International Journal on Recent Technologies in Mechanical and Electrical Engineering
ISSN: 2349-7947 Volume: 9 Issue: 3
***Article Received:** 29 June 2022 **Revised:** 27 August 2022 **Accepted:** 04 September 2022*

Numerical Simulation of Detection and Classification of Symmetrical and Unsymmetrical Faults using Improved Stockwell Transform

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Abstract: In the electricity industry, dispersed generators' changing behavior has a number of systemic effects that need to be looked at. Power system protection equipment is widely employed, dispersed across the whole network, and helps utilities strengthen the system against a variety of symmetrical and asymmetrical faults; their identification and segregation are thus essential. The Stockwell Transform is used to generate an S-matrix from signal characteristics in the unique fault diagnosis approach that has been developed. This method, which is evaluated using MATLAB Simulink and IEEE 33 Bus systems, depends on thresholds and an algorithm to identify errors.

Keywords: Fault protections, Symmetrical and Unsymmetrical Faults, Fault-Index, Stockwell Transform.

1. Introduction

In power systems, distribution and transmission systems play an most significant role in supplying bulk power from generator terminals or gird to load centres where there is a consistent rise in electrical power demand with population growth around the world. Faults influence the output of the electrical power grid, causing power flow to be disrupted in the utility network. Power engineers can quickly and accurately identify faults, allowing them to fix and restore power in the time allotted.

RK kaushik et al. [1] Renewable is currently settled all throughout the planet as standard wellsprings of energy. Quick development, especially in the force area, is driven by a few elements, including the working on cost-intensity of inexhaustible advancements, developing interest for energy in creating and arising economies, and the requirement for admittance to present day energy.Anjali et al. [2] the extension in overall energy solicitation and augmentation thought with respect to regular issues has provoked the examination of environmentally friendly power sources, for instance, sunlight based and wind.

Hassan et al. [3] proposed a filter-based ANN for identifying short circuit faults, in which the certified hybrid method was evaluated on the fault detection mechanism for one loop, resulting in improved results. In a wavelet-based fault identification and classification scheme for short transmission lines, Abdul gafoor shaik et al. compared indices to determine the fault type [4]. Advanced statistical methods and techniques have been developed to guarantee the stability of control systems. It can also be used to distinguish between a healthy power grid and a faulty power system network. The use of such a strategy in power system protection means that relay processes are as effective as possible. To define and detect faults in, Moslem et al. [5] proposed employing fuzzy logic and singular wavelet entropy in combination with DG sources.

Moreover, Hussain et al. [6] suggested an unsynchronized calculation-based algorithm for locating faults in multi-terminal transmission lines. Aleena et al. also suggested a method for detecting fault location in all possible faults, including shunt faults such as long distance faults [7]. 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 [8]. By estimating terminal bus current at transient signals, [9] suggests a radical mechanism to fault classification and location estimation using the WT and SVM.

An all-encompassing type of CWT is known as ST which was created by R.G. Stockwell. Both the range for example sufficiency and stage give the data in this change. [10] For the situation of UPFC for a twofold circuit, differential handing-off is utilized as a wellbeing plan for commonly coupled high voltage transmission lines [11]. The handing-off point strategy is utilized to recognize flaws in an extra-high-voltage transmission line, which is an inventive way to deal with fast security. [9]. A

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DWT and SVD-based calculation is utilized to distinguish deficiencies [12].Afterward, Zhara et al [13] proposed utilizing the DWT method to find flaws. Fixated on cover discrete wavelet change coefficient investigation, FB Coasta et al. [14] proposed a novel and viable methodology for constant shortcoming recognition. Besides, [15] utilizes Weibul's likelihood thickness capacity to look at the infiltration of wind power into the force network, just as the effect on the financial burden dispatch issue. Krishna Murari et al. proposed a creative technique for estimating and examining the expense of framework upgrade on purchasers associated with sustainable interconnected circulation networks[16]. The standard based choice tree (RBDT) was presented by the Breiman in 1980 and applied in the field of force framework by the Wehenkel in 1989. In this method, choice upheld rules are utilized for grouping of PQ unsettling influences to anticipate the information reactions [17].The Stockwell transform technique was used to define and classify the types of faults in the proposed solution. This approach provides an excellent classification and detection of various disturbances on the power transmission and distribution network. For our study and investigation, the IEEE-33 Bus test system was considered, and the above test system was implemented on the Simscape Electrical platform. The test results show that the proposed method produces more reliable and efficient results.
The proposed approach has been fully clarified in the following section, section 2. The dataset pertaining to the test system was given in section 3. The simulated results and conclusion have been addressed and extensively discussed in the last two sections 4 and 5.

