© August 2021| IJIRT | Volume 8 Issue 3 | ISSN: 2349-6002

An Efficient Protection Scheme for Microgrid Based on Wavelet Transform and Data-Mining technique

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***Abstract* - With the rising trend of the use of the potential of distributed energy resources, for the management of the ever-growing demand for electrical energy, the microgrid have come to the fore. Microgrid offers significant advantages in distribution systems but the integration of the synchronus DER and the renewable energy sources made the issue of protection. The failure related with the renewable energy sources is only 2-3 times higher than the rated voltage, as compared with a synchronous DER. For this reason, the associated security issues becoming even more complex. The value of the fault current depends on the mode of operation and the microgrid works on islanded and grid connected mode. Therefore, it is necessary to use an accurate and reliable technique that can operate in two modes with reliability and efficiently. In this context, an algorithm that is based on the structure of discrete wavelet transform (DWT) and bagged decision tree method is used in this. A direct current voltage signals are pre-processed with the DWT, and the standard deviation is calculated on the basis of the current participants in the course will be used to train the model based on data mining. The DWT-based feature extraction method we can use for all the useful features of the voltage and current signals in less estimated time.**

***Index Terms* - Fault detection, microgrid protection, Feature extraction, Discrete wavelet transform, Data mining.**

I.INTRODUCTION

The microgrid concept faces many challenges in various fields, not in terms of the protection point but also in the control and dispatch perspective. Although they have very good features and operations for the security of the system so they can solve any type of technical problems both in the medium and low voltage generation system because of having bidirectional power flow in them. Microgrid operates in two modes which are grid connected and islanded (standalone) mode. There is topological change in the lv network which results of the connecting/disconnecting from the power generator and storage system. In the microgrid the interrupt generation on a multiple of the micro sources are combined. A reliable microgrid operation demand resilience against shunt faults with reduced restoration time, which is directly related to the potential of its protection scheme in order to correctly detect and classify with also locate the fault. However, unlike conventional macro-grids, the wide range of operating terms, conditions, and disparity in the operational dynamics of individual sources and their dependency on weather condition makes the microgrid protection task quite challenging. Shunt faults occurring in the microgrid can occur either in the grid connected or disconnected mode (islanding). Synchronous generators on the grid side can withstand high fault current due to their large, short circuit mega volt ampere (MPV) capacity but the same is beyond the capacity of PVDG during islanding.

Microgrid has many important advantages is that the strength and reducing the network investment due to the lower bandwidth requirements, reduce operating costs and losses, which reduces the peak load, and reliability. Microgrid has been designed to improve the energy efficiency, reduced greenhouse gases and pollutant emissions, improved service quality and reliability, cost efficient electricity infrastructure replacement. Nevertheless, on account of all these qualities, microgrid have raised a number of issues associated with the issue of protection. For eliminating the issues of protection task the advanced stages of the wavelet transform method is used in this paper. However, this work rarely mention about the location of the fault on multi terminal. The wavelet transform is used to analyze the signals of transient voltage and current which can be associated with both the frequency and the time domain signal in healthy conditions. In this paper, a high-resolution wavelet analysis is used to enable detect, classify, and identify the faulty locations on the transmission lines.In this paper, A security algorithm that is based on the general structure of the discrete wavelet transform (DWT), and the processing of the data, methods have been developed for the microgrid. Instantaneous signals of voltage and current were pre-processed with the DWT, and the standard deviation is calculated with the use of estimated coefficients to be calculated and then used to train the model based on data mining. The DWT-based feature extraction method that allows for the maintenance of the healthy, the symptoms of the voltage and current signals in less estimated time.

