International Journal of Electrical and Electronics Engineering (IJEEE)
ISSN(P): 2278–9944; ISSN(E): 2278–9952
Vol. 10, Issue 1, Jan–Jun 2021, 1–10

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

FAULT DETECTION SCHEME FOR DISTRIBUTED AND INTER-CONNECTED POWER SYSTEM USING SHANNON WAVELET ENTROPY

V R. Sai Kumar Sripadanna[1] & B. Venkata Krishna[2]

[1]PG Student, Department of EEE, SRKR Engineering College, Bhimavaram, India

[2]Assistant Professor, Department of EEE, SRKR Engineering College, Bhimavaram, India

ABSTRACT

The Protection scheme is suggested for the detection of various faults in the Distributed Generation System and also for the detection of various faults in the interconnected network at different locations. In this method, positive components of currents are retrieved at fault location and are decomposed to get detailed coefficients of wavelet transforms. The concerned singular value matrices, and expected entropy values are calculated. Based on the Wavelet Shannon Entropy calculated. Indexes are defined to detect the fault. 'Haar' Wavelet Transform is used for the extraction of frequency components. The major priority of the protection scheme proposed is to reduce the tripping time to 10ms from the inception of fault occurrence. The proposed scheme for the detection of various faults is investigated in MATLAB-SIMULINK software environment.

KEYWORDS: *Detection of Faults, Wavelet Shannon Entropy, Haar Wavelet, Distributed Network, Inter-Connected Network*

Article History

Received: ***05 Nov 2020*** **|** ***Revised:*** ***10 Nov 2020*** **|** ***Accepted:*** ***21 Nov 2020***

INTRODUCTION

Power grids protection is an important issue that is able to detect fault and isolate the fault part.

Different methods for fault detection and classification have been recently reported. For all algorithms, extracting the features of fault signal is importance. Fault detection based upon the Rate of Change of Frequency (ROCOF) is proposed in [1]. The Vector Surge (VS) technique is suggested in [2], [3] while High Impedance technique is introduced in [4]. Authors of [5] presented Under/Over Voltage (U/OV) relay. The Wavelet Singular Entropy Index (WSEI) technique is proposed in [6] for islanding detection. An effective feature extraction method using wavelet transform (WT) is investigated in [7]. Ref. [8] suggests WTs suited for analysis of non-stationary signals measured by protection devices. In this paper, a protection scheme supported a mixture of wavelet Transform and Shannon entropy is presented for distribution lines in the presence of DG which each DG is in a position to take advantage of in islanding condition. Relay performance is investigated in different locations for the detection of various faults. Wavelet singular entropy (WSE) is used in [9] for fault detection and classification in transmission lines. In this paper, system is studied without the presence of Distributed Generator, in which with respect to the uses of these units in recent years, it is necessary to consider these resources. The ability of wavelet singular entropy to detect the fault at high speed is proven under various conditions such as fault resistance, fault distance and fault type. The Wavelet Singular entropy technique, which combines applications and benefits of Haar wavelet transform [10], Singular Value Decomposition (SVD) [11, 12], and spectrum entropy [13], is proposed to detect the various faults in this paper. This method is effective and has a high speed in fault detection and classification in distribution lines in the presence of distributed generations. Three phase current signals are retrieved at the point where the relay is placed; in the next step the positive component of current signals is calculated, then analysed by Haar wavelet transform; and the detailed coefficient will be retrieved. The SVD technique is used to compute the singular value from the detailed coefficient matrix, which computes WSE of the positive component and three phase current signals to detect the fault. In this paper, wavelet Shannon entropy concept with 'haar' wavelets is implemented for detection of various faults.