2. Methodology Descriptions

Distribution The proposed method for power transmission line safety involves fault detection using approach of fault index. For fault detection, the ST matrix is used. In the subsections that follow, we'll go over how to calculate fault index and a quick overview of the Stockwell transform.

2.1 Fault Transform Index

To distinguish between the defective and healthy stages, a fault index is suggested. On the EHV transmission line, this index is often used to distinguish between different faults. The following measures are used to measure the fault index:

i. The current of all phases is recorded on the test system's bus 800.
ii. Current signals are disintegrated using the Stockwell Transform at a sampling rate of 20 kHz, yielding an S-matrix.
iii. The S-median matrix's is found.
iv. The perfect value of the median is estimated and the fault index is assigned.
v. The fault indices is used to locate and detect faults

2.2 Stockwell

STFT of the signal c(t) is defined by the following relation.

$$STFT(\tau, f) = \int_{-\infty}^{+\infty} c(t)h(\tau - t)e^{-j2\pi ft}dt \quad (1)$$

where spectral localization time and Fourier frequency are denoted by 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 functiong(t).

$$.h(t) = \frac{|f|}{\sqrt{2\pi}} e^{-} \quad (2)$$

Hence

$$S(\tau, f) = \int^{+\infty} c(t) \frac{|f|}{} e^{-\frac{f^2(\tau-t)^2}{2}} e^{-j2\pi ft}dt \quad (3)$$

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 results higher frequency resolution for lower frequencies. Even though the window is smaller, it can results improved 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.

3. Proposed Test System

The proposed. system is a typical IEEE-33 bus test system. All of the feeders used in the test system are three step, with lengths equal to the feeders' original lengths. The loads in the test device are all 3 ϕ loads. Spot loads in the centre of the feeders are used to simulate distributed loads. Tables I, to III display the details of 3ϕ transformers, phase parameter for spot load andcapacitor banks. As outlined in the simulation results section, the faults are formed on the test system's bus-838 IEEE-33 bus test system.

Table 1. % Resistance and % Reactance of Transformers

Transformer	kVA	kV-high	kV-low	R(%)	X(%)
Substation	2500	69 - D	24.9 -Gr. W	1	8
XFM-1	500	24.9 - Gr.W	4.16 - Gr. W	1.9	4.08

TABLE 2. Phase Parameters for spot

Node	Load Model	Ph-1 (kW)	Ph-1 (kVAr)	Ph-2 (kW)	Ph-2 (kVAr)	Ph-3 (kW)	Ph-4 (kVAr)
860	Y-PQ	20	16	20	16	20	16
840	Y-I	9	7	9	7	9	7
844	Y-Z	135	105	135	105	135	105
848	D-PQ	20	16	20	16	20	16
890	D-I	150	75	150	75	150	75
830	D-Z	10	5	10	5	25	10
Total		344	224	344	224	359	229

TABLE 3. Capacitor phase parameters

Node	Ph-A (kVAr)	Ph-B (kVAr)	Ph-C (kVAr)
844	100	100	100
848	150	150	150
Total	250	250	250

4. Results & Discussion

The complete IEEE 33 bus test system is evaluated with the two types of results; in first result current waveform is obtained and another one result fault index graph is obtained for symmetrical and unsymmetrical faults. Effect of various types of faults mentioned in subsections are evaluated and plotted at the 6 cycle of the simulation of 12 cycles.

4.1 Analysis of Line to Ground Fault

Grounding the phase-A has resulted in the phase to ground (LG) fault. Figure 4 depicts the 3 ϕ current waveforms during the LG fault on phase-A. As can be seen in Figure 1, the present magnitude of phase-A has raised from 50 A up to 300 A. The level of current in the stable phases (phases A and B) is, however, unchanged. As a result, the current in the defective process rises by 600%.

