Soft computing approach for micro grid islanding detection

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Abstract: Integration proposed method develops a fuzzy rule-based classifier with passive algorithm was tested using features for islanding detection in micro grid. In the developed technique, the initial classification boundaries are found out using the decision tree (DT). From the DT classification boundaries, the fuzzy membership functions (MFs) are developed and the corresponding rule base is formulated for islanding detection. But some of the fuzzy MFs are merged based upon similarity the measure for reducing the fuzzy MFs and simplifying the fuzzy rule base to make it more transparent. The developed fuzzy rule-based classifier is tested using features with noise up to a signal-to-noise ratio of 20 dB and provides classification results without misdetection, which shows the robustness of the proposed approach for islanding detection for distributed generation in the distribution network. A fuzzy rule-based islanding detection technique is implemented in this project using Simulink MATLAB.

Keywords-Microgrid, Islanding operation, Fuzzy Logic Controller, Decision Tree.

I INTRODUCTION

uIntegration of Micro Grid (MG) in the distribution network is expected to play an increasingly important role in the electric power system infrastructure and market. This has given rise to certain technical issues, such as islanding detection of Micro grid. According to IEEE Standard 1547-2003 and UL 1741 [1-2], islanding detection was mandated and defined as a condition that a portion of an electric power system is energized separately when the utility grid is absent. The main function of islanding detection is to detect accurately the moment of islanding and isolate the Micro grid from the Distribution Networks. As Microgrid has become important part of the power grid, requires a increased safety hazard and an increased risk of damage to the power system.

It is necessary to detect islanding within the specified time limitation on failure to detect creates safety risks to electrical equipment, line workers and existing power system. Various methods for islanding detection have been discussed in recent years [3]–[6]. The detailed methodology of islanding detection for Microgrid in power distribution networks is given in [7]. Existing islanding detection methods that are based on measurements local to the microgrid classified as active and passive methods. [8], [9]. In Active Islanding methods, the required variations can be produced at the Microgrid outputs by designing a control circuits and disturbances that are intentionally injected into the existing power system. Non Detection Zones are less in Active methods compared to passive methods, but the Power Quality issues are the serious problem [10].

Without injecting any disturbance into the existing power system and also not having negative impact on power quality of the existing power system, Passive methods are independent of control algorithms and can detect the islanding on monitoring the electrical parameters. Passive methods have large NDZ; if this drawback can be overcome then passive islanding detection is preferred. Detection variables developed previously for passive algorithms which includes both the voltage magnitude and frequency at the PCC. [13],[14], rate of change of power [15], rate of change of frequency[16], total Harmonic distortion[17], power spectral density[18], voltage vector[19], system impedance[20],power spectral density[21]., these variables are compared with pre-set threshold values directly or by using classification algorithms. Classification algorithms uses signal processing techniques to analyze the system behavior such as Bayesian [22], data mining[23], In data mining methods based on network simulations a large sets of indices used to extract the information and that are screened offline through event analysis.

DT-based classifiers perform a rectangular partitioning of the input space while the fuzzy models generate non axis parallel decision boundaries. Hence, the main advantage of rule-based classifiers over crisp DTs, is greater flexibility of the decision boundaries. Therefore, fuzzy classifiers can be more interpretable compared to DT classifiers. Generally the initialization steps of the identification of the fuzzy model become very significant. Common methods for such as grid-type partitioning and rule generation on extreme initialization result in complex and non-interpretable initial models. To avoid such problems, a crisp decision tree, having high performance and computational efficiency, is proposed for initial partitioning of the input domain for the proposed fuzzy model. In the proposed approach, two major steps are involved. In the first step, features are extracted and in the second step, classification task is performed for islanding detection.

Thus, feature selection is one of the important tasks involved in the proposed approach. Different techniques have been proposed which work on one of the estimated parameter. Thus, we have derived all possible features such as change in power, change in voltage, rate of change of power, rate of change of voltage, total harmonic distortion (THD) (current), THD (voltage), change in power factor, etc., could be affected by islanding and can be measured locally at the target location. The derived features are used as inputs to the DT for deciding the most significant features which take part in the decision making process and the initial classification boundaries.

From the DT classification boundaries of the most significant features, trapezoidal fuzzy membership functions are developed and corresponding rule base is formed for classification. But some of the fuzzy MFs are merged depending upon the similarity measure and thus reducing the number of fuzzy MFs. From the reduced fuzzy MFs, a simplified fuzzy rule base is developed for islanding detection.

