International journal of Inventive Research in Science and Technology ISSN: 2583-5637 (Online)

Volume 4 Issue 10 October 2025

EXPERIMENTAL SCHEME FOR EFFICIENT PROTECTION OF MICROGRID BASED ON WAVELET TRANSFORM AND DATA-MINING TECHNIQUE

AAKASH KUMAR	**Prof. Amit Kumar Namdeo**
M.Tech Schollar,,MIT,Bhopal	Asst. Professor MIT,Bhopal
ashish07oct1994@gmail.com	ec.amitnamdeo@gmail.com

ABSTRACT :- The emerging trend of utilizing the potential of distributed energy resources (DER) in the present low voltage distribution framework to manage the rising power demand has led to the emergence of microgrid. The major idea behind large penetration of DERs is to facilitate the islanded mode operation of microgrid to feed the emergency power demand thereby ensuring the reliability, in the situations involving faults or disturbances in the grid. Though the microgrid possess significant advantages in the distribution systems but the integration issues associated with renewable and synchronous DERs have made the protection tasks inevitably challenging. The dynamic generating behaviour of renewable DERs with limited fault current carrying capability upto 2-3 times the rated current compared to synchronous DERs having the ability to withstand fault current upto even 10 times, form a wide demarcation between them in terms of operating conditions. Due to these reasons, the associated protection issues become further more complicated. Since the magnitude of fault current is mode dependent i.e. there is vast difference in the level of fault current between islanded and grid-connected mode.

Keywords: Microgrid Protection, Data mining, Bagged decision tree, Feature extraction, Discrete wavelet transform, fault detection

1.Introduction

The microgrid concept has to face a number of challenges in several fields, not only from the protection point of view, but also from the control and dispatch perspective [7]. Nevertheless, due to their specific characteristics and operation, microgrid protection systems have to deal with new technical challenges [5, 6]: Generation systems in both medium voltage (MV) and low voltage (LV) systems, making power flow bidirectional;

Two operational modes: grid connected and islanded/stand-alone;

Topological changes in LV network due to connection/disconnection of generators, storage systems and loads;

Intermittence in the generation of several micro sources connected in the microgrid;

Increasing penetration of rotating machines, which may cause fault currents that exceed equipment ratings.

Insufficient level of short-circuit current in the islanding operation mode, due to powerelectronics interfaced distributed generation (DG);Reduction in the permissible tripping times when faults occur in MV and LV systems, in order to maintain the stability of the microgrid;

• Nuisance tripping of protection due to faults on adjacent feeders

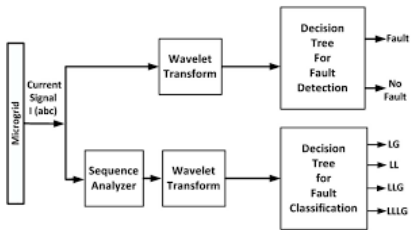

Figure 1.1: Microgrid based on Wavelet Transform and Data-Mining Technique.

Power systems currently undergo considerable change in operating requirements – mainly as a result of deregulation and due to an increasing amount of distributed energy resources. In many cases distributed energy resources include different technologies that allow generation in micro sources and some of them take advantage of renewable energy resources such as solar, wind or hydro energy. Having micro-sources close to the load has the advantage of reducing transmission losses as well as preventing network congestions and also consumers,

1.1 TECHNICAL CHALLENGES IN MICROGRID PROTECTION

One of the major challenges is a protection system for microgrid which must respond to main grid as well as microgrid faults. In the principal case the assurance framework ought to confine the microgrid from the fundamental matrix as quickly as important to ensure the microgrid loads. In the second case the security framework ought to seclude the littlest piece of the microgrid as ahead of schedule as conceivable to clear the shortcoming in the framework. A few issues identified with a security of microgrids and conveyance frameworks with an enormous entrance of appropriated vitality assets have been tended to in late distributions.

