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A Hybrid Time-Frequency Signal Processing Technique for Power System Fault Detection

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ABSTRACT: *The rapid evolution and intricacy of modern electrical power systems necessitate the adoption of a robust and efficient protection strategy to swiftly safeguard transmission lines during malfunctions. Power system fault diagnosis is a critical and extensively studied field, particularly for smart grid applications. A competent fault diagnosis technique can furnish control room operators with accurate and actionable insights, enabling prompt measures to maintain the power system's stability and security during faults. This research introduces a pioneering Time-Frequency (S – Transform) methodology for identifying faults in transmission lines using MatLab/Simulink. The S-transform, a hybrid time-frequency signal analysis method that merges aspects of the wavelet transform with the short time Fourier transform (STFT), involves capturing voltage and current signals at both ends of the transmission network. These signals are then analyzed using the S-Transform. The results from simulating both symmetrical and asymmetrical faults indicate that under normal conditions, the phase voltage's magnitude in both the time and frequency domains stands at 1pu and 75pu, respectively, while the phase current registers at 0.8pu and 75pu. When a three-phase fault occurs, the phase voltage magnitude plummets to zero in the time domain and to 74pu in the frequency domain. Conversely, the phase current magnitude surges to 45pu in the time domain and to 95pu in the frequency domain. Overall, the study observed a decline in the phase voltage values, the voltage energy, and the S-transform of the voltage during a three-phase fault, whereas the corresponding current values escalated in both domains. The findings demonstrate that the S-transform technique is effective in detecting faults along transmission lines.*

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I. INTRODUCTION

The power system transmission line is a critical link in the transmission of electricity to the consumer. Transmission line protection is a critical problem in power system engineering since transmission lines are the source of over 80% percent of failures. Any abnormal event in the system involving the electrical breakdown of equipment such as transformers, generators, bus bars, and so on is referred to as a fault in an electric power system (Neha, 2016). To ensure the safety of the electrical power system, fault detection and classification is an important task. It must be completed as fast and accurate as possible in order to isolate the faulty line and safeguard the system from the fault's damaging repercussions (Tirnovan, 2019). When two or more conductors come in contact with each other, or when one or more conductors make contact with ground, a fault occurs. Faults in three-phase systems are categorized as single line-to-ground, line-to-line, double line-to-ground, and three phase faults. These failures cause significant damage to power system components. Faults in transmission lines damage not just the equipment but also the quality of electricity supplied to customers. In order to avoid such losses, identifying the kind of fault on the transmission lines quickly is critical for the efficient running of power systems. Faster fault rectification, higher system availability, lower operating costs, and saving of time are all benefits of accurate fault identification. Transmission line faults must be recognized, classified, correctly identified, and removed as fast as possible. The two most essential elements that need to be addressed in a reliable and precise manner in power transmission line protection are faulty phase identification and localization of fault.

Signal Processing techniques involving Fourier Transform, Wavelet Transform and S-Transform have become very popular tools in detection of transients of power system network, diagnosis of Transmission line faults, classification of faults and identification of the affected phase. A technique of fault categorization for distribution systems is given in (Nor, 2010.) by using a different sequence networks. Different signal processing techniques have been applied for classifying different types of Transmission line faults in power systems. Among, the most widely used are the Fast Fourier transforms (FFT) and the Short Time Fourier Transforms (STFT) (Moussa, 2004). Fourier transform have restriction of constant bandwidth of window size so using Fourier Transform study of nonstationary signal is not possible. So Gabor develop new method i.e. STFT which consists of variable window. Wavelet theory, which deals with edifice a model for non-stationary signals, using a set of components that look like small waves, called wavelets. Discrete Wavelet Transform (DWT) is a dominant signal analysis tool which is broadly used for fault classification in transmission lines. Many vital features are mainly extracted from the line current or voltage signals using DWT method (Pratik, 2016). The S-transform is an expansion of the concept wavelet transforms, it is a combination of STFT and CWT and it provide excellent time localization of current signals throughout fault conditions. It has suitably and accurately identified power system disturbances in (Ameen, 2008). The output of the S-Transform is the complex S-Matrix. This S-Matrix is used to extract various characteristics. This straightforward feature extraction is programmed in MATLAB.

