INTERNATIONAL RESEARCH JOURNAL OF ENGINEERING & APPLIED SCIENCES
ISSN: 2322-0821(O) VOLUME 10 ISSUE 4
ISSN: 2394-9910(P) Oct 2022 - Dec 2022
www.irjeas.org

Original Article

Machine Learning Based Efficient Protection Scheme for AC Microgrid

*Abhishek Dixit [1], Santosh Kumar [2]

[1] *Research Scholar, Department of Electrical and Electronics Engineering, Millenium Institute of Technology and Science, Bhopal, India*
dixitabhishek601@gmail.com *https://orcid.org/0000-0003-4581-3104*
[2] *Asst. Professor, Department of Electrical and Electronics Engineering, Millenium Institute of Technology and Science, Bhopal, India*
Santosh21en@gmail.com

*Corresponding Author - *dixitabhishek601@gmail.com*

DOI - https://doi.org/10.55083/irjeas.2022.v10i04009

Received: 04 October 2022; Received in revised form: 09 December 2022; Accepted: 16 December 2022

Abstract: Micro grids have become popular as a way to reduce carbon emissions and use nonrenewable energy sources to produce power. Microgrids allow users to generate and regulate energy as needed, reducing their reliance on the utility grid. They may also sell excess electricity to the grid and make money. Due to its simple design, fast installation, and easy maintenance, photovoltaic systems are a vital microgrid resource. Microgrids threaten the reliability and optimum functioning of major power grids. It's crucial to discover defects early and fix them before catastrophic system breakdown. This research proposes a unique method based on Discrete wavelet transform and ensemble of Decision tree classifier for detecting and classifying microgrid faults. Once the particular fault type is recognised and categorised, a suitable protective strategy may be used to address it early, enhancing the system's overall safety.

Keywords: Classification, Ensemble classifier, Fault detection and categorization, Machine Learning, Microgrid, PV Systems, Wavelet Transform

1. INTRODUCTION

Ever-increasing electrical demands have pushed major transmission networks to the verge of stability. Updating the existing infrastructure to meet future demands is not a sustainable financial option. This has necessitated the development of novel approaches, one of which is the production of electricity at the point of use. Renewable energy sources, such as wind, sunshine, etc., may be harnessed to produce this electrical energy. Microgrids have emerged as a result, often made up of wind turbines, fuel cells, PV arrays, etc., and specialised load linked inside clearly defined electrical boundaries. Microgrids provide numerous benefits to consumers and grid operators, including decreased reliance on the main grid, operational and control flexibility, surplus power transfer to the main grid, enhanced reliability and service quality, decreased pollution, and increased use of renewable energy sources. The operation and safety of microgrids are becoming complicated by their increasing connectivity with the electric grid. The chosen protection system must react to both main grid and microgrid failures. An appropriate protection plan that can isolate the problematic portion and promptly rectify the issue must be put into action, therefore rapid fault detection and classification is essential.

In this study, we suggest a microgrid protection method that makes use of autocorrelation to effectively mitigate potential threats. The present signal envelope was analysed by squaring it and applying a low-pass filter. The instantaneous voltage and current data is processed using the discrete wavelet transform (DWT), and the standard deviation is then determined using the approximate coefficient estimates. This data is then utilised to teach the data mining-based decision tree model how to properly categorise the defect that has occurred. Extracting information from a voltage current signal using the DWT takes less computational time, and it retains relevant properties. The aforementioned protection strategy has shown effective in both operating modes, is simple to construct, and exhibits high performance in a looping and radial design. The acquired simulation results demonstrate the appropriateness of the suggested approach in detecting, and classifying faults.

2. LITERATUE REVIEW

In this part, we'll take a closer look at the methods that have been utilised in the past to identify and categorise microgrid faults.

The wavelet transform and deep neural network-based intrelligent defect detection system was suggested by James J. Q. Yu et at. [1]. The purpose of the system is to provide data on the problem's location, phase it occurred in, and fault kind. This data is crucial for efficient microgrid protection and quick fault isolation and restoration. Protective relays take readings of branch currents and use the wavelet transform to glean useful information, which is then fed into a deep neural network to inform its problem diagnosis.