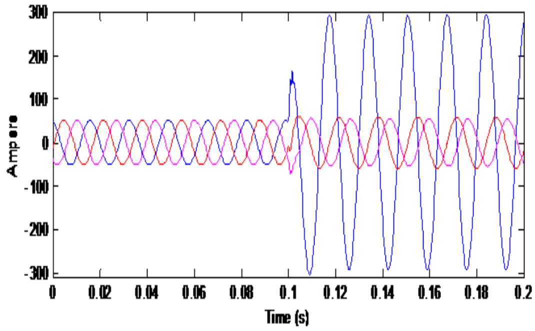

Fig. 1 Output Current plot when LG fault at bus 838

In Figure 2, the proposed fault index values for all 3 ϕ during the LG fault on phase-A are shown. The fault index for the defective process is maximum, while the fault indices for the stable phases are lower than the threshold value. The defective phase's fault index value is 13. As a result, the LG fault is effectively detected.

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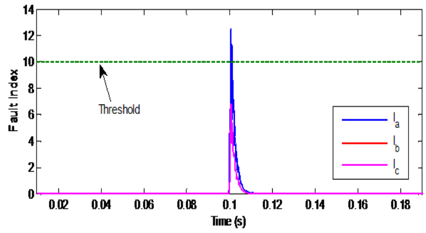

Fig. 2 Fault index with the help of Stockwell Transform based median

4.2 Analysis of Double Line Fault

By shorting phases A and B, the double line (LL) fault is formed. Figure 3 depicts the 3 ϕ current waveforms on phases A and B during the LL fault. The current magnitude of phases A and B got raised from 50 A reaching up to 350 A, as seen in this diagram. The magnitude of current in the healthy phase (phase-C) is, however, unchanged from before the fault. As a result, the current in the defective phases increased 700%.

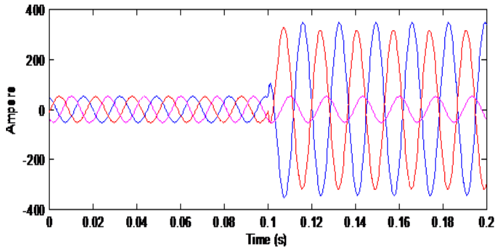

Fig. 3 Output Current plot during LL fault

Figure 4 depicts the measurements of proposed fault indices for all 3ϕ during the LL fault on phases A&B. The fault indices of defective phases A and B are found to be maximum at 16 value. The fault index for the safe phase (phase-C) is equal to zero and is well below the threshold value. As a result, the proposed algorithm effectively detects the LL fault.

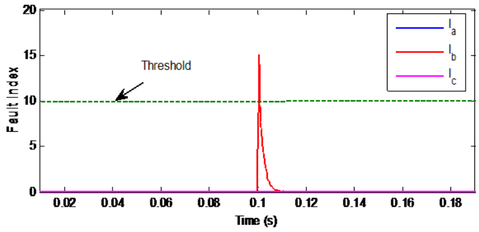

Fig. 4 Fault index for LL fault on bus 838 with the help of Stockwell Transform based median

4.3 Analysis of Double Line to Ground Fault

Phases A and B are simultaneously being grounded will cause the double fault. The 3 ϕ LLG fault waveforms are illustrated in Figure 5 It can be seen from this diagram that the current phase A/B magnitude has increased. However, magnitude of current (i.e.e. voltage) was the same prior to the fault occurrence. As a result, the current in the defective phases increased by a factor of 750.

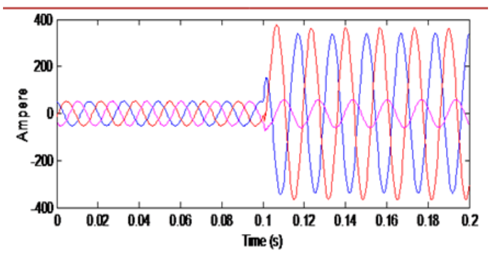

Fig. 5 Output Current plot during LLG fault at bus 838

The phase A & B and C index values can be seen in Figure 6, It is observed that A and B phase faults have 16 as the fault index. The fault index for the healthy phase (phase-C) is equal to 4 and is below the threshold value. As a result, the proposed algorithm effectively detects the LLG fault.