WAVELET ENTROPY CONCEPT FOR FAULT DETECTION

Wavelet transform (WT) is a powerful tool in the analysis of transient phenomena of the electrical signals during fault conditions in power systems. It has an ability to analyse the signals in frequency domain which can greatly facilitate the detection of signal features that are useful in characterizing the transient fault or the state of the post disturbance electrical system. The recorded transient waveforms in power system may contain unique signatures revealing the causes of the corresponding transient events. To automatically analyse those recorded waveforms, an important step is to find out those signatures. The transient signals have a non-stationary property where traditional analysis methods such as Fourier Transform are not very suitable for this task. Unlike Fourier Transform, Wavelet Transforms use fast decaying kernel functions, which may better represent and analyse the transient signals. The suitability of application of Discreet Wavelet Transform (DWT) for fault detection and classification process is already available in [4] and it is expressed as,

$$\boldsymbol{W_f(a,b) = \int_{-\infty}^{\infty} S(t).\varphi_{a,b}(t).dt} \quad (1)$$

Where $S(t)$is the signal which is to be transformedand $\varphi_{a,b}(t)$is the transformation function (mother wavelet function). In this paper, ten level one dimensional decomposition using 'Haar' wavelet family is used. In this paper, Wavelet Shannon entropy is calculated after calculating the SVD)[11, 12] of the detailed coefficients and obtaining the probability [14] of each signal

$$\text{WSE} = \sum_{i=1}^{r} P_i * lnP_i \quad (2)$$

SYSTEM STUDIED FOR FAULT DETECTION

In this study, Two Power System Models were chosen for fault Detection using Shannon wavelet Entropy. Initially, Primary System Model was chosen which is a distributed network connected to the load, at the point of common coupling, through the Transformer and Distribution line. The schematic diagram of Primary System Model was shown in Fig. 1. The relay will be placed at the end of the DG unit which allows the CB to trip when fault occurs in the distributed line or at the point of common coupling (PCC).

The details of the generator, transformer, distribution line and load for Primary System Model are considered as follows:

- **Distributed Generation***:* Diesel generator, 9.0 MW, 400 V, 60 Hz.
- **Transformer**: 10 MVA, *f* = 60 Hz, Rated kV = 400 V/20 kV,V_{base} = 20 kV, *R*1 = 0.00375 p.u., *X*1 = 0.1 p.u., *Rm* = 500 p.u., *Xm* = 500 p.u.
- **Distribution Line***:* PI-section, 5 km, rated kV = 20, rated MVA = 20, V_{base} = 20 kV, *R*0 = 0.1948 *X*/km, *R*1 = 0.027 *X*/km, *C*0 = 9e 9 F/km, *C*1 = 12.7e9 F/km, *L*0 = 2.067e3 H/km, *L*1 = 0.88586e3 H/km.
- **Load:**3 MW**.**

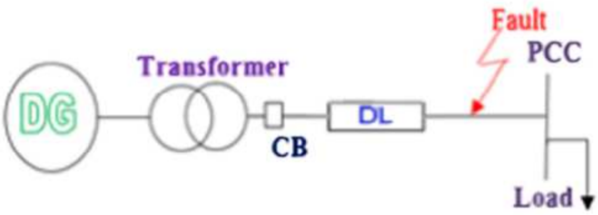

Figure 1: Test System (Model 1, Primary System Model) for Studying the Proposed Scheme.

The secondary system Model consists of two Distributed Generation units connected to the main supply system through the Point of Common coupling (PCC) is shown in Fig. 2. Each Distributed Generator unit is placed at a distance of 25 km from the point connected to the main supply. There will be a relay placed at each end of the DG unit to collect the current and voltage signals in different conditions for each Distributed Generator unit. Also, The Point of common coupling (PCC) circuit breaker CB2 is setup to trip in response to any kind of faults from the utility and will make the micro-grid to disconnect instantaneously from the utility and allow it to work under islanding mode.

The fault locations studied for the Secondary System Model are as follows:

- The fault location at point A which is close to the Point of Common coupling (PCC).
- The fault location at point B which is in the middle line between DG1 and DG2.