II. S –TRANSFORM

S-transform (ST) is the Combination of Wavelet transform and short time Fourier transforms, it overcomes the limitation of Wavelet transform and short time Fourier transforms (Srividya, 2013). S-Transform (ST) has the capability to detect a fault in the influence of noise. Because of this feature, it is very popular in detecting power system faults and power quality disturbances. S-transforms are notable for their ability to combine a frequency-dependent resolution of time-frequency space with local phase information that is absolutely referenced a property that the wavelet transform does not have. The local spectral phase characteristics of the S-transform make it a popular time-frequency representation. According to (H. Hasanvand et al, 2017), who studied distribution network fault location using the S-transform. The study showed that the S-transform may be used to locate distribution network faults based on transient signals. This approach is based on a moving and scalable localizing Gaussian window and is an extension of the Wavelet transform method. The location of the fault may be determined by looking at the connection between the signal energy of faults and so-called path characteristic frequencies associated with fault travelling waves, which have a high amplitude around specific frequencies. S-Transform is used to determine the energy of a transient voltage signal (H. Hasanvand et al, 2017). Also, (Neha Agarwal, 2016) proposed an approach for the detection of power system failures such as Line to Ground Fault, Double Line Fault, and Double Line to Ground Faults, when resistive-inductive loads are present in the power system. These faults were discovered by using the S–Transform (Stockwell's transform). They used MATLAB/Simulink to conduct this investigation. (Bhuvnesh R. et al, 2018) presents a Stockwell transform decision tree to diagnose transmission faults with two terminals

One of the most important technologies for enhancing distribution network operations' safety and efficiency is the capacity to quickly and accurately locate faults in a high-reliability distribution network. (Shuyu Guo et al, 2020) proposes a new technique for locating faults in a 35-kV high-reliability distribution system. An application of a signal processing model for fault detection on an electric power transmission line is discussed in (Ogboh, et al, 2020). There a 100Km, 50Hz, and 330kV transmission line was studied using Matlab to model the power line. The fault parameters, both symmetrical and unsymmetrical, were derived. The faults were detected by using Matlab's S – Transform mathematical expressions linked to the Simulink transmission line circuit. Using Signal Processing, (Pratik W. C., et al, 2016) offers a novel way to analyze transmission line faults in the power system using the multiresolution S-Transform method which utilizes a frequency-dependent variable-width window. Power electronics circuit fault diagnostics now includes a technique based on S transforms and support vector machines that uses time-frequency analysis of the fault signal to identify characteristics related to different types of faults. It also performs well in terms of noise robustness and computation complexity, making it useful for troubleshooting power electronics circuit faults (Wang, et al, 2016). Time-frequency analysis was used to pinpoint the exact location of the transmission line fault in (Shweta, et al, 2019). Moreover for the purpose of locating high voltage transmission line faults, (Panda G. et al, 2015) describes a number of different methods that have been utilized. S-transform was utilized as a time-frequency filter in (Pinnegar C. et al, 2003).Transmission line fault identification, classification, and localization are all accomplished with the use of time-frequency transforms like the S-Transform and its variants (Panda G. et al, 2015).

A picture is a function of the independent space variables. (Mansinha L, et al, 1997) introduces the two-dimensional S transform as a technique for calculating the local spectrum at picture pixel. Magnetic resonance imaging may be used to detect textural features of brain disease using the two-dimensional S-transform (2D-ST) (Drabycz S. et al, 2007). Electroencephalograph (EEG) signals are most often disturbed by ocular artefacts, which are visual distortions. These have a large amplitude, but they also have a frequency range that overlaps the usable signal. As a result, conventional filtering techniques fail miserably when trying to eliminate ocular artefacts. The S-transform is proposed as a novel method of artefact elimination by (Kedarnath S., et al, 2011). It's fascinating to see how humans interpret sound. Simple: it starts with hearing a sound, classifying it and then deciding how to respond. The stages are the same in audio signal processing. The S-Transform (ST) was utilized in terms of sound recognition and interpretation by (Nathan Fuhrer, 2010). (Ashrafian A., et al, 2012) The Stockwell transform (ST) is a multiresolution transform that was recently developed and provides frequency and phase information that are completely referenced to each other. (Yanwei Wang, 2011).