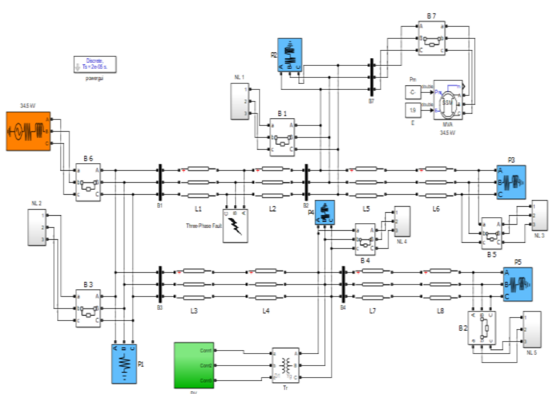


Fig.1 Simulink model of Microgrid considered under study

II. BACKGROUND IN MICROGRID PROTECTION

In the proposed work, the faults occurring in the distribution line has been analyzed, detected and classified. In this regard, the voltage-current waveform at the relaying bus have been extracted with wide variation in the fault parameters including fault resistance, inception angle, fault location and other operating conditions such as load variation. The derived signals are pre-processed using the Discrete wavelet transform (DWT) to determine the useful features for performing the fault detection and classification task. The standard deviation of approximate co-efficients derived using daubechies mother wavelet has been considered for machine learning classifier. The derived sets of features are used to train the Machine learning classifier for input-output mapping between the faulty and healthy set of scenarios. The trained classifier upto the acceptable level of accuracy is further used to test the performance of the proposed scheme. The unseen test scenarios are generated for the testing purpose.

The performance of proposed protection approach has been validated and compared against diverse fault and other operating conditions to examine its effectiveness over other protection approaches.

III. PROPOSED PROTECTION SCHEME

1) Simulation of Microgrid system

The single line diagram of proposed Microgrid system is illustrated in Figure 2. The system has been modeled using MATLAB/Simulink environment. The microgrid system considered under study include 12 km distribution line divided into four sections. Two DERs including PV and Synchronous generator are used to meet the load demand. For the proposed protection task, the buses B1 and B3 are considered for data acquisition which is further processed using DWT to derive useful feature. The dynamic response of the Microgrid components is presented when subjected to sudden changes in solar irradiance.

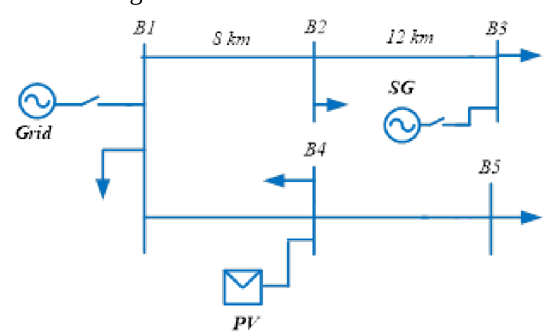


Fig.2 Microgrid system model

2) Generation of fault and other operating scenarios

The microgrid system considered under proposed study in Figure 2 is simulated to derive the diverse scenarios. The voltage-current waveform at the relaying bus have been extracted with wide variation in the fault parameters including fault resistance, inception angle, fault location and other operating conditions such as load variation as detailed in Table (a). For each fault type including LG, LL, LLG, LLL and LLLG, various fault and no-fault cases are generated for feature extraction.

S. No	Parameter	Variation
1	Features	Voltage and Current
2	Number of Features	12
3	Fault types	LG, LL, LLG, LLL,
4	Fault Resistance	Between 0 to 100 Ω
5	Fault Inception Angle	0, 90 Deg
6	Sources	PV and Synchronous generator

Table (a) Parameter variation for simulation of microgrid

3) Development of protection scheme for microgrid
The signals acquired on relaying buses are transformed using a wavelet into a combined frequency domain to generate the feature vector for performing the classification task. A flowchart is shown on the basis of the steps for performing the various fault detection and classification task. For each of the tasks mentioned above, a separate classifier has been developed.