Details of the Utility generator, DGs, transformers, distribution lines and loads are considered as follows:

- **Utility:** Rated short circuit MVA = 1000, *f* = 60 Hz, rated kV = 66, *V*base = 66 kV.
- **Distributed Generations (DGs):** DG1, DG2: Diesel generator, 9.0 MW, 400 V, 60 Hz.
- **Transformer: TR3:** Rated MVA = 50, *f* = 60 Hz, rated kV = 66/20, V_{base} = 20 kV, *R*1 = 0.00375 p.u., *X*1 = 0.1 p.u., *Rm* = 500 p.u., *Xm* = 500 p.u.
- **TR1, TR2:** rated MVA = 10, *f* = 60 Hz, rated kV = 400 V/20 kV, V_{base} = 20 kV, *R*1 = 0.00375 p.u.,X_1= 0.1 p.u., R_m= 500 p.u., X_m= 500 p.u.
- **Distribution Line (DL):** DL1, DL2: PI-section, 25 km, rated kV = 20, rated MVA = 20, V_{base} = 20 kV, R_0 = 0.1948 *X*/km, R_1 = 0.027 *X*/km, C_0 = 9e9 F/km, C_1 = 12.7e9 F/km, L_0 = 2.067e3 H/km, *L*1 = 0.88586e3 H/km.
- **Load:** L2, L3: 3 MW, *L*1 = 6 MW, 2 MVAR.

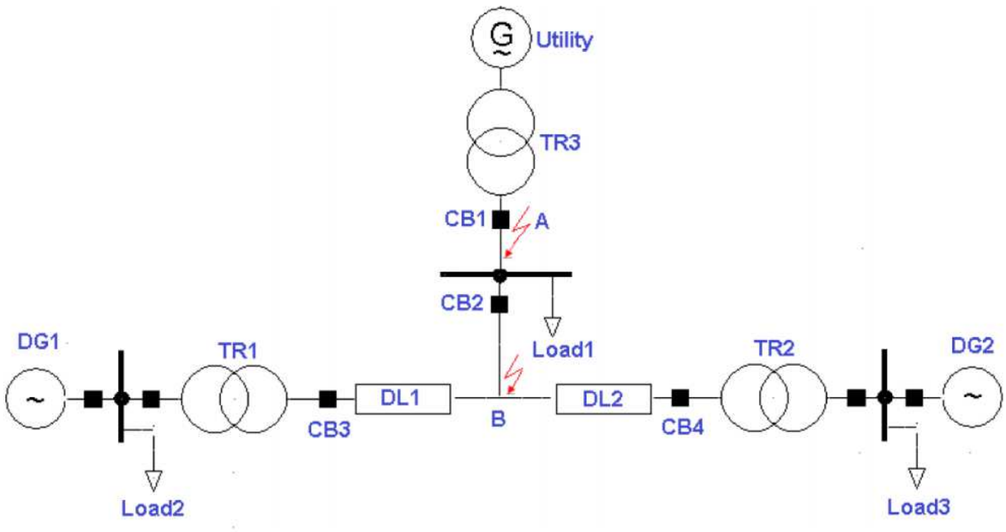

Figure 2: Test System (Model 2, Secondary System Model) for Studying the Proposed Scheme.

FAULT DETECTION PROCEDURE USING WAVELET SHANNON ENTROPY

The step by step procedure for calculation of Wavelet Shannon Entropy of the signal is as follows:

- The signal S (t) which is analysed using Wavelet Transform is taken from the location where the relay is placed, where the 'db10' Haar wavelet was selected for analysis. Then, a 10 ⁄ n Wavelet Transform coefficient matrix J_R can be calculated by the coefficient of WT.
- Then the Matrix J_R is decomposed by Singular Value Decomposition (SVD) theory and the singular-value array is retrieved.
- For the calculation of entropy of the singular value, the probability must be obtained as follows

$$P_i = \frac{\sigma_i}{\sum_{j=1}^{r} \sigma_j}$$

- Finally, the Wavelet Shannon Entropy of S (t) is obtained as follows

$$\text{WSE} = \sum_{i=1}^{r} P_i * lnP_i$$

SIMULATION RESULTS

In this study, the positive component of current signals is retrieved from the location where the relay is placed and the analysis of the signal for the fault detection using Shannon Wavelet Entropy is done according the step-wise procedure mentioned above.