The identification of power system failures such line to ground (L-G), double line (L-L), double line to ground (L-LG), and three phase fault affecting ground has been addressed in this study using a method based on the Stockwell Transform. The proposed study has been carried out in the MATLAB/Simulink environment using the Onitsha to New-Haven transmission line as test system. It has been concluded that the proposed algorithm is effective in the detection of power system faults.

III. METHODOLOGY

330kV transmission line Matlab/Simulink model extraction of the three-phase voltage and current signals

According to Sadiku and Alexandra, 2006, three – phase voltage and current signals of the transmission line are represented by equations 1.1 to 1.6.

(1.1) $$v_a = V_p \sin(\theta + \emptyset)$$

(1.2) $$v_b = V_p \sin(\theta + \emptyset)$$

(1.3) $$v_C = V_p \sin(\theta + \emptyset)$$

(1.4) $$i_a = I_p \sin(\theta + \varphi)$$

(1.5) $$i_b = I_p \sin(\theta + \varphi)$$

(1.6) $$i_C = I_p \sin(\theta + \varphi)$$

(1.7) $$V_p(n) = \frac{2}{3}\left[v_a + v_b(n)e^{\frac{j2\pi}{N}} + v_c(n)e^{\frac{-j2\pi}{N}} \right]$$

(1.8) $$I_p(n) = \frac{2}{3}\left[i_a + i_b(n)e^{\frac{j2\pi}{N}} + i_c(n)e^{\frac{-j2\pi}{N}} \right]$$

Equation (1.7) and (1.8) is the discretization equation used for the determination of discontinuous three – phase voltage and current signal from the transmission line.

employing the Time-Frequency approach to find faults in the transmission line of the power system. A .a strong tool for fault localization, classification, and detection for transmission line protection is the time-frequency analysis approach. It is a Short Time Fourier Transform (STFT) and Wavelet Transform-based invertible Time-Frequency (S-Transform) analytical tool (WT). In order to address the issue of STFT applications' limits, a mathematical expression derived from the Short Time Fourier Transform (STFT) and Wavelet Transform (WT) was developed. In that it offers multi-resolution analysis while preserving the absolute phase of each frequency, the S-Transform has an advantage. It has been adopted in the field of electrical engineering for defect identification in time series for this reason, among others.

The Time-Frequency (S-Transform) formulation for a continuous signal (voltage or current signal) is as follows: x(t);

(1.9) $$S(\tau, f) = \int_{-\infty}^{\infty} x(t)\left\{\frac{|f|}{\alpha\sqrt{2\pi}}\right\}. e^{\left(\frac{-f^2(\tau-t)^2}{2\alpha^2}\right)}. e^{(-2\pi i f t)}\, dt$$

Where f is the frequency, t is the time, τ is the parameter that controls the position of Gaussian window on the t-axis and α is a control factor of time and frequency resolution of the transform. The lower α means higher time resolution and lower frequency and vice versa.

A suitable value of α lies between the ranges of $0.2 \leq \alpha \leq 1$.

Given Equation 1.9's discrete representation of the continuous S-Transform (DST), the DST is defined by the following expression.

(1.10) $$S(j, n) = \sum_{m=0}^{N-1} X(m+n). e^{\left(\frac{-2\pi^2 m^2 \alpha^2}{n^2}\right)}. e^{(i2\pi mj)}$$

Where, j = 1……N – 1, n = 0, 1…N -1.

However, j and n stand for the frequency step and time samples, respectively.

X(m + n) can be obtained in a straight forward manner from equation 1.11 below.

