RESEARCH ARTICLE OPEN ACCESS

Recognition and Power Quality Estimation in Distribution Network in the Presence of Wind Generation: A Review

Himanshu Upadhyay [1], Dr. Bharat Bhushan Jain [2], Gori Shankar [3]

[1] M.Tech Student, Department of Electrical Engineering, Jaipur Engineering College,
[2] Professor, Department of Electrical Engineering, Jaipur Engineering College,
[3] Assistant Professor, Department of Electronics & Communication, Jaipur Engineering College,
Jaipur, Rajasthan - India.

ABSTRACT

Faults on transmission and distribution lines impair the performance of a power grid network, causing interruptions in power supply and, in some cases, blackouts. Faster maintenance and reconstruction of power supply was aided by fast identification of faults and precise estimate of fault position, resulting in increased economy and power supply reliability. Distributed generation (DG) has recently appeared as one of the most important events in the electricity industry's power network. The behaviour of the power grid is altered by DG units in distributed networks, and these units have various effects on the system, each of which can be studied independently. One of the most significant effects of these units is on distributed network security. Since the number of DG units can be changed and their broad distribution is high, the behaviour of defensive equipment has changed as these units are introduced into distribution networks. This paper is related to comparative study of fault detection using various transformation methods.

Keywords: -Distribution network; Hilbert transform; power quality; Solar energy; Stockwell transform; Rule based decision tree; wind energy.

I. INTRODUCTION

Faults are unavoidable in modern manufacturing processes, and they may degrade device efficiency or even cause disasters. External disruptions, component wear, and signal changes, among other things, can cause faults [1]. The location of faults on overhead power transmission lines is also a hot topic that has been researched extensively over the years. The detection of the time cause of faults, as well as the discovery and location of the incident that happened in these systems, are all part of fault diagnosis in power systems. For the detection and recognition of power system faults, various signal processing methods such as wavelet transform (WT), neural networks, and fuzzy logic have been extensively used [2]. [3] reports comprehensive survey of the intelligent systems application of fault diagnosis of electric power grid transmission lines in the sense of fault detection in electric power systems. The authors suggest a basic alternate fault position algorithm for multi-terminal transmission lines using synchronized measurements in [4]. Until calculating the fault position, the built data synchronisation protocol is used to locate the faulted step. The fault position algorithm is unaffected by differences in fault resistance and source impedance. Both major fault forms and various high fault resistances have been thoroughly checked with the proposed faulted phase detection and location algorithm. The findings indicate that the proposed multi-terminal fault position algorithm is fast, precise, and resistant to power system transients. The authors of [5] suggested a method for detecting, classifying, and locating faults on transmission lines using wavelet transforms. The sampling of voltage and current signals at both ends of the transmission line is synchronised using a Global Positioning System clock. To measure fault indices, the information coefficients of current signals from both ends are used. To detect and identify faults, these fault indexes are compared to threshold values. To find the fault, Artificial Neural Networks are used, which use approximate decompositions of the voltages and currents at the local end. Most of the most important developments in the electricity industry and power network in recent years is distributed generation (DG). The behaviour of the system is modified by DG units in distributed networks, and these units have various effects on the system, which each of them will examine independently. One of the most significant effects of these units is on distributed network security. Since the number of DG units can be changed and their broad deployment is high, the behaviour of defensive equipment has changed as these units are introduced into distribution networks [6].

A. Faults in Power Systems

The faults in the power system are undesirable events which may lead to tripping of these lines resulting in the interruption in the power supply in the large area. These may be symmetrical and unsymmetrical. In the event of symmetrical faults the voltage and current parameters of all the three phases are affected equally. However, in the case of unsymmetrical faults degree of changes in the pre-masters of all the three phases are different. Those faults on power system which give rise to unsymmetrical fault currents are known as unsymmetrical faults. On the occurrence of an unsymmetrical fault, the currents in the three lines become unequal and so is the phase displacement among them. However, the system impedances and the source voltage are always symmetrical through its main elements viz. Generator, transmission lines, synchronous reactance etc there are three ways in which unsymmetrical faults may occur in a power system.

