SESB'S 275 KV TRANSMISSION LINE FAULT CLASSIFICATION USING WAVELET-BASED NEURAL NETWORKS

NORAZLINA @ NORA BT ABDUL RASID

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical Power)

School of Electrical Engineering
Faculty of Engineering
Universiti Teknologi Malaysia

FEBRUARY 2022

DEDICATION

This thesis is dedicated to my father, who taught me that the best kind of knowledge to have is that which is learned for its own sake. It is also dedicated to my mother, who taught me that even the largest task can be accomplished if it is done one step at a time.

ACKNOWLEDGEMENT

Bismillahirrahmanirrahim. Thank you, Allah, for giving me the strength and *hidayah* for me to come out with this proposal report thesis of Final Year Project. I would like to express my sincere gratitude to my project supervisor Dr. Mohd. Hafiz Habibuddin who giving me the opportunity to proceed with this topic and guided me to complete the proposal throughout the semester. To my beloved husband, Mohd Haizal Bin Mohd Nazri Juanis who inspired me to pursue my master degree, his invaluable sacrifice and support always be the anchor whenever I was down. Biggest love and thank you to my mom, my parents in law and my sister Lina Rashid who are always there for me. My cherished friend; Zarinah Amri Aliaman, Linda Simon and Tracy Gualin who had helped me a lot along the journey to complete Master Degree, fellow classmates and colleagues who have helped, advice and provide useful tips at various occasions.

ABSTRACT

Fault in transmission lines might risks and contributes to the biggest impacts on power system security. Hence, early fault diagnosis is a prominent area of investigation in power utility with relevant intelligent system applications. The recent infrastructure for fault and event monitoring in transmission power systems using Disturbance Fault Recorders (DFR) becomes a common practice as it provides a high amount of data not only for grid operator for normalization purposes but beneficial to scholars in extending their progress research on fault classification studies. DFR is proven reliable in observability, but the large amounts of data and waveform may time consuming for the engineers to analyse the details. Therefore, there is a need to classify type of fault occurrence as both current and voltage waveforms contain significant high frequency transient signals during disturbance. Many studies revealed a lot of techniques and hybrid approaches for fault detection and classification. Though, among the various techniques reported, a combination of wavelet-based and neural networks techniques has been proven as the best approach to determine the correct fault type and classification with the approximation of 91% of accuracy. The objective of this study is to perform fault identification by using Discrete Wavelet Transform (DWT) module to extract feature of the transient signal and gain wavelet coefficient. The obtained data will be classified using Artificial Neural Networks (ANN) architecture by categorizing the types of fault based on details wavelet analysis. The feasibility of Discrete Wavelet Transform and Artificial Neural Network algorithm is tested on SESB's 275kV overhead transmission line using MATLAB software. The said techniques are simple and accurate in fault detection and classification. The algorithm produces good results in simulations, indicating that it will be highly beneficial in the future operational of power system.