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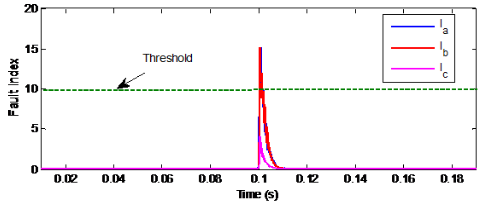

Fig. 6 Fault index for LLG fault on bus 838 with the help of Stockwell Transform based median

Analysis of Three Phase Fault Involving Ground

The 3∅ system has now been grounded The 3 ϕ current waveforms are illustrated in Figure 7 It can be observed from this diagram that the magnitude of the 3 ϕ is now 400 A. However,
magnitude of current (i.e.e. voltage) was the same prior to the fault incident. Thus, the current in all 3 ϕ has been doubled.

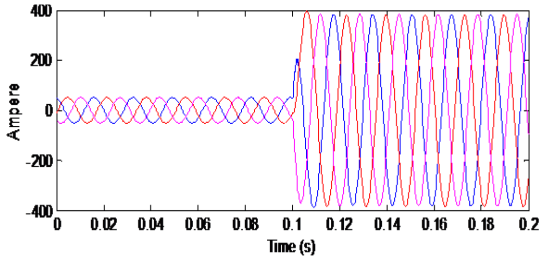

Fig. 7 Output Current plot for 3ϕ fault

In Figure 8, the proposed fault index values for all 3 ϕ of the LLLG fault are shown. The three phase fault indices are observed to be more than the permissible threshold. value and over 25. As a result, the proposed algorithm effectively detects the LLLG fault.

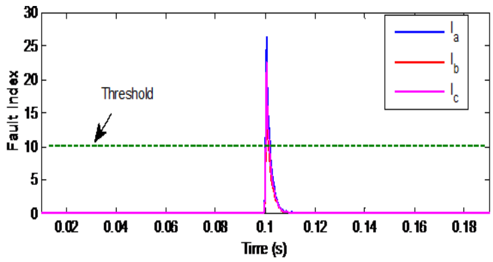

Fig. 8 Fault index for 3ϕ fault on bus 838 with the help of S Matrix based median

5. Comparative Study

Peak fault indices for each phase are provided in Table 5.1. The different types of faults can be distinguished from one another by examining the fault indices of all 3 ϕ across fault events. The LLLG fault yields the highest values, while the LG fault yields the lowest. The fault indices for the LL and LLG faults are the same in the defective phases, but zero for the stable period in the case of the LL fault and absolute for the LLG fault.

TABLE 4 Maximum Values of Fault Index of aults

Sr.No.	Fault Type	Phase -A	Phase -B	Phase -B
1	LG	13	7	7
2	LL	16	16	0
3	LLG	16	16	4
4	LLLG	27	24	24

Furthermore, the elapsed time for the fault detection has been evaluated from the proposed methods and it has been found that the proposed approach took lesser time compared to the proposed methods by Guillen et. al.. Table 8 describes the comparative analysis. Guillen et. al has proposed an algorithm were Non Radial High Voltage (NRHV) transmission lines were tested for the classification and identification of faults using discrete wavelet transform. The results of the elapsed time have been compared with the proposed methodology of stockwell transform to identify the faults on the transmission lines and its concluded that the computational burden and time detection is reduced.

TABLE 5 .FAULT IDENTIFICATION ELAPSED TIME

Sr.No.	Fault Type	NRHV Method	ST Mehtod (ms)
1	LG	1.18	0.09
2	LL	1.313	0.257
3	LLG	0.988	0.912
4	LLLG	1.118	0.098

6. Conclusions

With the IEEE 33 bus test method, a methodology is implemented and simulated in Simscape electrical. The fault indices were calculated and compared to the threshold values to identify the different types of faults that were caused in the system, and the fault type was classified and differentiated. Fault indices help one to deduce that different faults have unique index values and that fault forms can be predicted only by looking at them. Apart from Phase B and C has a value above the threshold value during LG fault, as shown in Tables 6 and 7, whereas the other two phases have values below it. Similarly, except for Phase C, both phases of the LL fault have exceeded the threshold value. Furthermore, all phases in LLG and LLLG phase faults have exceeded the threshold values and achieved maximum values of 27, 24, and 24 for Phase A, B, and C, respectively. As a result, the proposed test system is assessed using the framework proposed.