1. Phase to.Ground fault (SLG)
2. Double line fault (DLL)
3. Double line to ground fault (DLLG)

The symmetrical faults include the three-phase fault (LLL) and if the ground is involved it is known as three phase fault involving ground (LLLG).

II. LITERATURE REVIEW

Jingzhou Cheng et. al. [8] uses the transmission line, which transfers power between two ends, the Ultra High Voltage DC Transmission Line (UHVDC) which together form a complex network. Various types of compensations, such as series and shunt, have also been provided in the transmission lines to improve the power transfer capacity. These compensations in a transmission line increase the system's transient stability and voltage profile, as well as its power transfer capability. The safety scheme, however, faces some additional issues as a result of the inclusion of the compensation circuit in the defective circuit. These include decay DC current, sub synchronous frequency components, non-fundamental decaying components, odd-harmonic components, high-frequency components, and fundamental steady-state coherence in the voltage and current signals. For the purpose of relaying and safety, various time frequency techniques have been used to identify faults in transmission lines.

Bhargav Vyas et. al. [9] implemented the discrete wavelet transform (DWT) for a variety of protection of power system components, including the differential energy dependent method for differential protection of transmission lines, among the various time-frequency techniques. Although the wavelet provides a variable window for frequency and low components in the currents and voltages during faults. Under noisy conditions, however, special minimum techniques are needed. In addition, the wavelet transform splits the power signal into a description and an approximation coefficients frequently until the desired degree of decomposition is achieved using high pass and low pass filters. It can fail in cases where some information belongs to the higher frequencies regions because it only dissolves the signal approximations.

M.H. Naeem et. al. [10] showcase a complex collection of measurements, the precise amplitude, instantaneous phase, or frequency of the fundamental components required for safety cannot be obtained easily. Due to its superior properties of locating the time-frequency elements, describes a novel method for identifying, classifying, and identifying short-circuit faults in power transmission systems.

Hassan Fathabadi [11], presented a hybrid architecture based on the proposed approach is implemented in Proteus 6/MATLAB environments, consisting of a two-stage finite impulse response (FIR) filter, eleven support vector regressions (SVRs) and four support vector machines (SVMs). Short-circuit faults are detected and classified using the proposed two-stage FIR filter and SVMs, while short-circuit faults are located using SVRs. For training the SVMs and SVRs, the implemented system only needs a few training samples. As will be shown, only 6 training data are needed to train each SVR for a 50 km power transmission line.

Ebha Koley et. al.[12] proposed a low-cost, fast, and reliable microcontroller-based protection scheme based on wavelet transform and artificial neural network in, and its effectiveness was evaluated in real time. The proposed scheme, which is based on a hardware co-simulation approach, performs all fault detection/classification, fault zone/section recognition, and position estimation functions for transmission lines. The fundamental frequency current variable is used to estimate a fault index in the fault detection/classification and zone identification algorithms. The wavelet transform coefficients are combined with a parallel artificial neural network structure in the fault position estimation module.

The application of wavelet transforms for the identification, classification, and position of faults on transmission lines was proposed by Shaik et al. [13]. A GPS clock has been used to synchronise sampling both voltage and current signals at both ends of the transmission line in the proposed technique. To measure fault indices, the details parameters of current signals from both ends are used. To detect and identify faults, these fault indices are compared to threshold values.

To locate the fault, Artificial Neural Networks are used, which use estimated decompositions of the voltages and currents at the local end. The algorithm has been successfully validated for various locations and types of transmission line faults. Zarbita et.al. [14] proposed a research project aimed at developing a precise real-time system for fault detection and identification of High Voltage Class-B transmission lines. Distance safety relays with minimum impedance mounted in the electrical network obtain the voltage and current of oscillographic documents. The proposed method evaluates the Detail Spectrum Energy measured from the Discrete Wavelet Transform (DWT) applied to current phases by shifting data windows of one cycle of the fundamental power frequency. The fault detection algorithm is processed at first scale, with the sharp variation of DSE superimposed.in the fault current signal phases and ground. For the detection of transmission line faults, this method has been found to be reliable.