ABSTRAK

Kerosakan pada talian penghantaran mungkin berisiko dan boleh menyumbang kepada impak terbesar terhadap kestabilan bekalan elektrik. Oleh itu, diagnosis awal ke atas jenis kerosakan adalah sangat penting dalam utiliti bekalan elektrik yang dilengkapi dengan sistem aplikasi pintar yang berkaitan. Pepasangan insfrastuktur Alat Perakam Gangguan atau *Disturbance Fault Recorder* (DFR) merupakan keperluan terkini untuk memantau dan merekodkan setiap data kerosakan terutama sekali dalam sistem penghantaran. Dengan rekod jumlah data yang banyak, ianya bukan sahaja berguna kepada pengendali grid untuk melaksanakan proses normalisasi malah bermanfaat kepada penyelidik dalam meneruskan kajian berkaitan klasifikasi jenis gangguan. DFR terbukti boleh dipercayai dalam pemantauan sistem grid, walaubagaimanapun, jumlah data dan gelombang yang banyak mungkin memakan masa bagi seseorang jurutera untuk menganalisis setiap butiran rekod gangguan.Oleh itu, adalah penting untuk mengklasifikasikan jenis kerosakan kerana kedua-dua bentuk gelombang arus dan voltan mengandungi tenaga isyarat frekuensi tinggi semasa gangguan. Terdapat banyak kajian menunjukkan pelbagai jenis teknik dan pendekatan hibrid yang sesuai untuk mengesan dan mengklasifikasi jenis kerosakan. Walaubagaimanapun, di antara kepelbagaian teknik yang dilaporkan, gabungan algoritma berasaskan wavelet dan neural networks telah terbukti di antara pendekatan yang terbaik dalam menentukan jenis kerosakan yang betul dan jitu dengan anggaran ketepatan sebanyak 91%. Objektif kajian ini adalah untuk mengenalpasti jenis kerosakan menggunakan modul *Discete Wavelet Transform* (DWT) untuk mengekstrak ciri yang terdapat dalam rekod gelombang gangguan. Data tersebut seterusnya akan dikelaskan menggunakan modul Artificial Neural Networks (ANN) dengan mengkategorikan jenis kerosakan berdasarkan analisis perincian wavelet. Kebolehlaksanaan algoritma DWT dan ANN ini diuji ke atas rekod gangguan yang yang terdapat pada talian penghantaran atas 275kV Sabah Electricity Sdn Bhd (SESB) dengan menggunakan perisian MATLAB. Teknik tersebut adalah mudah dan tepat dalam pengesanan dan pengelasan kerosakan gangguan. Algoritma ini menghasilkan keputusan yang baik dalam simulasi, menunjukkan bahawa ia akan sangat bermanfaat dalam pengoperasian sistem bekalan elektrik pada masa hadapan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANN	-	Artificial Neural Network
DWT	-	Discrete Wavelet Transform
SESB	-	Sabah Electricity Sdn Bhd
M&E	-	Management & Engineering
DFR	-	Disturbance Fault Recorder
OHL	-	Overhead Lines
WT	-	Wavelet Transform
FZ	-	Fuzzy Logic
RMS	-	Root Mean Square
BPNN	-	Back Propagation Neural Networks
I_N	-	Neutral Current
R	-	Red Phase
Y	-	Yellow Phase
B	-	Blue Phase
G	-	Ground

LIST OF SYMBOLS

DWT	-	Discrete Wavelet Transform
m	-	Frequency Domain
n	-	Time Domain
$f(k)$	-	Function of original signals equations
k	-	Original signal equation
Ψ	-	Mother Wavelet
E_w	-	Energy Wavelet
N_w	-	Window length
$d_w(k)$	-	k_{th} wavelet coefficient
N_s	-	Number of samples

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Sabah Electricity Sdn Bhd (SESB) is the only power utility supplying electrical energy to the whole Sabah and Labuan Federal Territory. It is a significant necessity in driving economic development and determines the continuous growth of this North Borneo State in Malaysia.

Thus, it becomes extremely important to attain energy security and reliability by maintaining continuous supply efficiently and effectively.

SESB's network is divided into two main regions namely West Coast Region and East Coast Region. Both regions are interconnected via 275kV Transmission Overhead Lines from 132/275kV Kolopis Substation to 275/132kV Segaliud Substation.

With total dependable capacity of 1275MW in 2017, 85% of them are available in the west as most of the biggest power stations including Independent Power Producers (IPP) in SESB's network are located in West Coast Region.