Types of faults for which System is studied

- SPTG fault (fault occurs between phase 'a' and the ground)
- DPTG fault (fault occurs between phases 'a' and 'b' to the ground)
- TPTG fault (which occurs between phases 'a', 'b', 'c' to the ground)
- PTP fault (which occurs between phase 'a' and phase 'b'),

For Primary System Model

The study is done for the different types of faults (mentioned above) occurred at the end of the distributed line i.e. at the point of common coupling (PCC).The value of the fault resistance at the point of occurrence of fault is **R_f=1e-3Ω.** The fault Occurs at time of 1sec. The tripping of the different phases of the line for some faults are shown in Fig. 3, Fig. 5 and Fig. 7 and the corresponding tripping time for respective faults were shown in Fig. 4, Fig. 6, Fig. 8. The tripping time for every fault is tabulated in the table. 1.

For Secondary System Model

- **Fault in point 'A'**

In this section, the system is studied for various faults occurred at point A (between CB1 and CB2) which is close to the PCC. The positive component of the current signal is retrieved at the CB1 and CB2 places and the Wavelet Shannon Entropy of the positive component is calculated. The WSE technique detects the change in the signal during fault conditions. Thus, the circuit breaker will disconnect the Utility and the micro-grid will go to the islanding mode The value of the fault resistance at the point of occurrence of fault is **R_f=1e-3Ω.** The fault Occurs at time of 0.4sec

- **Fault in point 'B'**

In this section, the system is studied for various faults occurred at point B (between CB2, CB3 and CB4). The WSE technique is able to detect the fault at CB2, CB3 and CB4 and the circuit breaker will disconnect the each DG and each DG goes to islanding mode separately. As a result, each DG produces the power to feed the local load in islanding mode. The value of the fault resistance at the point of occurrence of fault is **R_f=1e-3Ω.** The fault Occurs at time of 0.4sec.

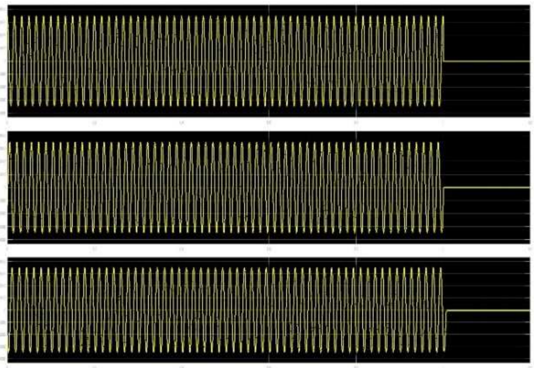

Figure 3: Detection Results of AG Fault for A, B and C Phases Respectively for Model 1.

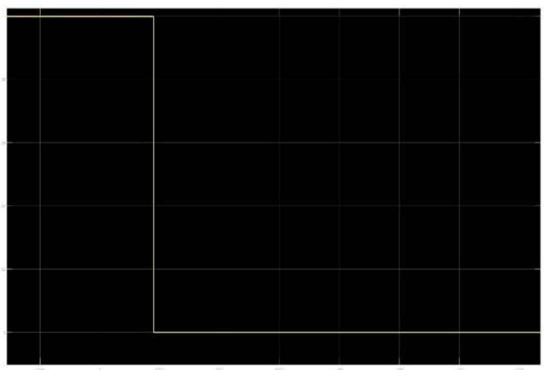

Figure 4: Circuit Breaker Tripping Time Recorded as 8 Milliseconds for AG Fault.

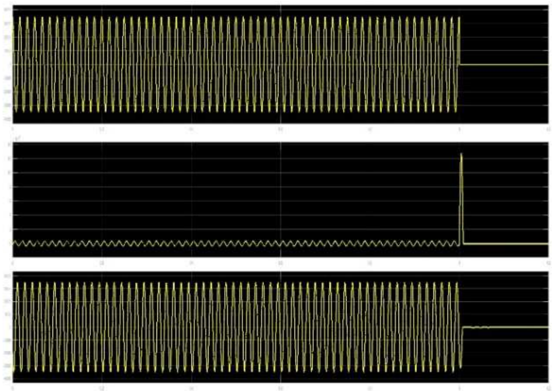

Figure 5: Detection Results of ABG Fault for A, B, and C Phases Respectively for Model 1.