Dehghani et al. [16] Centered on a combination of wavelet singular entropy and fuzzy logic, authors proposed a method of fault detection and identification in asymmetrical distribution networks with distributed generation to detect islanding and perform protective action. The proposed method adjusts comprehensive parameters of wavelet transforms and singular value matrices using the positive components of currents at common reference points, and predicted entropy values are determined using a stochastic process. To detect and classify the fault, indexes are defined based on wavelet singular entropy in positive components and three phase currents. The proposed safety scheme is put forward for fault identification and is examined in various types of faults in distribution lines in the presence of distributed generations, such as single-phase to ground, double-phase to ground, three-phase to ground, and line to line, and different positions of faults are tested when the distributed generation is linked to the utility.

Cruz et al. [17] Proposed a technique for fault position based on the concept of state estimation in order to more precisely calculate the location of faults by taking into account practical systematic errors that might exist in voltage and current measurements. The variance associated with the distance found is also calculated using the errors principle in this technique, in addition to calculating the most probably fault distance obtained from measurement errors. The obtained results reveal that the proposed calculation method works even though practical variances are used.

Using fault transients, Zhengyou He et al. [18] proposed a novel technique for fault classification and detection in extremely high-voltage transmission lines. Wavelet singular entropy (WSE) is a new technique that combines the benefits of the wavelet transform, singular value decomposition, and Shannon entropy. WSE is resistant to fault transient noise and is unaffected by transient magnitude, allowing it to be used to automatically extract features from fault transients and articulate fault features intuitively and quantitatively both in high-noise and low-magnitude fault transients.

Ray et.al. [21] looked into a long transmission line's fault form and distance estimation scheme using a support vector machine. The proposed technique employs a post-fault single-cycle current waveform, with wavelet packet transform used to pre-process the samples. The decomposed coefficients are used to calculate energy and entropy, and a feature matrix is formed. The forward feature selection approach is then used to remove the redundant features from the matrix, which is then normalised. Test and training data are generated by considering variables such as fault form, resistance direction, inception angle, and distance in a simulation scenario.

Using wavelet transform (WT) and linear discriminate analysis, Yadav et al. [22] proposed a fault detection and classification scheme for transmission line safety (LDA). Faulty phases are detected and identified using current signals from each phase, while ground is detected using zero sequence currents. Discrete wavelet transform with daubechies wavelet db-4 is used to process current signals up to level 3. Wavelet reconstruction is used to reconstruct approximate coefficients. Variations in parameters such as fault type, position, fault resistance, fault inception angle, and power flow angle are used to evaluate the proposed scheme's performance.

Fathabadi et al. [23] defined two methods for detecting short-circuit faults in power transmission lines. Both theoretically and technically, the two approaches proposed are entirely new. The first process employs a discrete wavelet transform with Daubechies mother wavelets db1, db2, db3, and db4 for soft computing. The second method is a hardware-based method that employs a newly proposed two-stage finite impulse response filter with a sampling frequency of 32 kHz and a processing time of three samples. Theoretical findings are presented to compare and contrast the two methods. The theoretical findings are validated by simulated results obtained by simulating a three-phase 230 kV, 50 Hz power transmission line, which clearly verify that the filter-based approach has an accuracy of 100 percent in the presence of 10% disturbance, while the wavelet transform-based approach has an accuracy of 97 percent, but it is less complicated and easier to implement.

Qiu Qin et al. [24], the authors justified and implemented a multiple model filtering method for diagnosing three-phase short to ground faults on transmission lines in the presence of defence mis-operations. The electric network dynamics and wide-area measurements are used in this approach to provide diagnosis results.