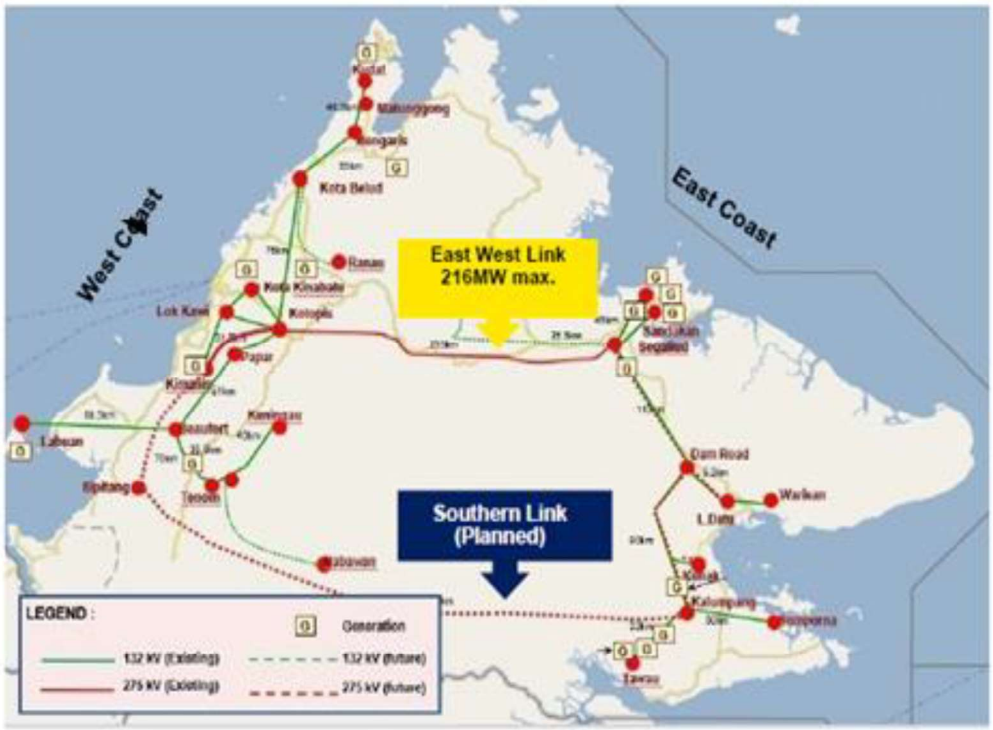

Figure 1.1: SESB Grid System [1]

Due to the network constrains, the risk of major blackout at the east side of Sabah Grid is high if the said interconnections experience breakdown or interrupted due to fault occurrence.

It is undeniably that fault may occur at any time on the transmission overhead lines due to lightning, vegetation and encroachments. Based on SESB's Transmission Overhead Tripping Statistics Report in 2020, four years trending shows that lightning contributes to the highest tripping rates, followed by vegetation and crane encroachment.

All of the tripping occurrences are unbalanced fault type that is single phase to ground fault and double line to ground fault.

Table 1.1: SESB's Transmission Line Root Cause Analysis [2]

TRIPPING STATISTICS

Description	FY2017	SFY2017	CY 2018	CY 2019	CY 2020
Vegetation	6	0	4	2	0
Crane Encroachment	2	0	2	2	1
Lightning	14	8	17	28	11
Total	**22**	**8**	**23**	**32**	**12**

TRIPPING LINE RATE

Description	FY2017	SFY2017	CY 2018	CY 2019	CY 2020
Vegetation	0.21	0.00	0.14	0.07	0.00
Crane Encroachment	0.07	0.00	0.07	0.07	0.03
Lightning	0.75	0.54	1.04	1.13	0.61
Total	1.03	0.54	1.25	1.27	0.64

275kV Kolopis – Segaliud Lines is identified as critical line as it is the main trunk in supplying east sides of Sabah. Prolonged downtime and major outages not only provide significant economic impact on end users but also increase the System Average Interruption Duration Index (**SAIDI**), a designated main performance criterion to measure duration of interruptions and the ability of the system to provide adequate supply back to consumers. Longer restoration time will affect the SAIDI performance.

Since geographical factor is one of the contributions for longer restoration period, SESB had implemented asset assessment and diagnostic initiatives which is proven helpful in maintaining the power supply reliability in the grid system. Disturbance Fault Recorder (DFR) type BEN5000 is a mandatory requirement to be installed at 275kV Transmission Lines for tripping event and fault disturbance recording. Through the fault analysis using DFR, precise fault location and type of fault for overhead line can be detected and this enabling quicker decision by grid operator in normalizing the supply.

Information obtained from the DFR is used to confirm the fault occurrence, determine the fault location, magnitude of short circuit current, system voltage during disturbance, nature type of fault and assess the performance of both protection schemes and circuit breaker operations in isolating the fault. It records all digital and analogue indication captured by protection relays and the sinusoidal three phases of voltage and current waveform during pre-fault, fault interception and post fault conditions for the ease of sequence of events analysis.

DFR also capture any changes or incidents occur on the normal balanced power system condition not only during wide system transient but also during dynamic events including voltage violations, low frequency oscillations or any abnormality exceeds the limitations of voltage and current normal operation according to Sabah and Labuan Grid Code.

The installed DFR is proven helpful in maintaining the power supply reliability in the grid system. However, there could be at least 100 records triggered across the network in a day during normal condition and more than 300 records generated during wide system disturbance.