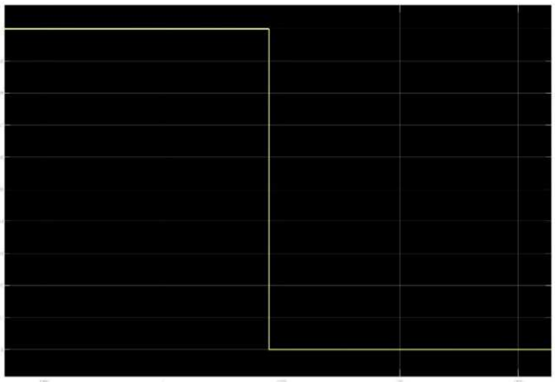

Figure 6: Circuit Breaker Tripping Time Recorded as 6.5 Milliseconds for ABG Fault.

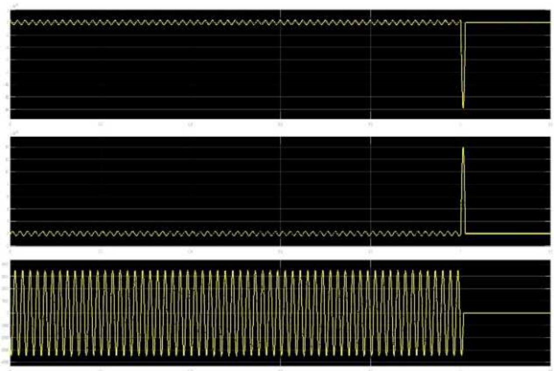

Figure 7: Detection Results of AB Fault for A, B, and C Phases Respectively for Model 1.

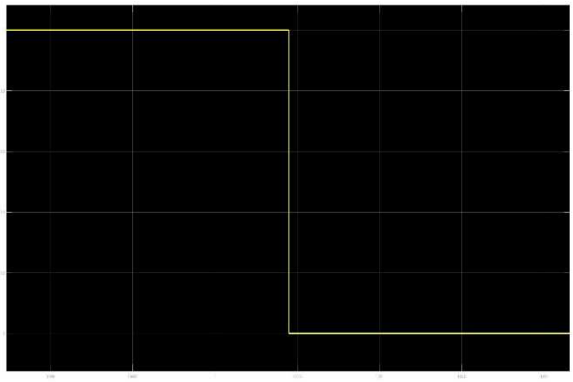

Figure 8: Circuit Breaker Tripping Time Recorded as 6.6 Milliseconds for AB Fault.

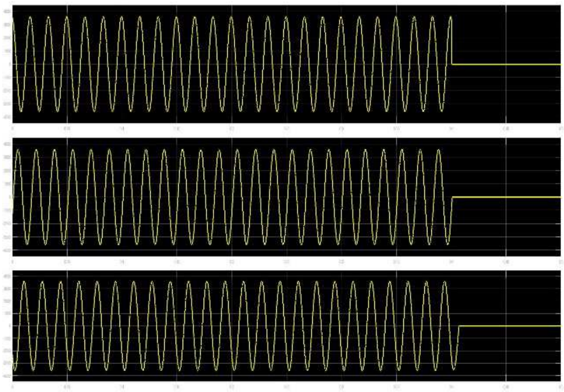

Figure 9: Detection Results of AG Fault at Point A for A, B, C Phases Respectively for Model 2.

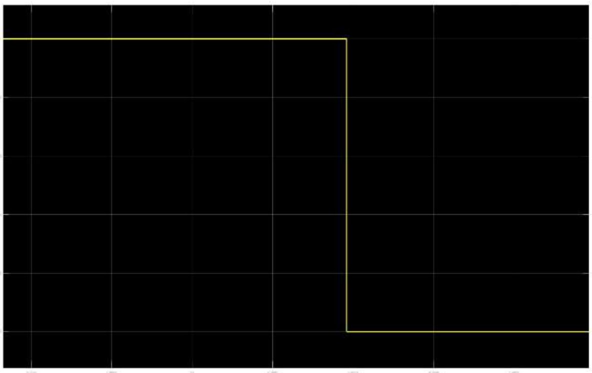

Figure 10: Circuit Breaker Tripping Time Recorded as 7.0 Milliseconds for AG Fault.