Zin et al. [25] describes a new fault detection and classification algorithm based on Clarke's transformation on parallel transmission that uses the discrete wavelet transform (DWT) and a back-propagation neural network (BPNN). Clarke's transformation produced alpha and beta (mode) currents, which were used to convert the signal of a discrete wavelet transform (DWT) into wavelet based coefficients (WTC) and wavelet energy coefficients (WEC) (WEC). To disintegrate the high frequency components of the signal malfunction, Daubechies4 (Db4) was used as a wavelet function.

Roy et al. [26] describes a software reliability allocation scheme for evaluating the performance of a multi-functional, multi-user digital relay that detects, classifies, and locates transmission line faults.

R. Aguilar et al. [27] defined a transmission line protection scheme that included two types of protection: directional zone and fault classification. For determining the fault path, the faulted line, and the fault type, the proposed scheme needs no information from remote ends and relies solely on current measurements from one phase of three-phase systems. The high-frequency components of transient current signals are extracted using a discrete wavelet transform (DWT) and an adaptive wavelet as an analysis filter, which has been explicitly developed for relaying purposes. Following that, Bayesian linear discriminant analysis is used to classify the data.

The author Gomes [28] proposed a new model for functionally describing the phases of a transmission line. The parameters of the model were examined, and the identification and classification methodology was put to the test using a database of real faults and simulated faults. The results show that using a vastly simplified mathematical method, the proposed model can correctly discern faults and detect them quickly.

Jiang et al. [29] proposed a novel hybrid framework for detecting and locating power transmission line faults quickly. As faults occur in the power transmission system, the proposed algorithm uses three-phase voltage and current waveforms to provide fault discrimination approach. Negative-sequence components of three-phase voltage and current quantities are used to achieve fast online fault detection. The fault detection method then triggers the fault identification and fault location methods.

Based on oscillo graphic results, Silva et al. [30] proposed a novel technique for identifying and classifying transmission line faults. To evaluate fault detection and clearing time, a set of rules derived from current waveform analysis in the time and wavelet domains is used. The method will differentiate faults from other power system disturbances such as voltage sags and oscillating transients, all of which are common in power systems.

The various aspects of power system faults have been mentioned in the literature explained by Naeem et al. [31]. A pattern recognition method for current differential relaying of power transmission lines was proposed by M. R. Noori et al. [32].

The expansion in worldwide energy request and increment consideration regarding natural issues has prompted the investigation of renewable energy sources, for example, solar and wind [33].

In the recent years wind energy (WE) integration to utility grids is increasing rapidly, hence there is a need to design effective approaches for identification of PQ issues and identification of events in the presence of high level of WE in DN [34].

Renewable is now established around the world as main- stream sources of energy. Rapid growth, particularly in the power sector, is driven by several factors, including the improving cost-competitiveness of renewable technologies, growing demand for energy in developing and emerging economies, and the need for access to modern energy [35].

An extended form of CWT is known as ST which was developed by R.G. Stockwell. Both the spectrum i.e. amplitude and phase provide the information in this transform.

The rule-based decision tree (RBDT) was introduced by the Breiman in 1980 and applied in the field of power system by the Wehenkel in 1989. In this technique, decision supported rules are used for classification of PQ disturbances to predict the data responses.

III. STOCKWELL TRANSFORM METHOD

The Stockwell transform is a hybrid of the short time Fourier transform and the wavelets (WT), but it belongs to a different family of transforms. In 1996, R. G. Stockwell was the first to suggest this method. This method analyses multi-resolution signals with disturbances while keeping the phase of the each frequency variable in the signal. The frequency of this technique is proportional to the length of the window used. As a result, obtain higher time resolution at higher frequencies while also providing higher frequency resolution at low frequency is extremely beneficial.