DFR network topology explained in [3] shows that fault information management system connected through RS232/485 via Ethernet communication which is connected via utility's Wide Area Networks and took about 10 minutes to be sent to Load Dispatch Centre. This large amount of power quality disturbance not only affect traffic on the WAN network for data archiving but also time consuming for the engineer to further analyze the details [3]

The existing DFR was proposed in [4] to have a platform for proper data retrieval according to the latest IEC61850 medium and [5] had proposed web service for automated fault analysis including signal segmentation and analysis, fault classification and fault location services.

In [6] and [7] an automated analysis called Centre Point Energy was introduced. It is a custom web-based system that automatically retrieve and analyze fault events and send pertinent data to utility workers and management through SMS or email. Though, the software must be adjusted in order to accomplish complete classification and analytical automation, which necessitates more data and staff time.

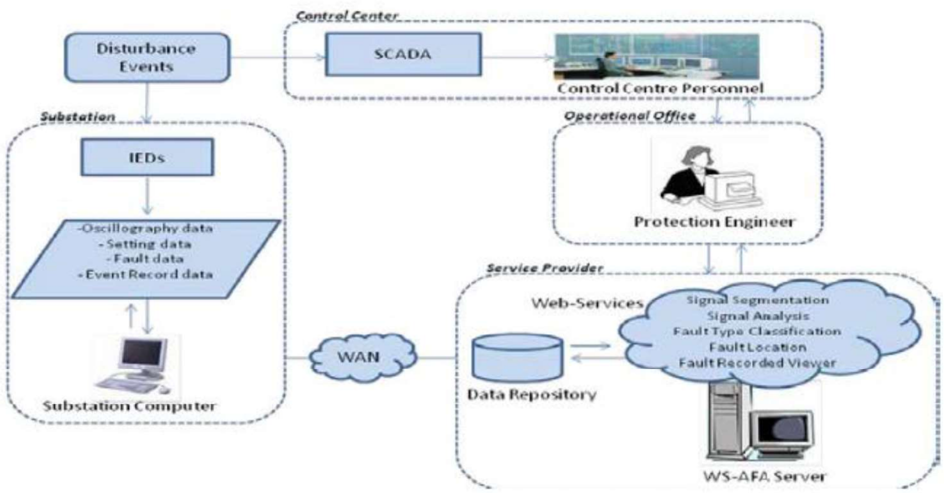

Figure 1.2 : Web Services for Automated Fault Analysis (WSAFA) [6]

Thus, to perform [3] - [7], fault type classification services plays an important role to identify the type of a fault that occurred on a transmission line. This area requires the data from recorded signals, fault inception start and end times and fundamental frequency RMS value. Therefore, it is necessary to perform fault detection and identification based on the retrieved DFR waveform and to keep only relevant data especially fault type information to be distributed to the respective personnel in SESB for their next necessary action.

1.2 Problem Statement

SESB's 275 kV Overhead Line (OHL) equipped with DFR for it provides precise fault location and type of fault on the overhead line which benefits grid operator in restoring the grid supply.

DFR brought a lot of advantages in observability, but the large amounts of data, signals and waveform sometimes makes event analysis difficult be performed by engineers [8]. In [9], the advantages of the disturbance files being automatically sorted and classified is the engineer in charge of studying them would focus on the most critical ones first, taking corrective action as needed. As a result, records that don't need to be analyzed further could be preserved without the requirement for human intervention.

In dealing with computational intelligent analysis, [10] signal processing techniques is required to process analog waveform and evaluate fault occurrence in order to fault detection and feature extraction.

Therefore, it is proposed for additional aided method to be applied in analyzing the existing DFR data in order to provide fast and early information such as fault type to SESB's relevant key personnel for next appropriate action. Fault type information is required for early fault diagnosis and to do this, relevant method is required to extract and classify DFR's waveform which can potentially valuable in the future operational of power system.

Even though there are a lot of methods of pattern recognition are available in the previous research [11], a combination of Discrete Wavelet Transforms (DWT) and Artificial Neural Networks (ANN) techniques has been proven as the best approach to determine the correct fault type and classification with approximation of 90.1% of accuracy. [12] In light of this conclusion, the viability of the proposed algorithm shall be tested using existing SESB's DFR data and verified via MATLAB software.