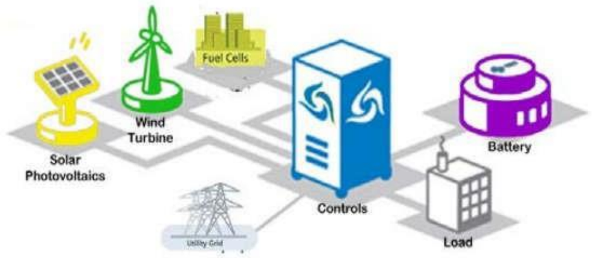

Figure 1.2: Micro Grid Connected Energy Resourcesto utility Grid

As a result of these headings and amplitudes of short out flows will fluctuate as per the framework variations from the norm. Actually, working states of microgrid are continually changing a direct result of the irregular smaller scale sources like breeze and sun based and occasional burden variety. Additionally a system geography can be consistently changed focused on misfortune minimization or accomplishment of other monetary or operational targets. What's more controllable islands of various size and substance can be framed because of flaws in the primary framework or inside a microgrid. In such conditions lost hand-off coordination may occur and conventional over-current insurance with a solitary setting gathering may get deficient, for example it won't ensure a particular activity for every single imaginable shortcoming.

2. LITERATURE REVIEW

In this section the comparison of the techniques which are proposed by several authors in order to perform fault detection as well as the classification is discussed.

In paper [17], the author has introduced microgrids of varying size and applications are regarded as a key feature of modernizing the power system. The protection of those systems, however, has become a major challenge and a popular research topic because it involves greater complexity than traditional distribution systems. This paper addresses this issue through a novel approach which utilizes detailed analysis of current and voltage waveforms through windowed fast Fourier and wavelet transforms. The fault detection scheme involves bagged decision trees which use input features extracted from the signal processing stage which are selected by correlation analysis. The technique was tested on a microgrid model developed using PSCAD/EMTDS, which is inspired from an operational microgrid in Goldwind Science Technology Co. Ltd., in Beijing, China. The results showed a great level of effectiveness to accurately identify faults from other non-fault disturbances, precisely locating the fault and trigger opening of the right circuit breaker/s under different operation modes, fault resistances, and other system disturbances.

In this paper [1] author has explained Fault detection is essential in microgrid control and operation, as it enables the system to perform fast fault isolation and recovery. The adoption of inverter-interfaced distributed generation in microgrids makes traditional fault detection schemes inappropriate due to their dependence on significant fault currents. In this paper, we devise an intelligent fault detection scheme for microgrid based on wavelet transform and deep neural networks.

The proposed scheme aims to provide fast fault type, phase, and location information for microgrid protection and service recovery. In the scheme, branch current measurements sampled by protective relays are pre-processed by discrete wavelet transform to extract statistical features. Then all available data is fed as input to the deep neural networks to develop fault information. Compared with previous work, the proposed scheme can provide significantly better fault type classification accuracy. Moreover, the scheme can also detect the locations of faults, which are unavailable in previous work. To evaluate the performance of the proposed fault detection scheme, we conduct a comprehensive evaluation study on the CERTS microgrid and IEEE 34-bus system. The simulation results demonstrate the efficacy of the proposed scheme in terms of detection accuracy, computation time, and robustness against measurement uncertainty.

In this paper [2] author presents an intelligent protection scheme for microgrid using combined wavelet transform and decision tree. The procedure begins at recovering current signs at the transferring point and preprocessing through wavelet change to infer compelling highlights, for example, change in vitality, entropy, and standard deviation utilizing wavelet coefficients. When the highlights are extricated against blamed and unfaulted circumstances for each-stage, the informational collection is worked to prepare the decision tree (DT), which is approved on the inconspicuous informational collection for shortcoming recognition in the microgrid. Further, the shortcoming characterization task is done by including the wavelet based highlights got from succession segments alongside the highlights got from the current signs. The new informational index is utilized to fabricate the DT for deficiency identification and arrangement. Both the DTs are broadly tried on an enormous informational collection of 3860 examples and the test outcomes demonstrate that the proposed handing-off plan can adequately secure the microgrid against defective circumstances, remembering wide varieties for working conditions.

3. THEORETICAL BACKGROUND

The Wavelet Toolbox software includes a large number of wavelets that you can use for both continuous and discrete analysis. For discrete analysis, wavelet toolbox consists orthogonal wavelets (Daubechies' extremal phase and least asymmetric wavelets) and B- spline biorthogonal wavelets. For continuous analysis, the Wavelet Tool boxes of software includesMorlet, Meyer, derivative of Gaussian, and Paul wavelets. The choice of wavelet is dictated by the signal or image characteristics and the nature of the application. If you understand the properties of the analysis and synthesis wavelet, you can choose a wavelet that is optimized for your application. Wavelet families vary in terms of several important properties which very useful in image processing applications. Symmetry or anti- symmetric of the wavelet.