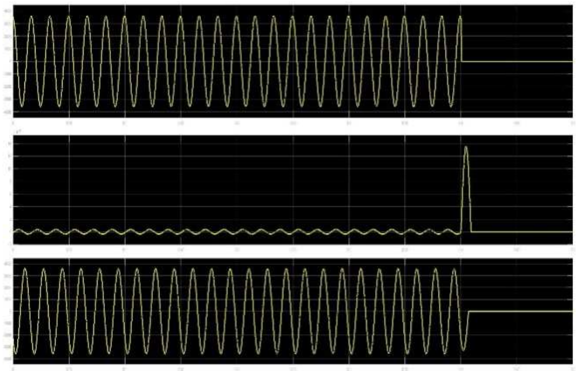

Figure 11: Detection Results of ABG Fault at Point A for A, B and C Phases Respectively for Model 2.

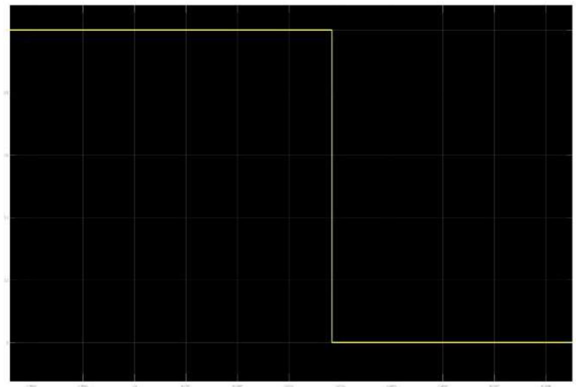

Figure 12: Circuit Breaker Tripping Time Recorded as 9.1 Milliseconds for ABG Fault.

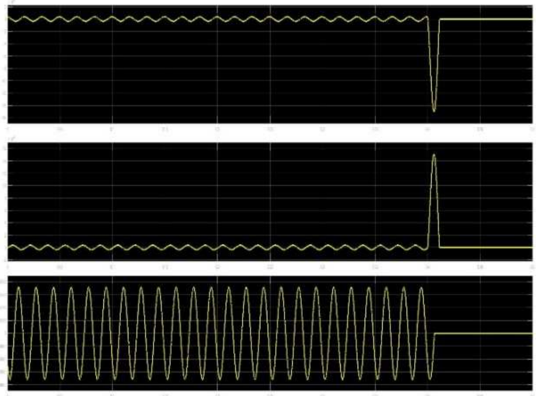

Figure 13: Detection Results of AB Fault at Point A for A, B and C Phases Respectively for Model 2.

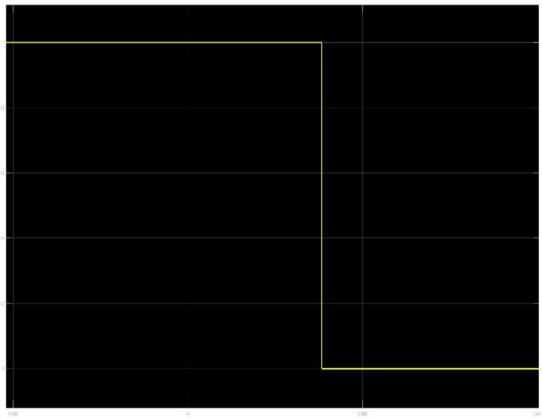

Figure 14: Circuit Breaker Tripping Time Recorded as 11.0 Milliseconds for AB Fault.

Table for Simulation Results

Table 1: Tripping Time for Various Faults in the Different Models Considered

FAULT	MODEL 1 AT'1 SEC' TRIPPING TIME (MILLISECONDS)	MODEL 2 AT POINT 'A' TRIPPING TIME (MILLISECONDS)	MODEL 2 AT POINT 'B' TRIPPING TIME (MILLISECONDS)
PHASE AG	8.0 ms	7.0 ms	7.4 ms
PHASE BG	7.0 ms	8.5 ms	8.8 ms
PHASE CG	6.5 ms	5.1 ms	5.0 ms
PHASE AB	6.6 ms	11 ms	10.7 ms
PHASE BC	6.6 ms	7.4 ms	7.2 ms
PHASE AC	6.7 ms	4.5 ms	4.6 ms
PHASE ABG	6.5 ms	9.1 ms	8.8 ms
PHASE BCG	6.5 ms	9.2 ms	8.85 ms
PHASE ACG	6.7 ms	5.1 ms	4.95 ms
PHASE ABC	6.5 ms	9.1 ms	7.2 ms
PHASE ABCG	6.6 ms	9.1 ms	8.85 ms