At the relaying point, Debi Prasad Mishra et al. [2] employed effective information acquired from the current signal using wavelet coefficients. Next, a decision tree is constructed using characteristics extracted from the current signal and features generated from the sequence components to identify and categorise faults. Both Decision Trees are extensively evaluated using 3860 data points [3].

The collected findings show that the suggested protection mechanism is efficient and effective in preventing faults from arising throughout a broad spectrum of microgrid operating circumstances. The protection strategy developed by Shazia Baloch et al. [4] relies on the autocorrelation of the current signal across three phases. MATLAB/Simulink (Version: R2017b) was used to simulate the medium voltage microgrid and investigate the performance of suggested design. The suggested approach not only detects the issue and classifies it, but also safeguards against the occurrence of critical insurance violations, as shown by the simulation results. The state of the art of different adaptive approaches used in micro grid protection is discussed by Sisitha Senarathna et al.[5]. They analyse the many possible implementations, highlighting the benefits and downsides of each.

The author of this research elucidated the myriad of factors acquired by Microgrids throughout the previous decade that have transformed the core resource into a profitable enterprise. One of the key reasons for the success of microgrids is their simplicity in terms of both setup and maintenance. Microgrids may be readily combined with a broad range of Distributed Generation (DG) choices, such as wind turbines, other smaller-scale turbines, PV systems, fuel cells, etc., allowing them to function in both grid-connected and islanded modes. One of the many obstacles that must be overcome before microgrids can be used to their full potential is insurance.

Different insurance arrangements were developed as a result of developments in insurance policies and practises. One such new approach for protecting microgrids is called versatile assurance. In this study, we provide a comprehensive audit of flexible insurance for microgrids, discussing both their advantages and their drawbacks. It also delves into the top research that uses artificial intelligence to deploy flexible insurance. These arrangements have launched the full categorization of insurance arrangements leading to increasingly flexible and stable framework that may be adopted all inclusive.

According to Lai Lei et al.[6], overcurrent protection strategies are weakened due to differences in fault current between islanded mode and grid linked mode. In this research, we suggest a safeguard based on the cosine and differential plan of features. A first proposal called "feature cosine" is made, which counts the unified performance of voltage and current by means of the equation of ellipse and the minimal least squares. Finally, the high accuracy of the proposed protection strategy was verified by studying several time domain imitations, such as various microgrid operating modes, fault types, defective section identification, and noise effect. Microgrid protection presents unique difficulties when switching between the two modes of operation, as explored by M. Amin Zamani et al. [7].

Using microprocessor-based relays, a protection mechanism for low-voltage microgrids was devised and described in depth in this study [8-15]. The suggested scheme's primary benefits are its independence from the operating mode and the amount of the fault current, as well as the absence of a need for communication or suitable protective devices. For transient time-domain simulation research, scientists turn to the PSCAD/EMTDC software suite [16-21].

3. PROBLEM DEFINITION

Motivated by the difficulties presented by grid-scale integration of DERs and their operation in islanded mode to meet emergency power demand while maintaining reliability during grid failures and disturbances, this proposal sets out to address these issues. The situation may be improved by using the data-mining and microgrid-specific discrete wavelet transform (DWT) approach for straightforward fault identification and classification.

While synchronous DERs can handle fault currents up to ten times their rated current, renewable DERs can only handle currents up to two or three times their rated value. Because of this significant gap exists between their respective operating environments. Such factors further complicate the related protection difficulties.

Therefore, it is necessary to design a microgrid protection strategy that is robust enough to handle the harmonics produced by power electronic interface devices and non-linear loads, while yet providing enough protection for the microgrid in both operating modes.

4. PROPOSED METHODOLOGY

In this paragraph, we will go through the basics of the suggested technique, which utilises a wavelet transform and a decision tree classifier.