3.1 WAVELET TRANSFORM

The aim of the image transform is to pack as much information as possible into smallest number of coefficients. Need of image transform is to convert the data into a form where the compression is easier which facilitates reduction of redundant irrelevant information. Fast data computation is also possible in transform domain. Wavelet has finite energy and limited duration signal which is referred as a basis function. Each basis function represents small wave. Representing an image in the form of basis function is called wavelet transform. It gives both time resolution and frequency resolution. Wavelet transform provides multi-resolution analysis for a given signal or image. Due to its oscillating nature and has the ability to represent the signal in time and frequency simultaneously. It is an appropriate tool for time-frequency analysis of signal and image [31].

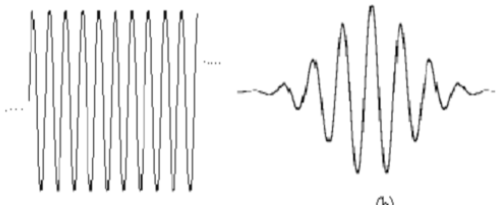

Figure 3.1 wave (a), and its wavelet (b)

3.2 MULTI-RESOLUTION ANALYSIS IN DATA MINING

Multi-resolution analysis is defined as the Representation of signals or images at different resolutions. For better interpretation, the large objects or high contrast images require low resolution, whereas the small objects or low contrast images require high resolution. This can be achieved by multi-resolution approach. Different resolutions of signals or images are achieved by filtering and sub sampling operations of wavelet transform. Sub sampling is nothing but reducing sampling rate or removing of some samples. This multi-resolution concept is very useful in wavelet analysis in image processing.

3.3 MACHINE LEARNING

Machine learning teaches computers to do what comes naturally to humans: learn from experience. Machine learning algorithms use computational methods to “learn” information directly from data without relying on a predetermined equation as a model. The algorithms adaptively improve their performance as the number of samples available for learning increases.

Machine learning uses two types of techniques: supervised learning, which trains a model on known input and output data so that it can predict future outputs, and unsupervised learning, which finds hidden patterns or intrinsic structures in input data.

The aim of supervised machine learning is to build a model that makes predictions based on evidence in the presence of uncertainty. A supervised learning algorithm takes a known set of input data and known responses to the data (output) and trains a model to generate reasonable predictions for the response to new data. Supervised learning uses classification and regression techniques to develop predictive models.

4. PROBLEM DEFINITION & PROPOSED METHODOLOGY

4.1 PROBLEM DEFINITION

Since, Microgrid (MG) is a building block of future smart grid, it can be defined as a network of low voltage power generating units, storage devices and loads.

1. In this dissertation work major idea has been taken from the large penetration of DERs which is to facilitate the islanded mode operation of microgrid to feed the emergency power demand thereby ensuring the reliability, in the situations involving faults or disturbances in the grid which is then overcome using the discrete wavelet transform (DWT) and data-mining technique that has been developed for the microgrid.

2. The microgrid possess significant advantages in the distribution systems but the integration issues associated with renewable and synchronous DERs have made the protection tasks inevitably challenging.

3. The dynamic generating behaviour of renewable DERs with limited fault current carrying capability upto 2-3 times the rated current compared to synchronous DERs having the ability to withstand fault current upto even 10 times, form a wide demarcation between them in terms of operating conditions. Due to these reasons, the associated protection issues become further more complicated. Since the magnitude of fault current is mode dependent i.e. there is vast difference in the level of fault current between islanded and gridconnected mode.

4.1 PROPOSED METHODOLOGY

Simulation of Microgrid understudy

The operation of Microgrid in performing load leveling and voltage regulation in the local power system are demonstrated. The dynamic response of the Microgrid components are presented when subjected to sudden changes in solar irradiance. Battery energy storage is shown to be very effective in complementing and compensating the fluctuation of generated power from the PV. Microgrid is also shown very effective in regulating the voltage.

Design and simulation of Microgrid model

The design of microgrid includes a presence of solid-state converters is a critical issue in the analysis of protection of microgrids, for the reason that the current that can be supplied through such converter based DERs is mostly limited to a maximum of twice the rated current. This limits the fault current amount which intern causes sensitivity issues in the protection of microgrids.