The short time Fourier Transform of a signal h is defined by the following relationship (t).

$$STFT(\tau, f) = \int_{-\infty}^{+\infty} h(t) g(\tau - t) e^{-j2\pi f t} dt \tag{4.1}$$

Where spectral localization time and Fourier frequency are denoted by τ and f, respectively, and g(t) is a window function. The S transform can be derived from the above equation by substituting the Gaussian function for the window function g(t).

$$g(t) = \frac{|f|}{\sqrt{2\pi}} e^{-\frac{f^2 t^2}{2}} \tag{4.2}$$

& S-Transform is defined as:

$$S(\tau, f) = \int_{-\infty}^{+\infty} h(t) \frac{|f|}{\sqrt{2\pi}} e^{\frac{f^2(\tau - t)^2}{2}} e^{-j2\pi f t} dt \tag{4.3}$$

The S transform is thus a variant of the STFT with a Gaussian window function. If the time domain window of the S-transform is larger, it can provide higher frequency resolution for lower frequencies. Even though the window is smaller, it can provide better time resolution for higher frequencies. The S-transform produces an S-matrix, which is a matrix. The S-matrix can be used to extract knowledge about the signal's frequency and amplitude.

IV. CONCLUSIONS

To detect power system faults, an algorithm based on the median calculated from the S-matrix can be obtained by decomposition of current signal using Stockwell transform. The suggested algorithm is built on the use of threshold values to detect faults. The threshold values can be determined by putting the algorithm through its paces on a 30-fault data set. In this review paper we have concluded that Stockwell method is one of the best methods to detect different types of faults such as symmetrical and unsymmetrical faults in distribution as well as transmission system.

V. FUTURE WORK

In the presence of solar power generation, the Stockwell method can be tested for detecting power system faults. This approach can also be tested in a hybrid power system that combines different forms of renewable energy sources, such as wind power, solar power, and fuel cell generation, all at the same time. In the presence of renewable sources in the utility network, the other features measured from the S-matrix can also be used to detect power system faults.

REFERENCES

[1] LIU Yang, HE Xiao, WANG Zidong, and ZHOU Dong-Hua, "Fault Detection and Diagnosis for a Class of Nonlinear Systems with Decentralized Event-triggered Transmissions," IFAC-Papers On Line (Elsevier), pp. 1134–1139, 2015.

[2] Ch. Durga Prasad, N. Srinivasu, "Fault Detection in Transmission Lines using Instantaneous Power with ED based Fault Index," Proceedia Technology, Vol. 21, pp. 132 – 138, 2015.

[3] Dr. Bharat Bhushan Jain, shradha Agarwa and Gori Shankar, "Numerical Simulation of Fuzzy Logic Based Maximum Power Point Tracking System for Solar Photovoltaic System", International Journal of Advanced Science and Technology, Vol. 29, No. 4, pp. 9516 – 9525, 2020. ISSN: 2005-4238.

[4] Shoaib Hussain, A.H. Osman, "Fault location scheme for multi-terminal transmission lines using unsynchronized measurements," International Journal of Electrical Power and Energy Systems, Vol. 78, pp. 277–284, 2016.

[5] Abdul Gafoor Shaik, Ramana Rao V. Pulipaka, "A new wavelet based fault detection, classification and location in transmission lines," International Journal of Electrical Power and Energy Systems, Vol. 64, pp. 35–40, 2015.

[6] Moslem Dehghani, Mohammad Hassan Khooban, Taher Niknam, "Fast fault detection and classification based on a combination of wavelet singular entropy theory and fuzzy logic in distribution lines in the presence of distributed generations," International Journal of Electrical Power and Energy Systems, Vol. 78, pp. 455–462, 2016.

[7] Aleena Swetapadma, Anamika Yadav, "Directional relaying using support vector machine for double circuit transmission lines including cross-country and inter-circuit faults," International Journal of Electrical Power and Energy Systems, Vol 81, pp. 254–264, 2016.

[8] Jingzhou Cheng, Minyuan Guan, LV Tang, Hongyang Huang, "A fault location criterion for MTDC transmission lines using transient current characteristics," International Journal of Electrical Power and Energy Systems, Vol. 61, pp. 647–655, 2014.