II SYSTEM DESCRIBTION

Figure 1 shows the Power distribution system with multiple DG (distributed generations) interface with fault. Each DG system is comprised of a synchronous machine with exciting system and HTG (hydraulic turbine governor scheme). During normal mode of operation Microgrid is connected to Utility grid at the point of common coupling through CB-1

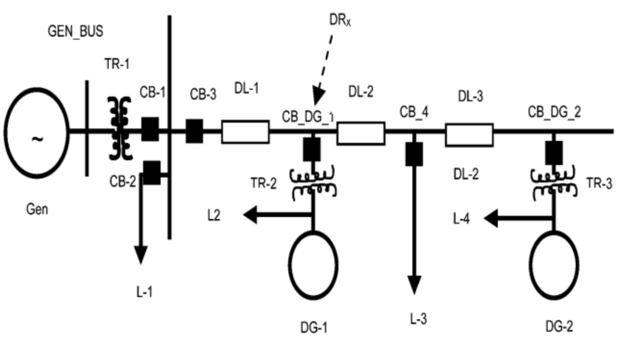

Figure 1 Power distribution system (microgrid)

When the utility system under fault condition or fails to supply the power to the loads, CB-1 opens and the two DG systems in microgrid supply the power to all critical loads within the microgrid. When the fault is cleared, the microgrid resynchronized with the utility grid before the CB-1 is reclosed and the grid connected mode operation is continued to supply the demanded load. The islanded condition is identified using fuzzy logic controller based on the changes in the power, frequency and frequency change with respect to time (dF/dt). The algorithm in fuzzy logic controller is executed during islanding condition which is set 0.5 and 0 for non-islanding condition. Fuzzy inference interprets the values in the input vector and, based on user defined rules, assigns values to the output vector. The output from the fuzzy logic controller decides to disconnect the DG system from the main grid at PCC during islanded condition.

TABLE I. POWER SYSTEM PARAMETERS OF THE TEST SYSTEM

System Component	Active Power (MW)	Reactive Power (kVAR)
L1- (R-L Load)	5	3.5
L2- (R-L-C Load)	50	25
L3- (R-L-Load)	5	3
L4- (R-L-Load)	5	2
DG-1	5	0
DG-2	5	0
Generator (Utility)	100	30

III ISLANDING DETECTION METHODLOGY

Fuzzy logic Controller: The behaviour of the Fuzzy logic Interface system can be analysed using GUI editors and viewers in Fuzzy tool.Fig.2 shows the algorithm of proposed islanding detection method.

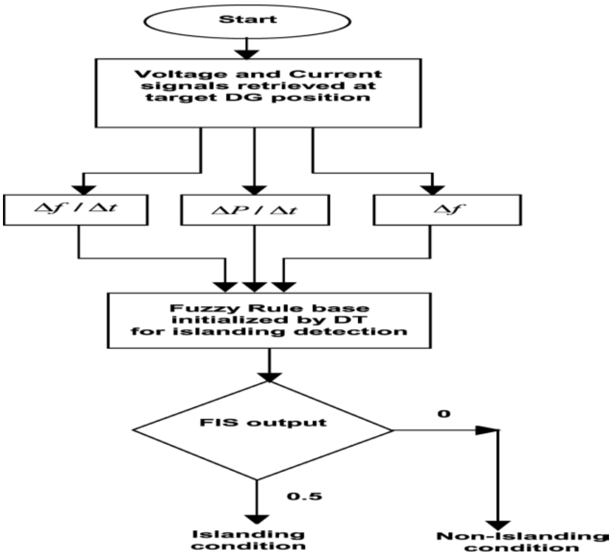

Figure 2. Algorithm of the proposed islanding detection method.

Voltage and current signals are retrieved at DG terminals, based on that values the change in frequency with respect to time, change in power and the change in frequency are found and given as a input to Fuzzy Rule base. The Fuzzy Rule bases have two conditions.

Condition1: FIS output is 0 then the operating mode is concluded as Non-island.
Condition 2: FIS output is 0.5 then the operating mode is concluded as Island.