Generation of fault and other operating scenarios

The major challenges regarding the protection of microgrids arise from the construction features of a microgrid, which involve large scale presence of converter type DERs and the possibility of two way power flow. That is to be added to the low inertia of the systems especially in the island mode of operation. This makes microgrids easily susceptible to instability due to changes in load and generation.

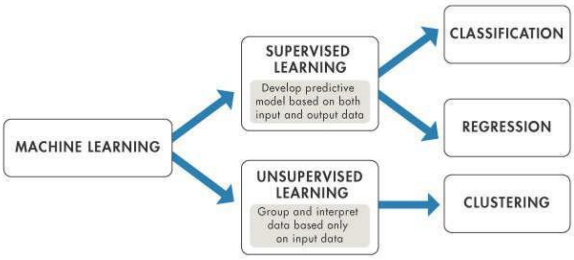

Figure 4.1: Data mining technique for the evaluation of faults.

The proposed adaptive protection scheme also employs auto reclosures, through which the proposed adaptive protection scheme recovers faster from the fault and thereby increases the consistency of the microgrid. The effectiveness of the proposed adaptive protection is studied through the time domain simulations carried out in the proposed software environment.

4.2 Bagged Decision Tree

Decision trees are one of the information mining methods that have been utilized for the characterization of utilizations for various years [18]. The strategy has seen ongoing restoration because of higher exactness being accomplished through the disclosure of strategies for ensembling of more than one trees [19,20]. A choice tree is where complex issues are separated into a progressive system of more straightforward ones. While preparing a choice tree, all preparation information is sent into the tree so as to enhance the boundaries of the interior hubs. The testing of a choice tree includes rehashed twofold testing of information at the inward hubs and the outcome being sent to the suitable (the privilege or left) kid until it arrives at a terminal hub (leaf). The leaf hubs for the most part contain an indicator (a classifier for this situation) that will relate a yield (a class name of 1 or 0 to speak to presence or non-presence of a deficiency) to the info accomplishment.

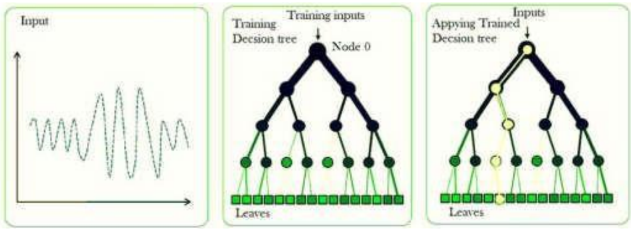

Figure 4.2: Training and applying decision trees.

Algorithm Flowchart

In the above figure 4.4 the flowchart for the proposed algorithm is shown.Below is the descriptionof the following steps involved in the flowchart-

Step 1: The work of the proposed algorithm starts from the design and simulation of the microgrid understudy model which is the first step.

Step2: In the second step the function call goes at generation of faults and other operating scenarios.

Step 3: In the third step the control will switch to the extraction of the voltage and current signals from the point of common coupling (PCC) with the help of discrete wavelet transform.

Step 4: In the next step training of bagged decision trees will work thoroughly. The loop will follow the following conditions- if the fault detects then the function control will show the type pf fault which occurs. Otherwise, in second category it will generate output as-no fault.