(1.11) $$X(n) = \frac{1}{N}\sum_{K=0}^{N-1} x(k) . e^{(i2\pi nk)}$$

Where, n = 0, 1…, N-1

Also, the Fourier spectrum of the Gaussian window at a specific n (frequency) is called a voice Gaussian and for the frequency $f_1(n_1)$, the voice can be obtained as;

(1.12) $$S(j, n_1) = A(j, n_1). e^{(j\phi(j,n_1))}$$

Where the voice's pick value is

(1.13) $$\max\big(S(j, n_1)\big) = \max(A(j, n_1))$$

And

$$\phi(j, n_1) = \text{atan}\left\{\frac{\text{imag}\,(S(j,n_1))}{\text{real}\,(S(j,n_1))}\right\} \quad (1.14)$$

The energy E of the signal is then determined using the S-Transform as

$$E = \{\text{abs}(S(j, n_1))\}^2 \quad (1.15)$$

The energy signal obtained from S - Transform is used to detect and classify the fault on the transmission line (Dash P. et al, 2007).

b. Modeling the Discretization Equation

Equations 1.7 and 1.8 were modeled using MATLAB/SIMULINK block to obtain Figures 1. 9. and 1.10. However, the input ports figures 1.9 and 1.10 are connected to output signal port of the voltage – current Matlab/Simulink measurement block to extract the continuous phase voltage and current signals as input signals into the system. They processes the signals in-line their modeled mathematical derivations to obtain the discontinuous output voltage (Vp) and current (Ip) as their discrete version.

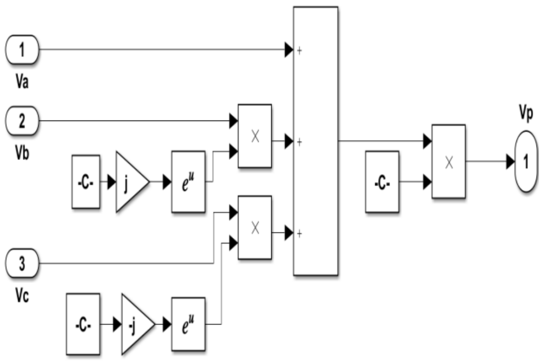


Figure 1.9: Discrete Voltage Simulink Block

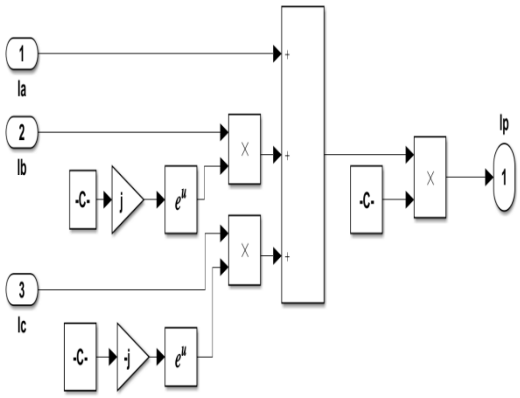


Figure 1.10: Discrete Current Simulink Block

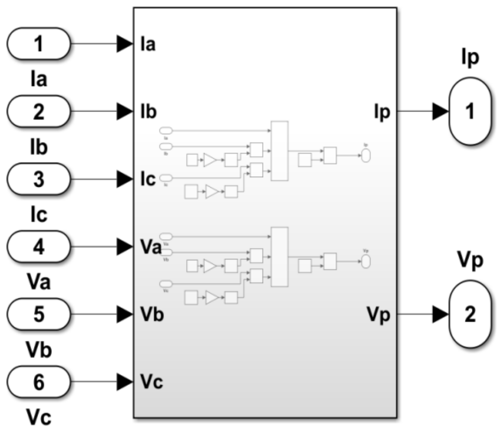


Figure 1.11: Phase Voltage and Current Subsystem

MODELING THE DISCRETIZED TIME – FREQUENCY EQUATION .c

Figures 1.12 and 1.13 are the Matlab/Simulink models of equation 1.10 for voltage and current signals respectively. The input port of figure 1.12 is connected to the output port of figure 1.9, while the input port of figure 1.13 is connected to the output port of figure 1.10 for extraction of the discretized voltage and current signals respectively.