1.3 Research Objectives

The research work has the following specific objectives:

1. To gather and evaluate 3 years of fault data and disturbance waveform of SESB's DFR at both Kolopis and Segaliud Substations. The recorded data and disturbance waveform will determine the reading of fault current and type of fault.

2. To use Discrete Wavelet Transform (DWT) module for fault identification. DWT will extract feature and gain wavelet coefficient from the obtained waveforms. Waveform with short circuit contains high energy details which is the main feature of fault identification.

3. To utilize Artificial Neural Networks (ANN) algorithm for fault classification by categorizing the types of fault based on details wavelet energy. The neural network schemes shall classify if the specific phase (Red, Yellow and Blue) involve in fault scenarios or not.

1.4 Project Scope

The scope of this project is to perform fault identification and classification on 275kV Kolopis to Segaliud Transmission Overhead Line System of SESB grid network by using a combination of the following method for the following purposes.

1. Discrete Wavelet Transforms (DWT): DWT is used to extract transient features and energy of the three-phase current to detect short circuit faults. The obtained details coefficient will used as input to the neural network architecture

2. Artificial Neural Networks (ANN): This method is used to classify the types of fault obtained from the detail coefficient gained via wavelet analysis. The input and output layers have fixed three phase currents and four neurons of phase A, B C and G. The ANN algorithm shall be able to recognize type of the fault category correctly.

3. The applied data is utilizing 3 years tripping and disturbance records of the installed Disturbance Fault Recorder (DFR) type BEN5000 at both Kolopis and Segaliud Substation. Simulation to be carried out via MATLAB software using the proposed techniques and algorithm. Real diagnose and expected diagnose result to be compared for the accuracy to be justified.

LIST OF PUBLICATIONS

[1] E. &. Young, ""SESB Management and Engineering 2018 Audit Report"," Earnt & Young for SESB Audit Report, 2018.

[2] SESB, ""SESB Transmission Outage Tripping Meeting Report for December 2020"," Tranmsission Division, SESB, 2020.

[3] T. L. Q. Bi, "Multi-layer disturbance processing system based on multiple information sources.," in *IEEE Power Engineering Society General Meeting (pp. 1-4). IEEE.*, 2007, June.

[4] M. Z. a. M. S. S. Alias, " "The design of IEC 61850 based disturbance and fault recorder for online fault analysis in system verification and simulation laboratory."," in *2015 International Symposium on Technology Management and Emerging Technologies (ISTMET)*, 2015.

[5] T. a. Q. L. Bi, " "Multi-layer disturbance processing system based on multiple information sources."," in *2007 IEEE Power Engineering Society General Meeting.* , 2007.

[6] D. a. R. L. Sevcik, " "Automated Analysis of Faults and Disturbances: Utility Expectations and Benefits-CenterPoint Energy."," in *2007 IEEE Power Engineering Society General Meeting. IEEE, 2007.*, 2014.

[7] D. A. R. a. T. B. Bordon, ""Internet-based monitoring and control of protective relays and disturbance recorders."," 2004.

[8] M. a. R. Z. Musaruddin, ""Web services for automated fault analysis in electrical power system."," in *2009 Fifth International Joint Conference on INC, IMS and IDC. IEEE, 2009.*, 2009.

[9] M. a. J. G. R. Moreto, ""Automated analysis of digital fault recorder data in power generating plants."," in *International Journal of Innovations in Energy Systems and Power 3.2 (2008): 1-6.*, 2008.

[10] L. Z. L. a. S. H. Yue, " "Fault diagnosis based on fault recorder data and temporal constraint network in HV transmission system."," in *The 2010 International Conference on Green Circuits and Systems. IEEE, 2010.*, 2010.

[11] A. J. B. E. a. K. R. Prasad, ""A review on fault classification methodologies in power transmission systems: Part—I."," *Journal of electrical systems and information technology 5.1,* pp. 48-60., 2018 .

[12] H. a. F. M. N. Okumus, " "Power system event classification based on machine learning."," in *3rd International Conference on Computer Science and Engineering (UBMK). IEEE, 2018.*, 2018.

