IMPROVEMENT OF MICRO-GRID ISLANDING DETECTION USING SMART METHODS BASED ON MULTI-RESOLUTION ANALYSIS AND DATA WHITENING

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ABSTRACT

These Islanding of Distributed Generations (DGs) in Micro-grids cause serious problems in operation and management of network. Therefore, proper detection of this event is of great importance. This paper presents a proper, fast and accurate method for detecting Islanding mode in unbalanced micro-grids. The proposed method uses multi-resolution analysis for pre-processing of measured data and using whitening for extracting of proper features. As a result, the accuracy of detection in micro-grid relation to measured noise and calculation window will increase. First, the voltage, current and frequency of DG's terminal is measured and sampled. This data is pre-processed by multi-resolution analysis of relays and then main features are extracted by whitening. Then, the featured are considered by categorizing part whether these features indicate Islanding mode or not. In order to select the best method the classification methods like decision tree, neural network and support vector machine are compared. The proposed method is tested on an unbalanced micro-grid with DGs, wind and photovoltaic sources. Simulated results verify the accuracy of the method.

INTRODUCTION

A micro grid is a local electrical network that (1) comprises power generation sources, loads, and a means of delivering power from the generation units to the loads, (2) may be connected to a larger utility power system, and (3) operates to balance the power supply and demand within the micro-grid[1]. These networks are sensitive and stable performance of them is faced with different problems. Sudden changes in micro grids cause unstable situations that results in Islanding mode in a grid connected micro grid. Therefore, proper and correct detection of this situation is of great importance. Thus, interconnection codes have been developed to ensure that any distributed generation device connected to the grid will disconnect in the event of an outage in the utility within a specified interval of time[2]. According to IEEE 1547-2003 Islanding mode defined as a situation in which part of the system is electrically separated but receive its energy from distributed energy sources[3]. Islanding detection methods are various. These methods are divided in two types of local and remote detection. Each method has its own advantages and disadvantages[4]-[8]. In this paper a proper, fast and high accurate method is proposed for Islanding detection that is based on data mining. Using multi-resolution analysis and proper features extraction based on whitening are proposed. The method is tested on an unbalanced micro-grid and classification methods like decision tree, neural network and support vector machine are compared.

In section II of this paper, proposed method, data processing and Islanding detection are presented. Numerical results of testing of the proposed method is represented. Finally, last section is conclusion.

PROPOSED METHOD

Figure1 shows the flowchart of the proposed method. Each part in the figure is explained below.

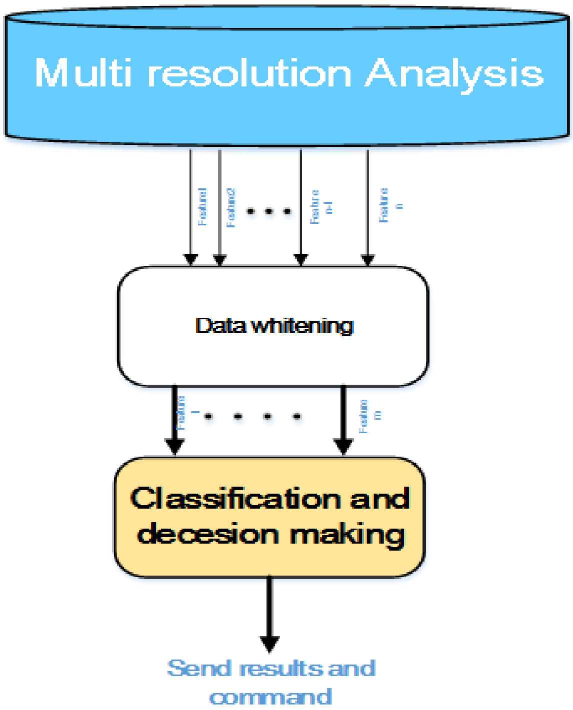

Figure 1. The flow chart of the proposed method

Wavelet transform and multi-resolution analysis

Wavelets transform is based on wavelet functions. Wavelets are transmitted and scaled samples of a function (mother's wavelet) with finite length. A mother's wavelet, $\psi(t)$, should be described as (1) and (2):

$$\int_{-\infty}^{\infty}\psi(t).dt = 0 \quad (1)$$

$$\int_{-\infty}^{\infty}\psi^2(t).dt = -1 \quad (2)$$

Each wavelet is the result of a transmitted and scaled of a mother's wavelet. Equation (3) shows this relation:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}}\psi\left(\frac{t-b}{a}\right) \quad (3)$$

In this paper stationary discrete wavelet transform is used[9].

Proper features extraction and data classification

In Islanding mode, the loads are locally supplied by generators. It is obvious that in this mode, dynamic parameters of the network are changing. These changes are the basis of Islanding detection method in this paper. Thus, the first step is to select efficient and proper features. After using multi-resolution analysis, extraction of fast and slow components of voltage, current and frequency changes of PCC, the features are defined. These parameters are 25 cases that some of them are shown in table 1. that increase to 50 cases after extraction of fast and slow components. In this paper whitening has been used to reduce the size of features and increase the classification accuracy as equation (4) shows. K is the number of features extracted, n is the total number of them and λ_i is the special value of the covariance of features matrices.

$$\sum_{i=1}^{k} \lambda_i \Big/ \sum_{i=1}^{n} \lambda_i \geq 0.9 \quad (4)$$

After extracting the proper features, the average of each parameters is selected as features for classification in support vector machine algorithm.