4) Feature extraction using discrete wavelet transform
The derived signals generated during the data generation stage are pre-processed using the Discrete wavelet transform (DWT) to determine the useful features for performing the fault detection and classification task. The standard deviation of approximate coefficients derived using daubechies mother wavelet has been considered as input dataset for training the ensemble-based machine learning classifier.

5) Fault detection and classification using Ensemble classifier algorithm
The fault detection scheme involves random subspace ensemble which use input features extracted in the feature extraction stage which are selected randomly. As compared to the single classifier such as Support vector machine (SVM) or Decision Tree (DT), the ensemble-based technique possesses the advantage of low biasness towards the predicted class. The algorithm has been discussed in detail below.

6) Algorithm Flowchart

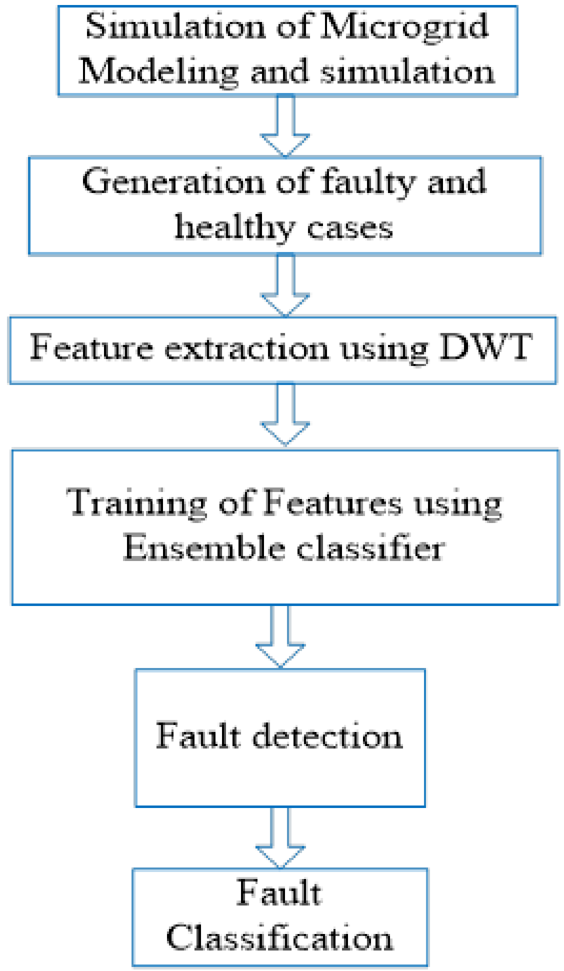


Fig. 2.2: Framework of proposed protection scheme

IV. TEST FEATURES AND SIMULATION SCENERIO

Matlab simulink model of micro-grid under study
Figure 1 illustrates the simulink model for the system to be studied. The displayed system is a microgrid connected to the utility grid via common connection point (PCC). For both operating modes of the microgrid, i.e. grid and island modes, the three-phase fault on the microgrid distribution line has been simulated. For both operations, voltage and current waveform are recorded at the relaying buses B1 and B3.

V. RESULT ANALYSIS

In order to analyze the diverse behaviour of three-phase fault (LG, LL, LLG, LLL and LLLG) considered in the proposed protection scheme, various fault cases have been demonstrated in figures shown below.

The Fig.5.1 illustrates the voltage waveform at B1 bus due to phase A to ground (A-G) fault occurred in microgrid system when connected to utility grid. Figure is showing the variation of voltage post fault at t=0.5sec.

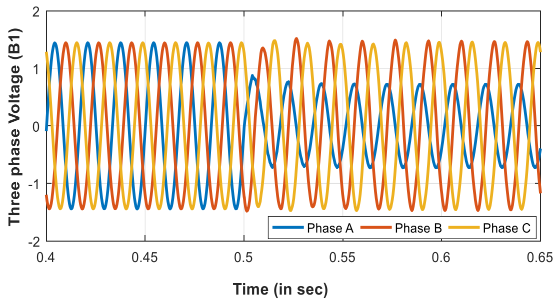


Fig. 5.1 Three-phase voltage at Bus B1 (in pu) due to A-G fault during the grid-connected mode.