4.1. Microgrid System under study

Microgrid operations including load balancing and voltage control in the distribution grid at the local level are simulated. We also detail the dynamic reactions of the Microgrid's components to transient variations in solar irradiation. The battery storage effectively smoothed out the PV system's output variations. This causes sensitivity problems in microgrid protection since it restricts the maximum size of fault current that can be handled.

The design aspects of a microgrid, such as the widespread presence of DERs, provide significant hurdles in terms of microgrid safety. That's in addition to the systems' already low inertia, which is notably noticeable while running in island mode. Consequently, fluctuations in demand and generation pose a significant threat to the stability of microgrids.

4.2. Development of protection scheme for microgrid

Using MATLAB, the time domain simulations on the suggested adaptive protection were carried out in order to evaluate its efficiency and efficacy.

In the field of image processing, the WT has been used for deriving the features in order to enable the picture to be represented in the condensed and unique form of a matrix vector consisting of single values.

The inout characteristics from the signal processing step have been selected via the use of correlation analysis, and these features are then utilised for training of Bagging tree for the purpose of finding defects in the proposed protection strategy. The microgrid model has been utilized for the testing of the method.

4.3. Algorithm Flowchart

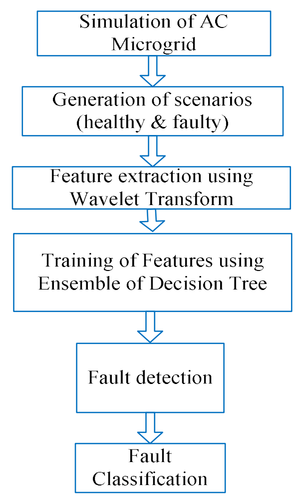

Figure 1. Algorithm flowchart

The suggested approach is shown in Figure 1, which may be seen above. The following is a list of the numerous stages that are involved in the flowchart:

Step 1: The work of the suggested algorithm begins with the design and simulation of the microgrid understudy model, which is the first step. This is the beginning of the process.

Staep 2: The function call is executed during the second step, which occurs during the formation of errors and other operational conditions.

Step 3: The control will then move to the process of extracting the voltage-current signals from the relay bus with the assistance of discrete wavelet transform in the third step of the procedure. The training of bagged decision trees will be carried out in depth in the next stage, which is the fourth step. The conditions that will be followed by the loop are as follows: if the fault is detected, the function control will reveal the sort of fault that has occurred if it is detected. In such case, it will fall into the second group and create output as no fault.

5. SIMULATION SETUP

In this section illustrates the simulation models used in the study:

5.1. MATLAB Simulink model of Microgrid under study

Microgrids may be made up of a variety of distributed energy resources (DERs), which can either function independently or be linked to the larger power grid. The simulink model of the system that was taken into consideration for the inquiry can be seen in figure 3.

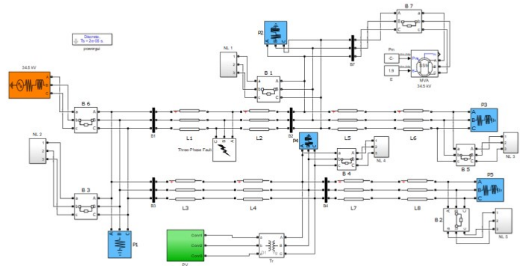

Figure 2. Simulink model of Microgrid considered under study

The representation model of the grid-connected photovoltaic system can be seen in figure 2, which can be seen above. This system includes the following components: mathematical modelling accomplished via the use of MATLAB and Simulink. Figure 3 provides further information on the design of the microgrid, which is made up of a photovoltaic array, a low-pass filter, an inverter, a boost converter control for maximum power point tracking, and a vsc control.