[9] Bhargav Vyas, Biswarup Das, Rudra Prakash Maheshwari, "An improved scheme for identifying fault zone in a series compensated transmission line using un-decimated wavelet transform and Chebyshev Neural Network," International Journal of Electrical Power and Energy Systems, Vol. 63, pp. 760–768, 2014.

[10] K.R. Krishnanand, P.K. Dash, M.H. Naeem, "Detection, classification, and location of faults in power transmission lines," International Journal of Electrical Power and Energy Systems, Vol. 67, pp. 76–86, 2015.

[11] Hassan Fathabadi, "Novel filter based ANN approach for short-circuit faults detection, classification and location in power transmission lines," International Journal of Electrical Power and Energy Systems, Vol. 74, pp. 374–383, 2016.

[12] Ebha Koley, Raunak Kumar, Subhojit Ghosh, "Low cost microcontroller based fault detector, classifier, zone identifier and locator for transmission lines using wavelet transform and artificial neural network: A hardware co-simulation approach," International Journal of Electrical Power and Energy Systems, Vol. 81, pp. 346–360, 2016.

[13] Abdul Gafoor Shaik, Ramana Rao V. Pulipaka, "A new wavelet based fault detection, classification and location in transmission lines," International Journal of Electrical Power and Energy Systems, Vol. 64, pp. 35–40, 2015.

[14] S. Zarbita, A. Lachouri, H. Boukadoum, "A new approach of fast fault detection in HV-B transmission lines based on Detail Spectrum Energy analysis using oscillographic data," International Journal of Electrical Power and Energy Systems, Vol. 73, pp. 568–575, 2015.

[15] Shoaib Hussain, A.H. Osman, "Fault location scheme for multi-terminal transmission lines using unsynchronized measurements," International Journal of Electrical Power and Energy Systems, Vol. 78, pp. 277–284, 2016.

[16] Moslem Dehghani, Mohammad Hassan Khooban, Taher Niknam, "Fast fault

detection and classification based on a combination of wavelet singular entropy theory and fuzzy logic in distribution lines in the presence of distributed generations," International Journal of Electrical Power and Energy Systems, Vol. 78, pp. 455–462, 2016.

[17] Melinda C.S. da Cruz, Marcos A.D. de Almeida, Manoel F. de Medeiros Júnior, "A state estimation approach for fault location in transmission lines considering data acquisition errors and non-synchronized records," International Journal of Electrical Power and Energy Systems, Vol. 78, pp. 663–671, 2016.

[18] Zhengyou He, Ling Fu, Sheng Lin, and Zhiqian Bo, "Fault Detection and Classification in EHV Transmission Line Based on Wavelet Singular Entropy," IEEE Transactions on Power Delivery, Vol. 25, No. 4, pp. 2156-2163, 2010.

[19] Pathirikkat Gopakumar, Maddikara Jaya Bharata Reddy, Dusmanta Kumar Mohanta, "Transmission line fault detection and localisation methodology using PMU Measurements," IET Generation Transmission and Distribution, Vol. 9, Iss. 11, pp. 1033–1042, 2015.

[20] Chul-Hwan Kim, Hyun Kim, Young-Hun Ko, Sung-Hyun Byun, Raj K. Aggarwal, and Allan T. Johns, "A Novel Fault-Detection Technique of High-Impedance Arcing Faults in Transmission Lines Using the Wavelet Transform," IEEE Transactions on Power Delivery, Vol 17, No. 4, pp. 921-929, 2002.

[21] Papia Ray, Debani Prasad Mishra, "Support vector machine based fault classification and location of a long transmission line," Engineering Science and Technology, an International Journal, 2016.

[22] Anamika Yadav, Aleena Swetapadma, "A novel transmission line relaying scheme for fault detection and classification using wavelet transform and linear discriminate analysis," Ain Shams Engineering Journal, Vol 6, pp. 199–209, 2015.