The Fig. 5.2 illustrates the current waveform at B1 bus due to phase A to ground (A-G) fault occurred in microgrid system when connected to utility grid. Figure 5.2 is showing the significant rise of current post fault at t=0.5sec.

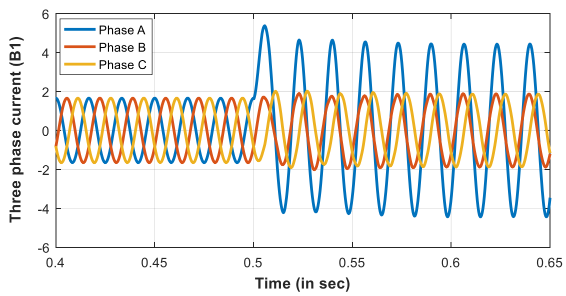


Fig 5.2 Three-phase current at Bus B1 (in pu) due to A-G fault during the grid-connected mode

Fig. 5.3 illustrates the voltage waveform at B1 bus due to ABG fault at fault resistance=5 ohm, occurred in microgrid system during grid-connected mode. Figure depicts the variation of voltage post fault at t=0.5sec.

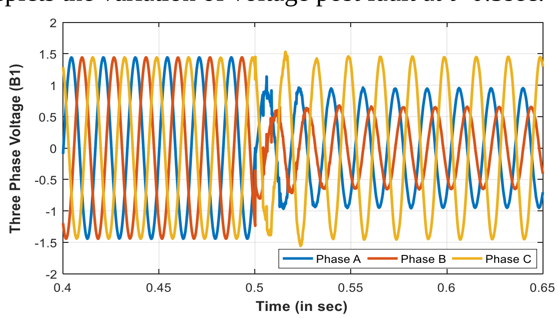


Fig 5.3 Three-phase Voltage at Bus B1 (in pu) due to ABG fault during the Grid-connected mode

For the same fault situation, Fig. 5.4 illustrates the current waveform at B1 bus due to ABG fault at fault resistance=5 ohm, occurred in microgrid system during grid-connected mode. Figure depicts the significant variation of current post fault at t=0.5sec.

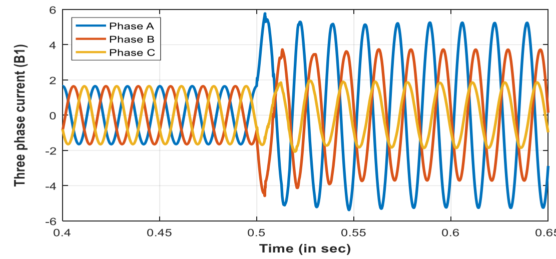


Fig 5.4: Three-phase current at Bus B1 (in pu) due to ABG fault during the Grid-connected Mode

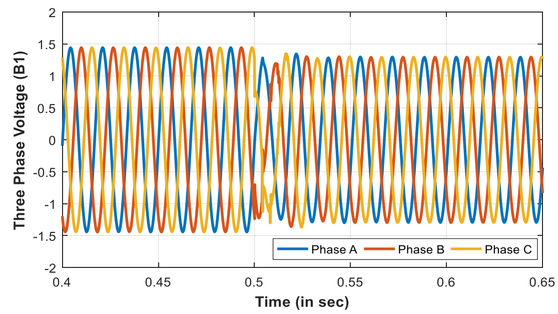
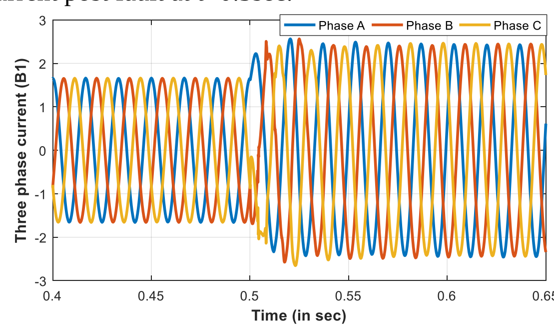