Decision Tree (DT): It is a classifier in high dimensions. Each internal node in the tree tests the value of a predictor while each branch of the tree represents the outcome of a test [11-15]. The DT is transformed to a fuzzy rule base by developing the fuzzy membership functions [20] from the partition boundaries of the DT. From the DT boundaries, rectangular MFs are developed for each independent variable. The Fuzzy interface model with Simulink is shown in Fig.3

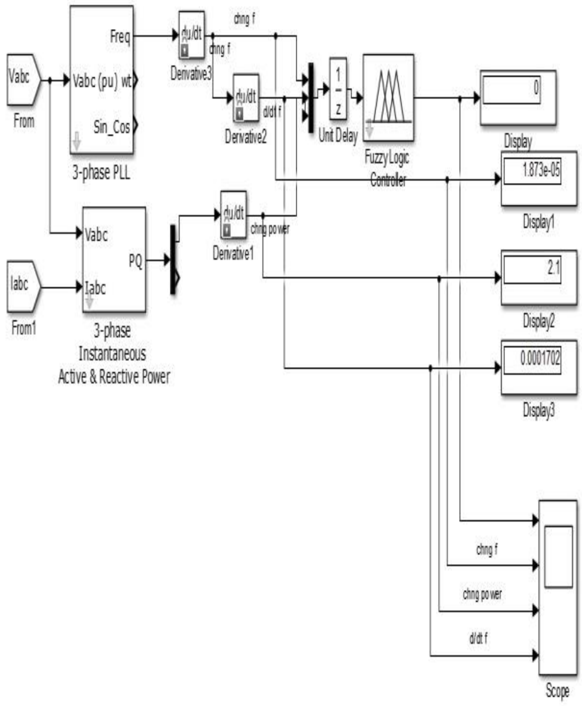

Figure 3. Fuzzy Interface in Simulink

Fuzzy Rule Base: The associated Trapezoidal fuzzy MFs are developed for variables as follows.

$$\mu_j(X_j, a, b, c, d) = \max(0, \min\left(\frac{x-a}{b-a)}, 1, \frac{d-x}{d-c}\right)) \quad (1)$$

From the fuzzy MFs, a simple rule base can be generated for classes 1 and 2 as follows:

$$If\ X_1\ is\ A_1\ and\ \ X_2\ is\ B_1,\ then\ class\ 1\ (C1)$$
$$If\ X_1\ is\ A_2\ and\ \ X_2\ is\ B_2,\ then\ class\ 2\ (C2)$$

In fuzzy rule-based models acquired from numerical data, redundancy may be present in the form of similar fuzzy sets that represent compatible concepts. This results in an unnecessarily complex and less transparent linguistic description of the system. By using a measure of similarity [21], a rule base simplification method is proposed that reduces the number of fuzzy sets in the model. The similarity measure based on the set-theoretic operations of intersection and union, can be expressed as follows:

$$S(A, B) = \frac{A \cap B}{A \cup B} \quad (2)$$

Where denotes the cardinality of a set, and the" and "operators represent the intersection and union, respectively. Rewriting this expression in terms of the membership functions give

$$S(A, B) = \frac{\sum_{j=1}^{m}[\mu_A(x_j) \cap \mu_B(x_j)]}{\sum_{j=1}^{m}[\mu_A(x_j) \cup \mu_B(x_j)]} \quad (3)$$

III RESULTS AND DISCUSSION

Figure 4. shows the simulink representation of sample power system in MATLAB. The Active Power = 5.83 kW and the Reactive Power=1.8 kVAR. The frequency change =49.56 Hz, Power Factor=0.85, THD= 0.06 and 0.156 for current. The fuzzy rule out value = 0.5 due to circuit breaker (CB) 1 opens in the generator side. Now the DG sets identified the absence of main supply and disconnect from the PCC within T= 0.4 Sec is less compared to earlier techniques used. DG-1 and DG-2 supplies the power to L-3 and L-4 only during islanding, once the fault is cleared again the DG System is resynchronised before the CB-1 recloses. The grid interface circuit continuous to supply the power to all the parallel connected loads. The governing systems in synchronous machine adjust the power based on the demand of the various loads.