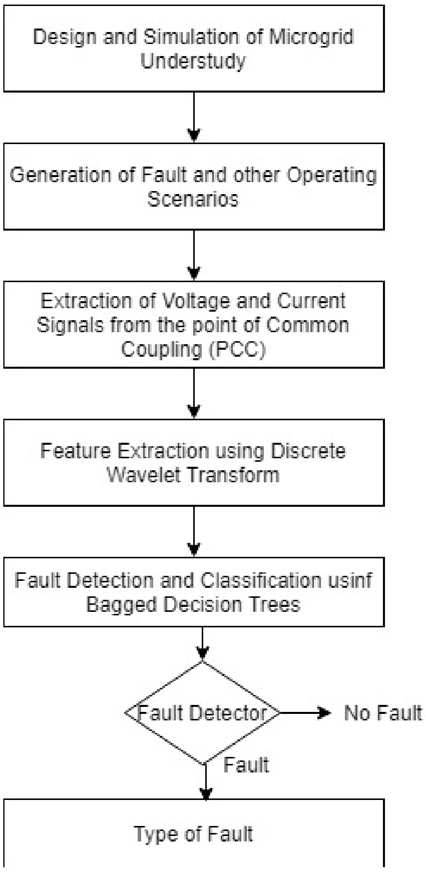

Figure 4.3: Algorithm flowchart

5. SIMULATION RESULTS

MATLAB Simulink has been used to carry out the simulation of proposed model. MATLAB m-file editor toolbox has been used for developing the MATLAB code. The simulink model, simulation results and performance of the designed algorithm are explained in the sections as given below.

MATLAB SIMULINK MODEL OF MICRO-GRID UNDER STUDY

Microgrid may consist of various distributed energy resources (DERs) can operated in islanded mode or grid connected mode. Fig. 5.1 shows the simulink model of the system considered for carrying out investigation. The system shown in figure consists of microgrid connected to the utility grid via point of common coupling (PCC). The Three phase fault has been simulated at bus B3B for both modes of operation of microgrid i.e. grid connected & island modes. The voltage and current waveform have been recorded for both the case of operations.

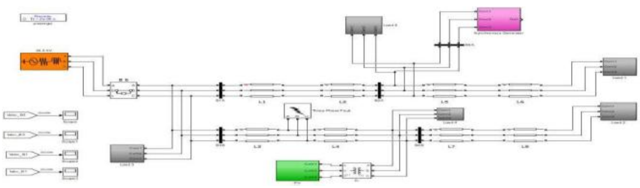

Fig 5.1: Simulink model of Microgrid considered under study

MATLAB SIMULINK MODEL OF PV ARRAY BASED GENERATOR IN THE MICROGRID

Fig. 5.2 details the microgrid configuration which consists of PV array, low pass filter, Inverter, Boost Converter Control for Maximum Power Point Tracking, Vsc Control.

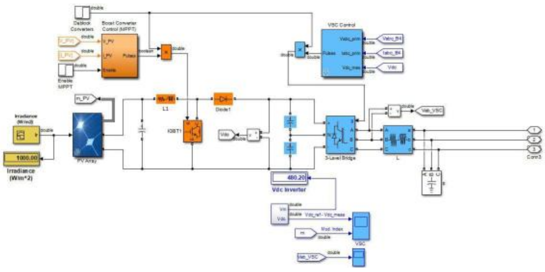

Fig 5.2: PV array based generator in the Microgrid

I-V AND P-V CHARACTERISTICS OF PV ARRAY

I-V characteristic of PV array represents the relationship between current and voltage for the existing condition of the irradiance. The curve provides the necessary information required to configure the PV system for operating it close to optimal peak power point.

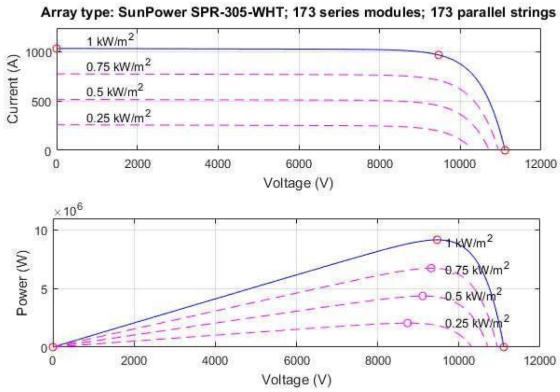

Fig 5.3: I-V and P-V Characteristics of PV array

Fig. 5.3 shows the I-V and P-V characteristics of the PV array (Sun Power SPR 305- WHT consisting of 173 series modules & 173 Parallel strings) considered for study. Value of current, voltage, maximum power point (MPP) for different level of irradiance level can be determined using these characteristics.

Table 5.1: Comparative study of power, voltage and current for different levels of irradiance level

Irridiance Level	Power (W)	Voltage (V)	Current (A)
1 kW/m^2	9 x 10^6	9000	1000
0.75 kW/m^2	7 x 10^6	8700	750
0.5 kW/m^2	4.5 x 10^6	8600	500
0.25 kW/m^2	2 x 10^6	8500	250

Table 5.1 illustrates the comparative analysis of the Maximum Power Point (MPP) for different levels of irrdiance. The above values have been derived from the I-V

and P-V characteristics of the PV array (Sun Power SPR 305-WHT consisting of 173 series modules & 173 Parallel strings) considered for study.

