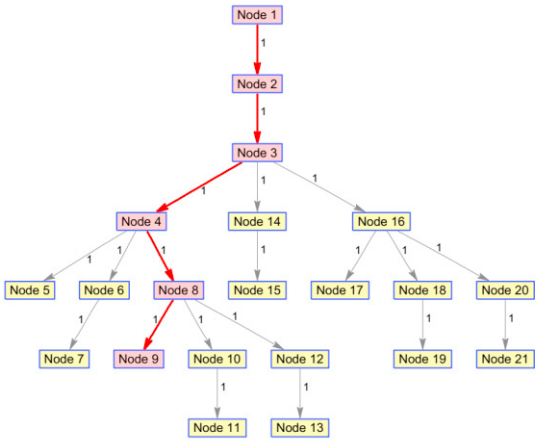

Fig. 5. Minimum weighted path For Fault Between Bus8 and Bus9 with CB4 open in IEEE 21-bus microgrid

Case 3: If CB17 trips and if a fault is raised near L2, the shortest path is Bus: 11- 10-8-3- 2- 1 (path weight =5) as shown in Fig. 6.

Case 4: If CB4 trips, to provide continuity of supply to consumers CB17 is restored. If a fault is initiated near L2, the shortest path is Bus: 11-10-8-4-3-2-1 (path weight =6) as shown in Fig. 7.

Case 1 to Case 4 implies that quick fault clearance maybe conveniently obtained for reconfigurable microgrid using the proposed shortest path algorithm.

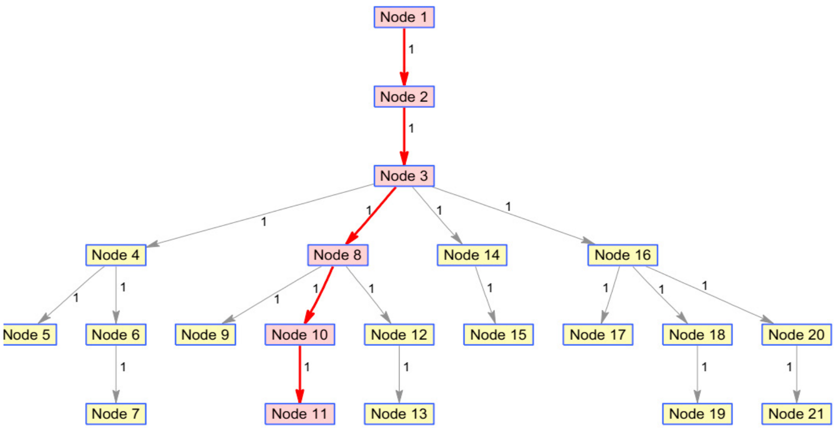

Fig. 6. Minimum weighted path for Fault between Bus10 and Bus11 in IEEE 21-bus microgrid

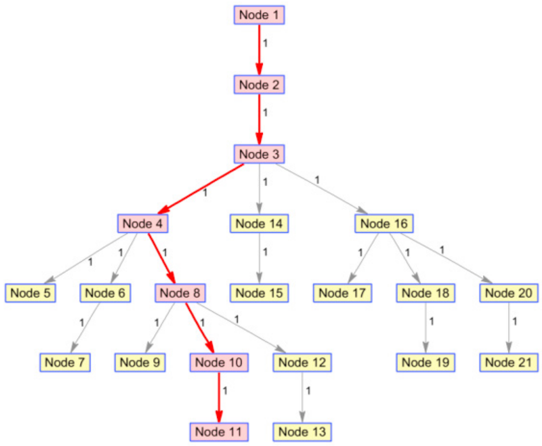

Fig. 7. Minimum weighted path for Fault between Bus10 and Bus11 with CB4 open in IEEE 21-bus microgrid

5. Conclusion

The microgrids are subjected to constant reconfiguration and hence prove challenging to protection engineers. Adaptive protection is a solution for such dynamic microgrids. In this paper, a central protection system (CPS) adaptively monitors and protects the microgrid. In the CPS, fuzzy logic is utilized for identifying fault in the network. After the fault occurrence and location is identified, Boruvka's aided Dijkstra's algorithm is employed to identify the microgrid topology at any instant of time and the minimum weighted path from the faulted point to the nearest active source. Hence during fault clearance, the graph algorithms thereby may cause minimum portion of network to be isolated. The proposed fuzzy and graph algorithms aided adaptive protection scheme is applied and verified successfully on reconfigurable IEEE 21-bus test microgrid system. This protection scheme maybe conveniently employed to any dimension of microgrid.

References

[1] Swathika OG, Hemamalini S. Prims Aided Dijkstra Algorithm for Adaptive Protection in Microgrids. IEEE Journal of Emerging and Selected Topics in Power Electronics: 2016; 4(4); p.1279-1286.

[2] Swathika OG, Karthikeyan K, Hemamalini S. Multiple DG Synchronization and De-synchronization in a Microgrid Using PLC. In Advanced Computing and Communication Technologies: Springer Singapore; 2016; p. 565-572.

[3] Swathika OG and Hemamalini S. Adaptive and Intelligent Controller for Protection in Radial Distribution System. In Advanced Computer and Communication Engineering Technology: Springer International Publishing; 2016; p. 195-209.

[4] Swathika OG, Hemamalini S. Prims Aided Floyd Warshall Algorithm for Shortest Path Identification in Microgrid. Emerging Trends in Electrical, Communications and Information Technologies; 2017; p. 283-291.

[5] Swathika OV, Indranil Bose, Bhaskar Roy, Suhit Kodgule, Hemamalini S. Optimization Techniques Based Adaptive Overcurrent Protection in Microgrids. Journal of Electrical Systems; 2016; Special Issue 3; p. 76-80.

[6] Swathika OV, Karthikeyan K, Hemamalini S. Multiple DG Synchronization and De-synchronization in a Microgrid Using PLC. Advanced Computing and Communication Technologies; Springer; 2016; p. 565-572.

[7] Swathika OV, Hemamalini S. Communication Assisted Overcurrent Protection of Microgrid. IEEE Computational Intelligence and Communication Networks (CICN); 2015; p. 1472-1475.

[8] Febin Daya JL, Subbiah V. Robust Control of Sensorless Permanent Magnet Synchronous Motor Drive using Fuzzy Logic. Proc. 2nd IEEE International Conference on Advanced Computer Control; 2010.

[9] Febin Daya JL, Subbiah V, Sanjeevikumar P. Robust Speed Control of an Induction Motor Drive using Wavelet-Fuzzy based Self-tuning Multiresolution Controller. International Journal of Computational Intelligence Systems; 2013; 6(4); p. 724-738.

[10] Febin Daya JL, Subbiah, V, Atif Iqbal, Sanjeevikumar P. A Novel Wavelet-Fuzzy based indirect field oriented control of Induction Motor Drives. Journal of Power Electronics; 2013; 13(4); p. 656-668.

[11] Febin Daya JL, Subbiah V. A Novel Fuzzy Logic Based Robust Speed Controller for Permanent Magnet Synchronous Motor Servo Drive. Proc. IEEE Asia Pacific Region Conference – TENCON; 2009.