[13] A. a. R. Z. Ukil, ""Automated analysis of power systems disturbance records: Smart grid big data perspective."," in *IEEE Innovative Smart Grid Technologies-Asia (ISGT ASIA). IEEE, 2014*, 2014.

[14] J. P. (. C. Willian Strang (Chairman), "Working Group Memebership Report of "Considerationfor Use of Disturbance Recorders - A report to the System Protection Subcommittee of the Power System Relaying Committee of IEEE Power Engineering Society"," IEEE Power Engineering Society, 2006.

[15] M. a. J. G. R. Moreto, " "Automated analysis of digital fault recorder data in power systems."," *"Automated analysis of digital fault recorder data in power systems." Sba: Controle & Automação Sociedade Brasileira de Automatica 21,* pp. 347-362, 2010.

[16] R. Dashti, " "A survey of fault prediction and location methods in electrical energy distribution networks."," vol. Measurement 184 , p. 109947, 2021.

[17] P. Poloni, ""A comparative study among three methods for classification and location of faults."," in *IEEE PES Transmission & Distribution Conference and Exposition-Latin America (PES T&D-LA). IEEE, 2016.*, 2016.

[18] A. J. B. E. a. K. R. Prasad, " "A review on fault classification methodologies in power transmission systems: Part-II."," *Journal of Electrical Systems and Information Technology 5.1 ,* pp. 61-67, 2018.

[19] M. P. N. a. P. B. Gowrishankar, ""Transmission line fault detection and classification using discrete wavelet transform and artificial neural network."," *Middle-East J. Sci. Res 24.4 ,* pp. 1112-1121, 2016 .

[20] J.-A. Jiang, ""A hybrid framework for fault detection, classification, and location—Part I: Concept, structure, and methodology."," *IEEE Transactions on Power Delivery 26.3,* pp. 1988-1998, 2011).

[21] J.-A. Jiang, ""A hybrid framework for fault detection, classification, and location—part II: implementation and test results.," *IEEE Transactions on Power Delivery 26.3 ,* pp. 1999-2008, 2011.

[22] M. J. B. P. G. a. D. K. M. Reddy, ""A novel transmission line protection using DOST and SVM."," *Engineering Science and Technology, an International Journal 19.2 ,* pp. 1027-1039, 2016.

[23] Y. Wang, " "Power system fault classification and prediction based on a three-layer data mining structure."," *IEEE Access 8,* pp. 200897-200914, 2020.

[24] J. C. A. Freire, ""Transmission line fault classification using hidden Markov models."," *IEEE Access 7 ,* pp. 113499-113510, 2019.

[25] J. Z. X. a. Y. C. Wang, ""Power quality disturbance classification based on compressed sensing and deep convolution neural networks."," *IEEE Access 7 ,* pp. 78336-78346, 2019.

[26] M. K. B. K. P. a. S. R. S. Jena, " "A new approach to power system disturbance assessment using wide-area postdisturbance records."," *IEEE Transactions on Industrial Informatics 14.3 ,* pp. 1253-1261, 2017.

[27] M. A. Aftab, ""Dynamic protection of power systems with high penetration of renewables: A review of the traveling wave based fault location techniques."," *International Journal of Electrical Power & Energy Systems 114,* p. 105410, 2020.

[28] Y. N. N. a. M. I. Rangelov, ""The IEC 61850 standard—Communication networks and automation systems from an electrical engineering point of view."," in *016 19th International Symposium on Electrical Apparatus and Technologies (SIELA). IEEE*, 2016.

[29] K. M. B. A. S. a. N. S. B. Silva, ""Fault detection and classification in transmission lines based on wavelet transform and ANN."," *IEEE Transactions on Power Delivery 21.4 ,* pp. 2058-2063, 2006.

[30] I. Monedero, " "Classification of electrical disturbances in real time using neural networks."," *EEE Transactions on Power Delivery 22.3 ,* pp. 1288-1296, 2007.

[31] M. S. F. M. B. I. R. a. F. M.-Y. Choong, " "FPGA realization of power quality disturbance detection: An approach with wavelet, ANN and fuzzy logic."," in *Proceedings of the International Joint Conference on Neural Networks, IJCNN. 2005.*, 2005.

[32] A.-M. Ahmed, " "Transient security assessment for power system stability: A review on artificial intelligence approach."," in *2009 IEEE Student Conference on Research and Development (SCOReD). IEEE, 2009.*, 2009.