CONCLUSIONS

In this paper, Shannon Wavelet Entropy based fault detection procedure was used to detect the faults in the Distributed Network (Primary System Model) and Interconnected Network (Secondary System Model) of Power System. The wavelet Shannon Entropy method uses Wavelet Transform, singular value decomposition (SVD) and Shannon Entropy Calculation of a signal to detect the fault. This method is fast, simple and reliable for the detection of all kinds of faults. Also, the tripping time of the circuit Breaker is less than 12 milliseconds (near to one half cycle) from the inception of fault. The minimum Tripping Time is obtained due the characteristics of the Wavelet Shannon Entropy for the sudden change in the input Signal which is retrieved from the point of fault location.

REFERENCES

1. *Freitas Walmir, Xu Wilsun, Affonso Carolina M, Huang Zhenyu. Comparative analysis between ROCOF and vector surge relays for distributed generation applications. IEEE Trans. Power Delivery 2005; 20(2):1315–24.*
2. *Freitas Walmir, Xu Wilsun. False operation of vector surge relays. IEEE Trans. Power Delivery 2004; 19(1):436–8.*
3. *Freitas Walmir, Xu Wilsun, Huang Zhenyu, Vieira Jose. Characteristics of vector surge relays for distributed synchronous generator protection. Electric Power Syst. Res. 2007; 77(2):170–80.*
4. *Wester C. High impedance fault detection on distribution systems. GE power management, 20 Technology Parkway, Suite 330 Norcross, GA 30092, USA. P.C5-1–C5-5.*
5. *Ndou R, Fadiran JI, Chowdhury S, P Chowdhury S. Performance comparison of voltage and frequency based loss of grid protection schemes for microgrids. IEEE; 2013.*
6. *Samui Ankita, Samantaray SR. Wavelet singular entropy-based islanding detection in distributed generation. IEEE Trans. Power Delivery 2013; 28 (1):411–8.*
7. *Xu X, Kezunovic M. Automated feature extraction from power system transients using wavelet transform. Proc. Int. Conf. Power. Syst. Technol.2002; 4:1994–8.*
8. *Chaari O, Meunier M, Brouaye F. Wavelets: a new tool for the resonant grounded power distribution systems relaying. IEEE Trans. Power Delivery1996; 11(3):1301–8.*
9. *He Zhengyou, Fu Ling, Lin Sheng, Bo Zhiqian. Fault detection and classification in EHV transmission line based on wavelet singular entropy. IEEE Trans. Power Delivery 2010; 25(4):2156–63.*
10. *Stankovic RS, Falkowski BJ. The Harr Wavelet transform: its status and achievement, vol. 29. Elsevier Science Ltd, Computers and Electrical Engineering; 2002.*
11. *Ellithy K, Shaheen M, Al-Athba M. Voltage stability evaluation of real power transmission system using singular value decomposition technique. In: International conference on power and energy (PECon 08). IEEE; Dec1–3, 2008. p. 1691–5.*
12. *Onn R, Steinhardt AO, Bojanczyk AW. The hyperbolic singular value decomposition and applications. IEEE. Trans Signal Process 1991; 39 (7):1575–88.*
13. *Shannon Claude Elwood. A mathematical theory of communication. ACM SIGMOBILE Mobile Comput. Commun. Rev. 2001; 5(1):3–55.*
14. *Xin-min Tao, Wan-Hai Chen, Bao-Xiang Du, Yong Xu, Han-Guang Dong, A novel model of one-class bearing fault detection using RNCS algorithm based on HOS. In: 2nd IEEE conference on industrial electronics and applications. ICIEA. IEEE; 2007. p. 965–70.*