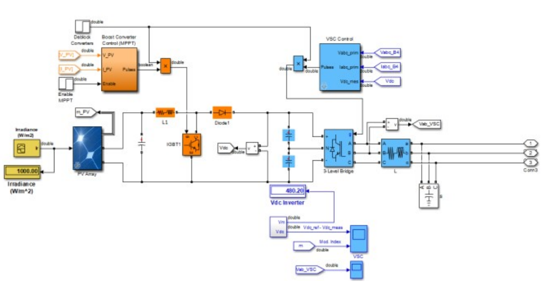

Figure 3. PV array based generator in the Microgrid

5.2. I-V and P-V Charateristics of PV Array

The I-V characteristic of a PV array is the relation between the array's voltage-current under its current irradiance conditions. The curve gives the essential information needed to set the PV system so that it may be operated in a manner that is relatively near to its ideal peak power point.

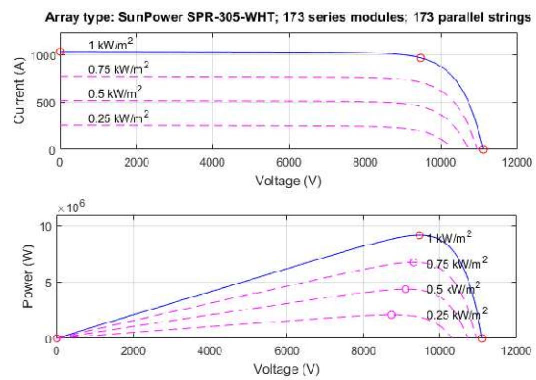

Figure 4. P-V and I-V behaviour of PV array

The I-V and P-V characteristics of the PV array (Sun Power SPR 305-WHT consisting of 173 series modules and 173 Parallel strings) that was taken into consideration for this investigation are shown in Figure 4. Using these properties, one is able to calculate the value of the current, the voltage, and the maximum power point (MPP) for each of the various irradiance levels.

Table1: Power, voltage, and current at various irradiance levels compared. Table 1 compares MPP for various irrdiance levels. The aforementioned numbers were generated from the P-V and I-V characteristics of the SPR 305-WHT array studied.

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

6. RESULT ANALYSIS

Several different fault instances have been illustrated in the figures provided below in order to study the varied behaviour of three-phase faults (LG, LL, LLG, LLL, and LLLG) that are taken into consideration by the suggested protection method.

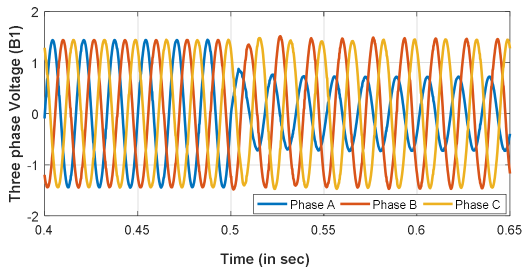

Figure 5: Voltage in the three phases measured at Bus B1 (in pu) during the GC mode because of an A-G fault

Figure 6 shows the B1 bus voltage waveform caused by the phase A to ground (A-G) failure in the microgrid system when it was linked to the utility grid. After the fault, voltage fluctuates at 0.5 seconds.

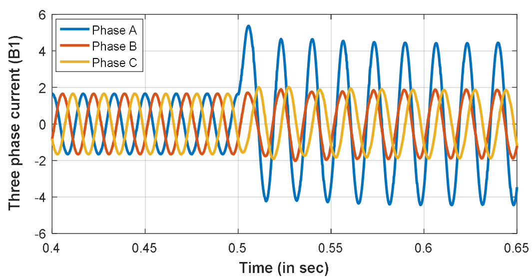

Figure 6: A-G failure at Bus B1 (in pu) during grid-connected mode

The wavelet process extracts important information from current and voltage signals generated by a phase-to-ground failure when the system was operating in Grid connected mode and island mode. This information is then put to use in the training of a bagged decision tree, which is utilised for categorising the many kinds of errors that might arise in a system. An large data set is created as part of the research that has been suggested in order to educate and evaluate the data-mining model that makes use of bagged trees in order to construct a reliable and dependable classifier. The Bagging tree module undergo training For instance, in a data set with a combination of 70–30, 70% of the data are considered for training, while 30% of the data are considered for testing purposes.