RESULT ANALYSIS

The results obtained after simulation has been discussed below:

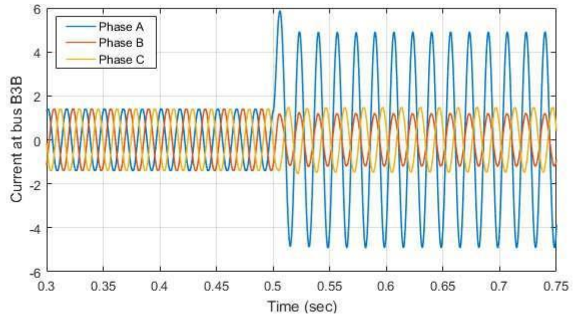

Fig 5.4: Current at Bus B3B due to A-G fault in the grid-connected mode

The Fig. 5.4 illustrates the current waveform at B3B 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 currents on ordinate while time has been taken on abscissa.

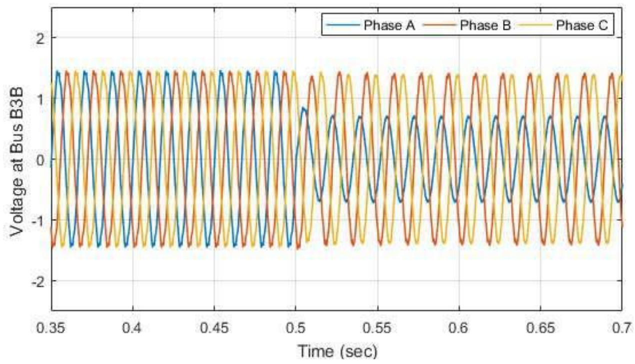

Fig 5.5: Voltage at Bus B3B due to A-G fault in the grid-connected mode

The Fig. 5.5 is showing the variation of voltage at B3B bus due to phase A to ground (A- G) fault occurred in microgrid system when connected to utility grid. The time has been taken on abscissa while variation of voltage has been taken on ordinate.

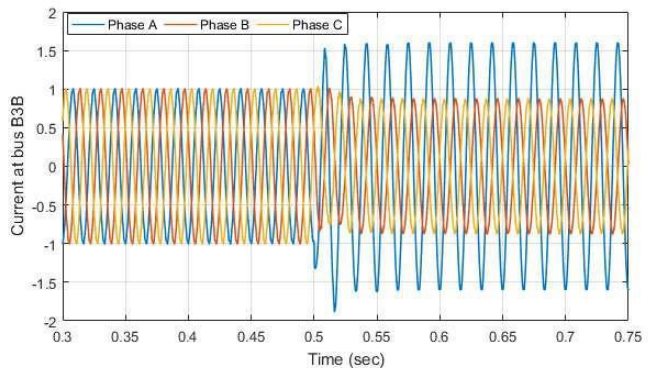

Fig 5.6: Current at Bus B3B due to A-G fault in the Off-grid mode

The Fig. 5.6 shown above illustrates the current waveform at B3B bus due to phase A to ground (A-G) fault occurred in microgrid system when operating in islanded mode. Figure is showing the variation of currents on y axis while time has been taken on x axis.

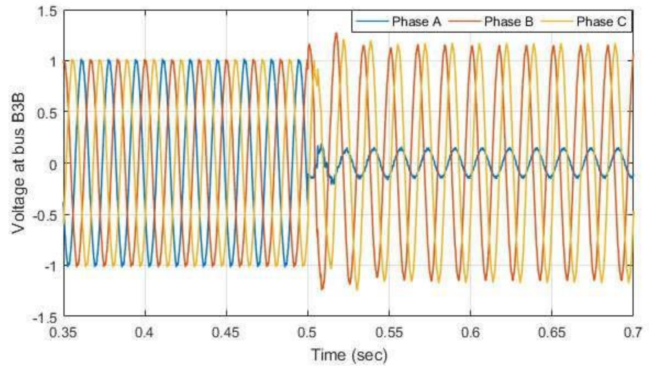

Fig 5.7: Voltage at Bus B3B due to A-G fault in the Off-grid mode

The Fig. 5.7 shown above illustrates the variation of voltage at B3B bus due to phase A to ground (A-G) fault occurred in microgrid system when operating in islanded mode. Figure is showing the voltage on y axis while time has been taken on x axis.