References

[1]. Kaushik RK, Pragati. Analysis and Case Study of Power Transmission and Distribution. J Adv Res Power Electro Power Sys 2020; 7(2):1-3.
[2]. Anjali, Raj Kumar Kaushik and Deepak Sharma (2018), "Analyzing the Effect of Partial Shading on Performance of Grid Connected Solar PV System," 3rd International Conference and Workshops on Recent Advances and Innovations in Engineering (ICRAIE), 1-4.
[3]. Hassan Fathabadi (2016), “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, 374–383.
[4]. Abdul Gafoor Shaik and Ramana Rao V. Pulipaka (2015), “A new wavelet based fault detection, classification and location in transmission lines,” International Journal of Electrical Power and Energy Systems, 35–40.
[5]. Moslem Dehghani, Mohammad Hassan Khooban andTaherNiknam (2016), “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, 455– 462.
[6]. Shoaib Hussain and A.H. Osman 2016, “Fault location scheme for multi-terminal transmission lines using unsynchronized measurements,” International Journal of Electrical Power and Energy Systems, 277–284.
[7]. Aleena Swetapadma and Anamika Yadav (2015), “All shunt fault location including cross-country and evolving faults in transmission lines without fault type classification,” Electric Power Systems Research, 1–12.
[8]. Sami Ekici (2012), “Support Vector Machines for classification and locating faults on transmission lines,” Applied Soft Computing, 1650–1658.
[9]. Rajkumar Kaushik, Om Prakash Mahela, Pramod Kumar Bhatt, (2021), "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), 415-420.
[10]. Rajkumar Kaushik, Om Prakash Mahela, Pramod Kumar Bhatt, Baseem Khan, Akhil Ranjan Garg, Hassan Haes Alhelou and Pierluigi Siano (2021), "Recognition of Islanding and Operational Events in Power System With Renewable Energy Penetration Using a Stockwell Transform-Based Method," in IEEE Systems Journal, 69798-69813.
[11]. L.N. Tripathy, S.R. Samantaray and P.K. Dash (2016), “A fast time–frequency transform based differential relaying scheme for UPFC based double-circuit transmission line,” International Journal of Electrical Power and Energy Systems, 404–417.
[12]. Z. Q. Bo, M. A. Redfern, and G. C. Weller (2000), “Positional Protection of Transmission Line Using Fault Generated High Frequency Transient Signals,” Ieee Transactions on Power Delivery, 888-894.
[13]. Zahra Moravej, Mohammad Pazoki, and MojtabaKhederzadeh (2015), “New Pattern-Recognition Method for Fault Analysis in Transmission Line With UPFC,” IEEE Transactions on Power Delivery, 1231-1242.
[14]. Flavio B. Costa (2014), “Fault-Induced Transient Detection Based on Real-Time Analysis of the Wavelet Coefficient Energy,” IEEE Transactions on Power Delivery,140-153.
[15]. Saxena N., Ganguli S. (2015), " Solar and Wind Power Estimation and Economic Load Dispatch Using Firefly Algorithm", Procedia Computer Science, 688-700.
[16]. K. Murari, N. P. Padhy, A. K. Pradhan and F. Li (2019), "Investigating the impact of protection system reinforcement cost on the consumers associated with renewable integrated distribution network," in IET Generation, Transmission & Distribution,1572-1588.
[17]. Rajkumar Kaushik, Om Prakash Mahela, Pramod Kumar Bhatt, Baseem Khan, Sanjeevikumar Padmanaban and Frede Blaabjerg (2020), "A Hybrid Algorithm for Recognition of Power Quality Disturbances," in IEEE Access, 229184-229200.