[23] Hassan Fathabadi, "Two novel proposed discrete wavelet transform and filter based approaches for short-circuit faults detection in power transmission lines," Applied Soft Computing, Vol.36, pp.375–382, 2015.

[24] Qiu Qin, N. Eva Wu, "A multiple model filtering approach to transmission line fault diagnosis," Control Engineering Practice, Vol. 52, pp. 93–102, 2016.

[25] Abdullah Asuhaimi Mohd Zin, Makmur Saini, Mohd Wazir Mustafa, Ahmad Rizal Sultan, Rahimuddin, "New algorithm for detection and fault classification on parallel transmission line using DWT and BPNN based on Clarke's transformation," Neurocomputing, Vol. 168, pp. 983–993, 2016.

[26] D.S. Roy, D.K. Mohanta, A.K. Panda, "Software reliability allocation of digital relay for transmission line protection using a combined system hierarchy and fault tree approach," IET Software, Vol. 2, No. 5, pp. 437–445, 2008.

[27] F.E. Pe´ rez, R. Aguilar, E. Ordun˜ a, J. Ja¨ ger, G. Guidi, "High-speed non-unit transmission line protection using single-phase measurements and an adaptive wavelet: zone detection and fault classification," IET Generation, Transmission & Distribution, Vol. 6, Iss. 7, pp. 593–604, 2012.

[28] André de Souza Gomes, Marcelo Azevedo Costa, Thomaz Giovani Akar de Faria, and Walmir Matos Caminhas, "Detection and Classification of Faults in PowerTransmission Lines Using Functional Analysis and Computational Intelligence," IEEE Transactions on Power Delivery, Vol. 28, No. 3, pp. 1402-1413, July 2013.

[29] Joe-Air Jiang, Cheng-Long Chuang, Yung-Chung Wang, Chih-Hung Hung, Jiing-Yi Wang, Chien-Hsing Lee, and Ying-Tung Hsiao, "A Hybrid Framework for Fault Detection, Classification, and Location—Part I: Concept, Structure, and Methodology," IEEE Transactions on Power Delivery, Vol. 26, No. 3, pp. 1988-1998, July 2011.

[30] K. M. Silva, B. A. Souza, and N. S. D. Brito, "Fault Detection and Classification in Transmission Lines Based on Wavelet Transform and ANN," IEEE Transactions on Power Delivery, Vol. 21, No. 4, pp. 2058-2063, October 2006.

[31] Anjali, Raj Kumar Kaushik and Deepak Sharma, "Analyzing the Effect of Partial Shading on Performance of Grid Connected Solar PV System," 2018 3rd International Conference and Workshops on Recent Advances and Innovations in Engineering (ICRAIE), 2018, pp. 1-4.

[32] Rajkumar Kaushik, Om Prakash Mahela, Pramod Kumar Bhatt, "Hybrid Algorithm for Detection of Events and Power Quality Disturbances Associated with Distribution Network in the Presence of Wind Energy," 2021 International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE), 2021, pp. 415-420.

[33] Rajkumar Kaushik, Alok Kumar Singh and Jitendra Sharma "Study & Analysis of

Incremental Conductance Method of Maximum Power Point Tracking System" published in International Journal of Engineering Research and Generic Science (IJERGS),Volume -3, Issue-1, January – February 2017, Page No. 26 – 33.

[34] Rajkumar Kaushik, Om Prakash Mahela, Pramod Kumar Bhatt, Baseem Khan, Akhil Ranjan Garg, Hassan Haes Alhelou and Pierluigi Siano "Recognition of Islanding and Operational Events in Power System With Renewable Energy Penetration Using a Stockwell Transform-Based Method," in IEEE Systems Journal.

[35] Rajkumar Kaushik, Om Prakash Mahela, Pramod Kumar Bhatt, Baseem Khan, Sanjeevikumar Padmanaban and Frede Blaabjerg "A Hybrid Algorithm for Recognition of Power Quality Disturbances," in IEEE Access, vol. 8, pp. 229184-229200, 2020.