PARAMETER USED

The necessary information from current and voltage signals so obtained due to phase to ground fault occurred while operating in Grid connected mode & island mode is extracted using wavelet transform. This information is futher used in training of bagged decision tree for the classifying the type of error occurred in the system.

In the proposed study, an extensive data set is generated to train and test the data-mining model (using Bagged trees) for developing an accurate and robust classifier to perform the fault detection and classification task. The Baaged decision tree model is trained and tested for different combination of data sets, involving variation in fault parameters and other operating scenarios. For example in combination of (70–30) data set, 70% of data are considered for training purpose and 30% of data for testing purpose. The confusion matrix generated for the above system is depicted in Fig. 5.8, 5.9 and 5.10, which provides the comparison results between the actual and predicted faults during testing for the given data set.

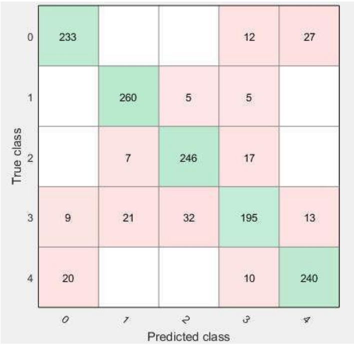

Fig 5.8: Confusion matrix showing the comparison between true and predicted class

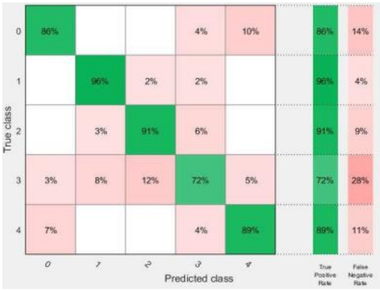

Fig 5.9: Confusion matrix showing the variation between true positive and true negative rate

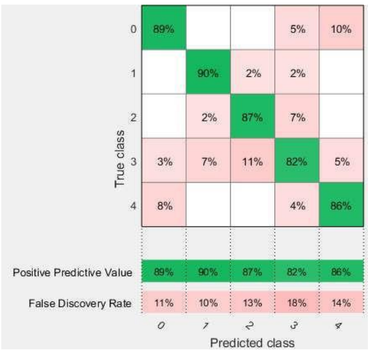

Fig 5.10: Confusion matrix showing the variation between positive predictive value and false discovery rate

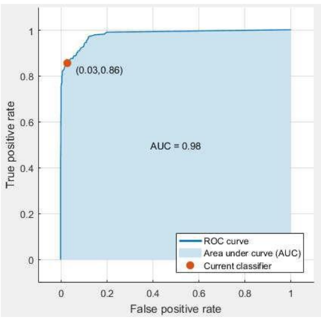

Fig 5.11: Receiver Operating Characteristic (ROC) curve of Bagged decision tree based classifier

In order to show the robustness of proposed bagged decision tree based classifier in performing the protection task, the Receiver Operating Characteristic (ROC) curve has been depicted in Fig. 5.10 which shows the ability in performing the intended tasks.

6. CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

Mircogrid consisting of various distributed energy resources and loads are getting popular these days due to their ability of catering the local needs within well defined electrical boundaries while operating in island mode and to transfer the surplus generation to the utility grid while operating in grid connected mode. However the penetration of distributed energy resources is also posing serious threats to the safe operation of utility grid. It is important to detect the faults occurring in microgrid & classify them as to adopt the best protection scheme for the overall optimal & safe operation of the system.

In this dissertation work microgrid consisting of PV system connected to the grid has been considered for study & simulation. In an order to adopt the efficient protection scheme for the system it is important to detect & classify the fault occurring the microgrid.

6.2 Future Work

The proposed scheme of fault identification and classification & subsequent analysis as elaborated in this thesis work suggest that devised methodologies are quite capable and practical in approach however some improvements still can be made which are as follows:

1. The microgrid considered for the study & simulation only consists of the PV arrays. Study can be futher carried out on microgrid constituting of other distributed energy resources such as fuel cell, wind turbines etc.
2. In this dissertation work a phase to groud fault has been simulated for one phase. The results can be verified for other different types of faults such as line to line (L-L), all line to ground (L-L-G) faults. Wavelet transform as a data mining tool uses the regeression as data mining technique. Other data mining techniques such as Tracking patterns, Classification, Association, Clustering etc. may be implemented to extract the information from the data captured during fault in the system.