Table 2 contains the results of a comparative evaluation that was carried out using Support Vector Machine (SVM) and Decision Tree (DT) classifiers. The purpose of this evaluation was to determine how well the proposed Ensemble-based classifier performed in comparison to other classifiers. The fact that the suggested Ensemble-based classifier was able to obtain a higher classification accuracy than the SVM and DT-based classifiers is undeniable evidence of the usefulness of the proposed technique in completing the fault detection and classification assignment.

Table 2: Comparison of proposed Ensemble based classifier with other individual classifier

Type of classifier	Number of test cases	Correctly predicted Test cases	Classification Accuracy
Ensemble of Decision Trees	550	544	98.90%
Support Vector Machine (SVM)	550	488	88.72%
Decision Tree (DT)	550	497	90.36%

7. CONCLUSION AND FUTURE WORK

This research studies and simulates a PV-based, utility-grid-connected microgrid. Quickly detecting and classifying microgrid issues is crucial for implementing an effective protection strategy. Wavelet transform is suggested for the protection strategy. It's used to extract information from fault current and voltage waveforms. This information is used to train Ensemble decision trees for identifying microgrid issues. Ensemble of decision tree is a data mining approach used in decision making. Once the defect is reliably recognised, an appropriate protection mechanism can assure the system's optimum and safe operation.

The suggested methodology of defect detection, categorization, and subsequent analysis in this study suggests that created procedures are extremely competent and practical, although some improvements may be done.

1. The study's microgrid exclusively includes PV panels. Microgrids with fuel cells, wind turbines, etc. may be studied further.

2. Wavelet transform employs recursion for data mining. Tracking patterns, Classification, Association, Clustering, etc. may be used to extract information from system failure data.

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] L. Solankee, A. Rai and M. Kirar, "An Intelligent Fault Diagnosis Scheme For PV Array Using Machine Learning Techniques," 2021 IEEE 2nd International Conference On Electrical Power and Energy Systems (ICEPES), 2021, pp. 1-5, doi: 10.1109/ICEPES52894.2021.9699839.

[4] Shazia Baloch 1 , Saeed Zaman Jamali 2 , Khawaja Khalid Mehmood 3 , Syed Basit Ali Bukhari 3 , Muhammad Saeed Uz Zaman 1 , Arif Hussain 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.

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

[6] 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.

[7] 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.

[8] 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.

[9] 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.

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

[11] 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.

[12] 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.

[13] 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.

[14] 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.

[15] 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.

[16] 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.

[17] P. Piagi and R. H. Lasseter, "Autonomous control of microgrids," in Proc. IEEE Power Eng. Soc. Gen. Meeting, Montreal, QC, Canada, 2006, p. 8. [17] A. Yazdani and R. Iravani, Voltage-Sourced Converters in Power Systems: Modeling, Control, and Applications. Hoboken, NJ, USA: Wiley, 2010.

[18] Solomon Netsanet 1,*, Jianhua Zhang 1 and DehuaZheng 2, Bagged Decision Trees Based Scheme of Microgrid Protection Using Windowed Fast Fourier and Wavelet Transforms, : 3 May 2018.

[19] Zamani, M.; Sidhu, T.; Yazdani, A. A protection strategy and microprocessor-based relay for low-voltage microgrids. IEEE Trans. Power Deliv. 2011, 26, 1873–1883. [CrossRef]

[20] Coffele, F.; Booth, C.; Dy´sko, A. An adaptive overcurrent protection scheme for distribution networks. IEEE Trans. Power Deliv. 2015, 30, 561–568. [CrossRef]

[21] Shen, S.; Lin, D.; Wang, H.; Hu, P.; Jiang, K.; Lin, D. An adaptive protection scheme for distribution systems with DGs based on optimized Thevenin equivalent parameters estimation. IEEE Trans. Power Deliv. 2017, 32, 411–419. [CrossRef]

Conflict of Interest Statement: *The authors declare that there is no conflict of interest regarding the publication of this paper.*