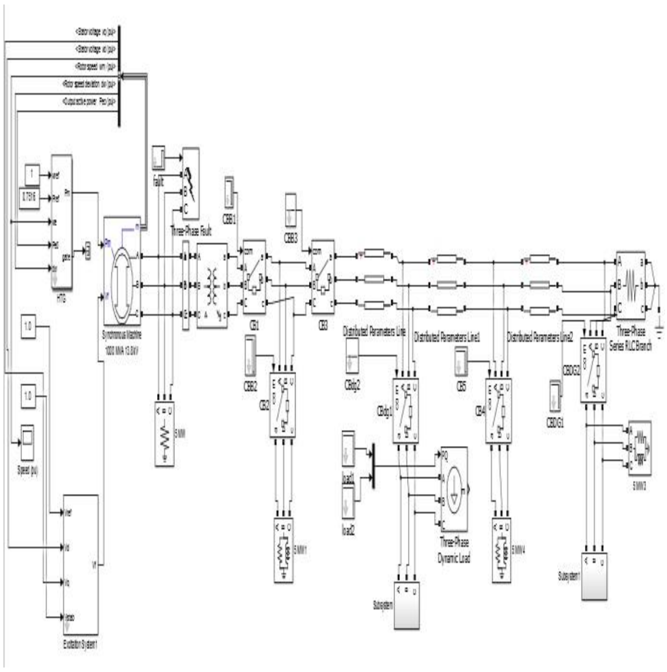

Figure 4. Simulink representation of Power system Network

Generator side: During islanding condition the generator side voltage and current is 0 at T>0.4sec absence of utility grid is monitored and shown in Figure 5.

TABLE II. PARAMETER CHANGES DURING ISLANDING

Case	Parameter	Change in value (p.u.)
Non-Islanding	I	5
	V	1
Islanding	I	0
	V	0

This variation is observed and change in frequency, power and rate of change of frequency with respect to time is calculated. The effect of variations of the parameters is shown in Figure 6. *Total Harmonic Disortion (THD):* The Harmonic distortion is found to be low THD = 0.06 for voltage and THD=0.156 for current compared to [22] and displayed in Figure 7. Fuzzy controller evaluate the changes in the parameters and at the same time the distortion produced in the system is reduced compared to the techniques used in earlier

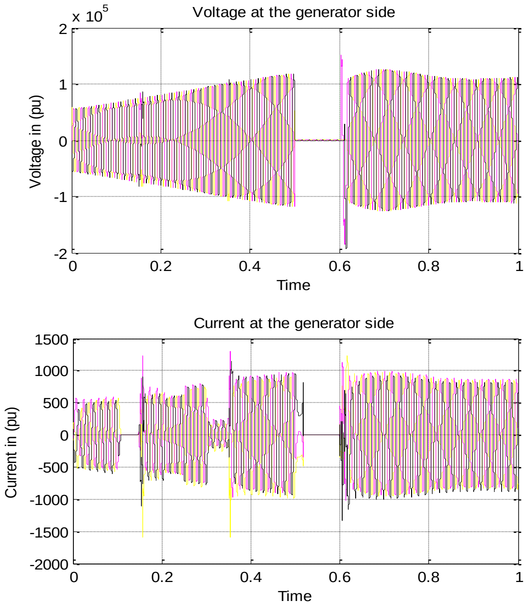

Figure 5. Generator side voltage and current variation during islanding

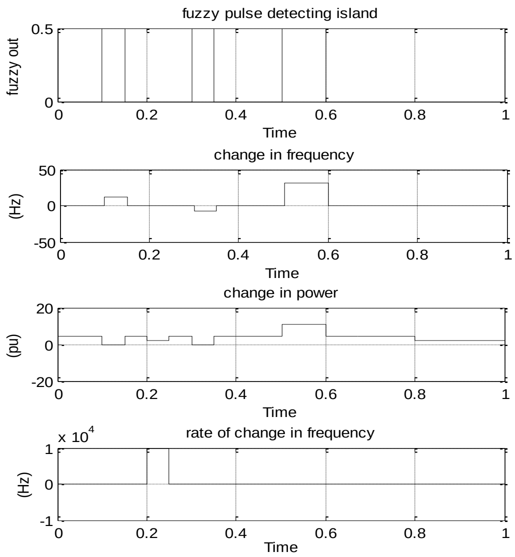

Figure 6. Effect of Islanding on Power, frequency, change in frequency

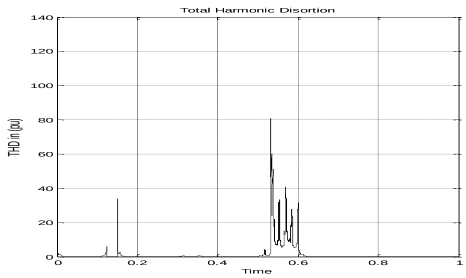

Figure 7. THD during Islanding

IV CONCLUSION

A DT-initialized fuzzy rule base classifier is proposed for islanding detection the initial classification model is developed using DT which is a crisp decision tree algorithm. The DT is transformed into a fuzzy rule base by developing fuzzy MFs from the DT classification boundaries. The fuzzy MFs reduction and rule base simplification are performed using similarity measure. The proposed method is tested on data with and without noise and found to provide 100% islanding detection. As the online implementation is easier with a fuzzy rule-based approach, it is thus suitable for developing real time relay for islanding detection in a large power network.

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