REFERENCES

[1]. James J. Q. Yu , Member, IEEE, YunheHou, Intelligent Fault Detection Scheme for Microgrids With Wavelet-Based Deep Neural Networks, IEEE TRANSACTIONS ON SMART GRID, VOL. 10, NO. 2, MARCH 2019.

[2]. Debi Prasad Mishra, SubhransuRanjanSamantaray, Senior Member, IEEE, and GezaJoos, Fellow, IEEE, A Combined Wavelet and Data-Mining Based Intelligent Protection Scheme for Microgrid, 1949-3053 © 2015 IEEE.

[3]. ShaziaBaloch 1 , SaeedZamanJamali 2 , Khawaja Khalid Mehmood 3 , Syed Basit Ali Bukhari 3 , Muhammad SaeedUzZaman 1 , ArifHussain 1 and Chul-Hwan Kim 1,*, Microgrid Protection Strategy Based on the

Autocorrelation of Current Envelopes Using the Squaring and Low-Pass Filtering Method, 8 May 2020.

[4]. T S SSenarathna and K T M UdayangaHemapala*, Review of adaptive protection methods for microgrids, 11 September 2019.

[5]. Lai Lei,1,2 Cong Wang,1 Jie Gao,3 Jinjin Zhao,2 and Xiaowei Wang4,5, , A Protection Method Based on Feature Cosine and Differential Scheme for Microgrid, 10 Mar 2019.

[6]. M. A. Zamani, T. S. Sidhu, and A. Yazdani, "A protection strategy and microprocessor- based relay for low-voltage microgrids," IEEE Trans. Power Del., vol. 26, no. 3, pp. 1873–1883, Jul. 2011.

[7]. P. Mahat, C. Zhe, B. Bak-Jensen, and C. L. Bak, "A simple adaptive overcurrent protection of distribution systems with distributed generation," IEEE Trans. Smart Grid, vol. 2, no. 3, pp. 428–437, Sep. 2011.

[8]. E. Sortomme, S. S. Venkata, and J. Mitra, "Microgrid protection using communication-assisted digital relays," in Proc. IEEE Power Energy Soc. Gen. Meeting, Minneapolis, MN, USA, 2010, p. 1.

[9]. H. Nikkhajoei and R. H. Lasseter, "Microgrid protection," in Proc. IEEE Power Eng. Soc. Gen. Meeting, Tampa, FL, USA, 2007, pp. 1–6.

[10]. T. S. Ustun, C. Ozansoy, and A. Zayegh, "Modeling of a centralized microgrid protection system and distributed energy resources according to IEC 61850-7-420," IEEE Trans. Power Del., vol. 27, no. 3, pp. 1560–1567, Aug. 2012.

[11]. T. S. Ustun, C. Ozansoy, and A. Ustun, "Fault current coefficient and time delay assignment for microgrid protection system with central protection unit," IEEE Trans. Power Syst., vol. 28, no. 2, pp. 598–606, May 2013.

[12]. M. A. Zamani, T. S. Sidhu, and A. Yazdani, "A communication-based strategy for protection of microgrids with looped configuration," Elect. Power Syst. Res., vol. 104, pp. 52–61, Nov. 2013.

[13]. S. R. Samantaray, G. Joos, and I. Kamwa, "Differential energy based microgrid protection against fault conditions," in Proc. IEEE PES Innov. Smart Grid Technol. (ISGT), Washington, DC, USA, 2012, pp. 1–7.

[14]. M. A. Haj-ahmed and M. S. Illindala, "The influence of inverter-based DGs and their controllers on distribution network protection," in Proc. IEEE Ind. Appl. Soc. Annu. Meeting, Lake Buena Vista, FL, USA, 2013, pp. 1–9.

[15]. E. Casagrande, W. W. Lee, H. H. Zeineldin, and N. H. Kan'an, "Data mining approach to fault detection for isolated inverter-based microgrids," IET Gener. Transm. Distrib., vol. 7, no. 7, pp. 745–754, Jul. 2013.