Table 1. Tagged parameters

parameter	Variable description
u_0	Magnitude of zero component of PCC voltage
u_1	Magnitude of positive component of PCC voltage
u_2	Magnitude of negative component of PCC voltage
$\measuredangle u_0$	Phase angle of zero component of PCC voltage
$\measuredangle u_1$	Phase angle of positive component of PCC voltage
$\measuredangle u_2$	Phase angle of negative component of PCC voltage
$\mathbf{u_m}$	Average of the voltages of different phases

NUMERICAL RESULTS

The network is IEEE 13 buses test system. This system is an unbalanced radial distribution network with total 3466 kws and 21.2 kvars loads. The network is simulated in power factory software. As figure 2 shows three distributed sources are wind, solar and gas turbine.

Islanding and anti-Islanding stated

In order to simulate different Islanding states in the network, main switch is opened and thus, the remained DGs are in islnding mode. As table 2 states, three scenarios are determined to produce Islanding states. Anti-Islanding states are comprise of short circuit states and some other states like capacitive switching using S2 and sudden opening of feeder and load changes with S6.

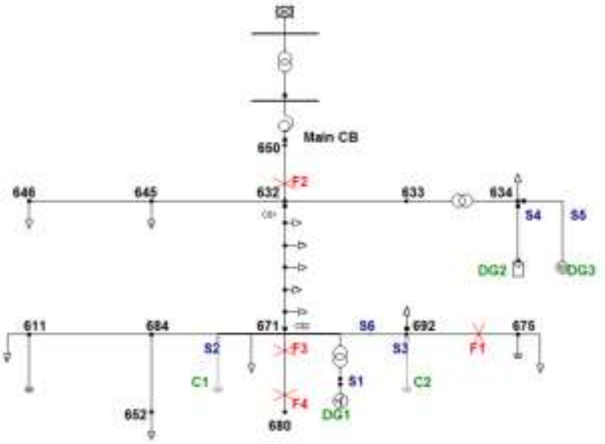

Figure 2. Test network

Study cases and comparison of classification methods

Based on Islanding and non-Islanding states, 2 study cases are considered to verify the proposed method. Each study case is tested by 3 classification method : support vector machine, decision tree and neural network. Training data is 148 cases that 78 cases are Islanding states and 70 cases are non-Islanding.

Study case 1 in 3 classsification methods

In this case, calculation noise effect and start time of calculation interval are considered. Multi-resolution is not used for data preprocessing, as well. Figure 3 shows confusion matrices of the 3 methods of classification. As shown, total accuracy of decision tree is 80.1%, neural network is 82.1% and support vector machine is 92%.

Table 2. Islanding scenarios

scenarios	DGs in Islanding mode	Switches states S1	S4	S5
Scenario-1	DG3	close	open	open
Scenario-2	DG1,DG3	close	close	open
Scenario-3	DG2,DG3	close	open	close

Study case 2 in 3 classification methods

In this case, multi-resolution method is used as data pre-processing. Total accuracy for Islanding detection in 3 methods are shown in figure 4. As shown, in this case, the accuracy of Islanding detection is more that indicates the correct performance of the proposed method.

Figure 3. Confusion matrices of study case 1

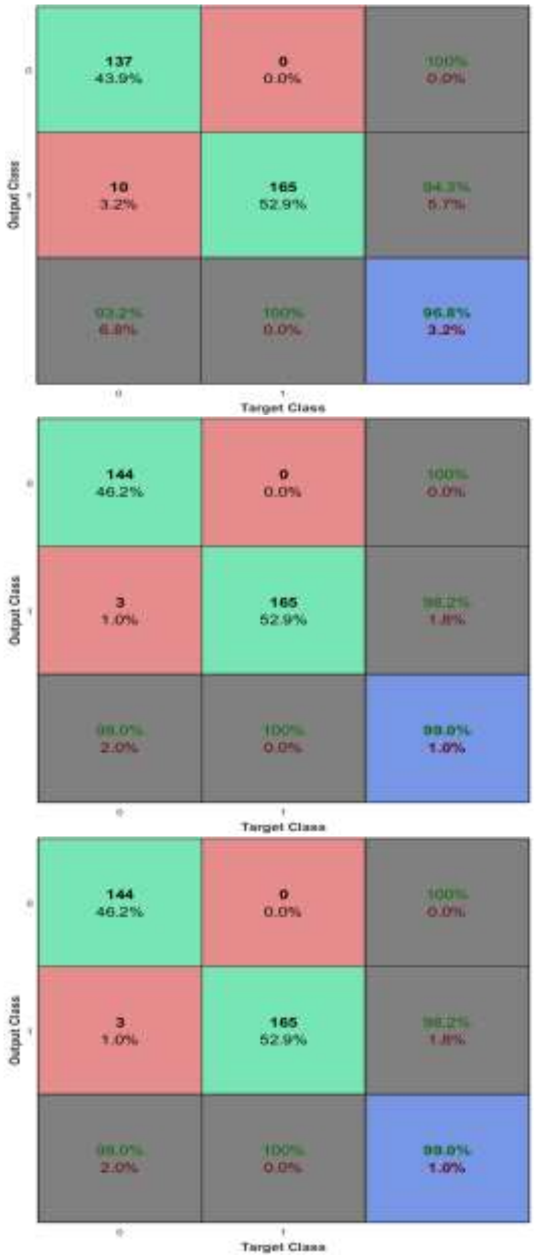

Figure 4- Confusion matrices of the study case 2.

CONCLUSION

In this paper, Islanding detection is considered using multi-resolution analysis and input data whitening. As already mentioned, after considering the PCC data by relay processing unit, main features are extracted. after applying the whitening method (to reduce the size of input data), the data are classified and the result is the state of the system: Islanding or non-Islanding state. Three classification method, decision tree, neural network and support vector machine, are used and compared. Summary of the results are written in table 2. The results verify the accuracy of the proposed method. More than 99% accuracy makes the use of this method justifiable despite the high complexity.

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