[33] M. Geethanjali, ""Combined wavelet transfoms and neural network (WNN) based fault detection and classification in transmission lines."," in *2009 International Conference on Control, Automation, Communication and Energy Conservation. IEEE, 2009.*, 2009.

[34] F. a. J. A. A. Martin, " "Wavelet-based ANN approach for transmission line protection."," *IEEE Transactions on power delivery 18.4 ,* pp. 1572-1574, 2003.

[35] P. a. P. A. D. Sebastian, ""A Neural Network based power quality signal classification system using wavelet energy distribution."," in *2015 International Conference on Technological Advancements in Power and Energy (TAP Energy). IEEE, 2015.*, 2015.

[36] A. a. J. B. E. Prasad, " "Application of wavelet technique for fault classification in transmission systems."," *Procedia Computer Science 92 ,* pp. 78-83, 2016.

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

[38] N. F. S. B. M. Nor, "Fault Classification In A Transmission Line Using Discrete Wavelet Transform and Artificial Neural Network," UTM, 2015.

[39] I. M. a. R. G. Karmacharya, " "Fault location in ungrounded photovoltaic system using wavelets and ANN."," *IEEE Transactions on Power Delivery 33.2 ,* pp. 549-559, 2017.

[40] M. S. K. S. a. R. S. Jamil, ""Fault detection and classification in electrical power transmission system using artificial neural network."," *SpringerPlus 4.1 ,* pp. 1-13., 2015.

[41] M. Z. A. A. K. H. H. E. M. Maryam Mirzaei, ""Comparative Analysis of Probabilistic Neural Network, Radial Basis Function and Feed Forward Neural Networks for Fault Classification in Power Distribution Systems"," *Electric Power Components and Systems 39.16 (2011): 1858-1871.,* pp. 1858-1871, 2011.

[42] SESB, ""SESB Transmission Outage & Tripping Commitee: 275kV Line Tripping Statistic"," Transmission Division, SESB, 2021.

[43] ""BEN Master Station Manual - Digital Fault Recording Equipment - 9200-08 REV C"," ELECTRONIC INSTRUMENTS INTERNATIONAL, 1999.

[44] R. a. P. K. Jędrychowski, ""MATLAB package applied to analyze Real-time fault signals."," *Computer Applications In Electrical Engineering, Poznań,* pp. 248-260, 2008.

[45] D. K. J. S. N. W. A. L. a. A. D. R. Jayamaha, ""Wavelet-multi resolution analysis based ANN architecture for fault detection and localization in DC microgrids."," *IEEE Access 7 ,* pp. 145371-145384, 2019.

[46] F. e. u. D. W. T. f. fault, " "Feature extraction using Discrete Wavelet Transform for fault classification of planetary gearbox–A comparative study."," *Applied Acoustics 188 ,* p. 108572, 2022.

[47] X. Deng, ""An improved method to construct basic probability assignment based on the confusion matrix for classification problem."," *Information Sciences 340 ,* pp. 250-261, 2016.

[48] C. a. A. N. Pothisarn, ""Discrete wavelet transform and back-propagation neural networks algorithm for fault classification on transmission line."," in *Transmission & Distribution Conference & Exposition: Asia and Pacific. IEEE, 2009.*, 2009.

[49] H. a. H. W. Weijian, ""Automatic power quality recognition and analysis system using wavelet-based neural network."," in *27th Chinese Control Conference. IEEE, 2008*, 2008.

[50] A. J. B. E. a. K. R. Prasad, ""A review on fault classification methodologies in power transmission systems: Part—I."," *Journal of electrical systems and information technology 5.1,* pp. 48-60, 2018.

[51] I. Monedero, " "Classification of electrical disturbances in real time using neural networks."," *IEEE Transactions on Power Delivery 22.3 ,* pp. 1288-1296, 2007.

[52] A. Abdullah, ""Ultrafast transmission line fault detection using a DWT-based ANN."," *IEEE Transactions on Industry Applications 54.2 ,* pp. 1182-1193, 2017.

[53] A. a. J. B. E. Prasad, " "Application of wavelet technique for fault classification in transmission systems."," *Procedia Computer Science 92 ,* pp. 78-83, 2016.