Fig. 5.5: Three-phase voltage at Bus B1 (in pu) due to ABCG fault during the islanded mode

A fault situation involving ABCG fault has been simulated in islanded mode of operation of microgrid at fault resistance=10 ohm. The corresponding voltage and current waveforms at B1 bus due to ABCG fault are demonstrated in figures 5.5 and 5.6 respectively. Figures depicts the significant variation of voltage-current post fault at t=0.5sec.



VI. PERFORMANCE EVALUTION OF ENSEMBLE BASED CLASSIFIER

This discusses how the proposed ensemble-based scheme will perform against different fault situations caused by changes in fault parameters such as the inception angle of the fault, the fault resistance, and the fault location. At different loading conditions, the no-fault test cases have also been generated. In order to examine failure detector/classifier performance a total of 550 test cases involving 500 fault and 50 no-fault cases has been considered. The findings of the analysis and comparative performance of proposed ensemble technique in terms of the classification accuracy, with SVM and DT based scheme shows clearly that the scheme proposed is efficient, reliable, and immune to nonlinear loading conditions.

In order to demonstrate the variation in data points in the two-dimensional space, the scatter plot of training dataset to fed to the ensemble classifier has been depicted in figure 6.

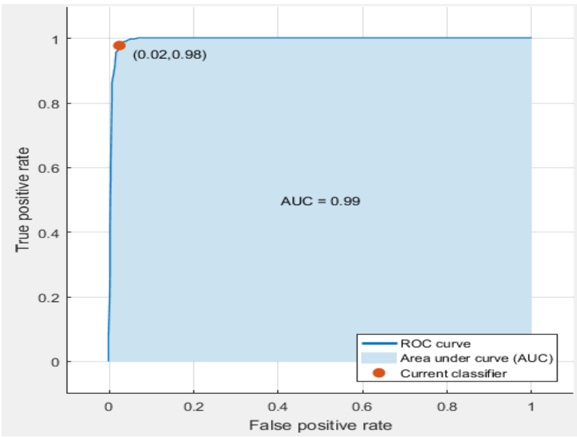


Fig 6.1: Receiver Operating Characteristic (ROC) curve of Ensemble based classifier

Using all the three methods which are random subspace ensemble, support vector machine and decision tree (DT) method we made a comparision and see the results for accuracy and find the Ensemble based classifier gives highest accuracy among all which is shown in the given figure below

Type of classifier	Number of test cases	Correctly predicted Test cases	Classification Accuracy
Random Subspace Ensemble	550	546	99.27%
Support Vector Machine (SVM)	550	499	90.72%
Decision Tree (DT)	550	510	92.72%

Table (a) Comparison of proposed Ensemble based classifier with another individual classifier

CONCLUSION

In microgrid, due to its capacity in Island modes to cater for local needs within well-defined electrical frontiers during operations, it consists of different distributed power resources and loads are popular these days and transfer the super-generation into the grid while operating in grid-connected mode. The penetration of the energy resources distributed also poses serious threats to the secure operation of the grid. In order to ensure the optimum and safe overall system operation, it is important that defects occur in microgrid, and they are classified as being the best protective system. The microgrid of a PV network connected to the grid was considered for study and simulation in this paper. It is important to detect and classify the microgrid failure if the efficient protection system is to be adopted. This paper proposes & implements the use of a Wavelet Transform to extract the information required from the faulty current and voltage waveform. This information is then used for the training and classification of the error type in the microgrid for ensemble-based classifier to detect and classify the faults.

ACKNOWLEDGEMENT

This work was supported in part by the University Institute of Technology RGPV Bhopal.

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