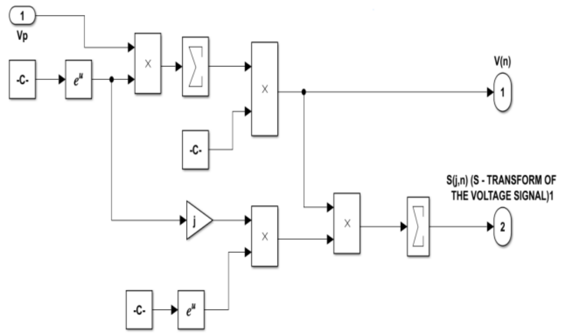


Figure 1.12: Discrete S -Transform Computation Model for Voltage Signal

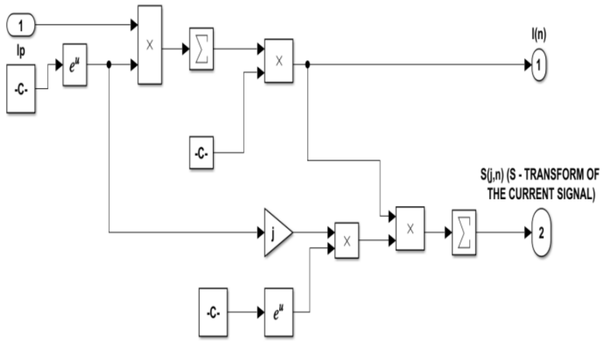


Figure 1.13: Discrete S -Transform Computation Model for Current Signal

DISCRETE ENERGY SIGNAL OF THE THREE-PHASE VOLTAGE AND CURRENT COMPUTATION .d

The voltage and current discrete energy signals are the signals that display the size, severity, and frequency of line faults.

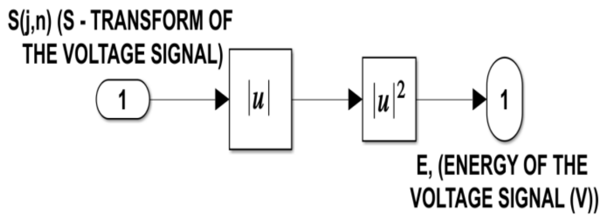


Figure 1.14: Discrete S -Transform Energy Signal Computation Model for Voltage Signal

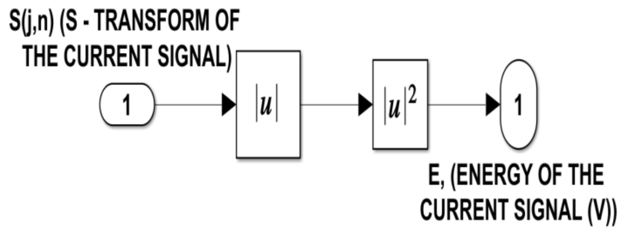


Figure 1.15: Discrete S -Transform Energy Signal Computation Model for Current Signal

Only when there is no network failure may the magnitude of the voltage energy signal be larger than the size of the current energy signal. The energy equation of 1.15 is incorrect if the magnitude of the voltage energy signal output is larger than the size of the current energy signal output following fault simulations. When a failure occurs in the network, the size of the voltage energy signal is anticipated to be lower than that of the current signal. This is because, according the standard electric circuit or network theories, when fault occurs on an electric circuit, the voltage magnitude decreases while the current increases, hence magnitude of energy signal of current during faulty condition is greater than that of voltage (Dash P. et al, 2007).

Discrete three-phase voltage and current signal computation

The computation of the discrete three – phase pre-fault and fault voltage and current signals is achieved using figures 1.9 and 1.10 respectively. Their values computed are shown in table 2.3 and 2.4 respectively.

Calculate the three-phase voltage and current time-frequency discrete signals.

Figures 1.8 and 1.9 are used to compute the time-frequency discrete three-phase pre-fault and fault voltage and current signal for single phase to ground, double phase to ground, phase to phase, and three-phase faults. Their values are shown on table 2.5 and 2.6 respectively.

Also, figure 1.14 which represent the computation model for computing the energy signal of the voltage and current of the transmission line for pre-fault and fault conditions. The fault signal for the parameter is represented by the energy signal equation 1.15, which also carries the parameter's fault frequency component.

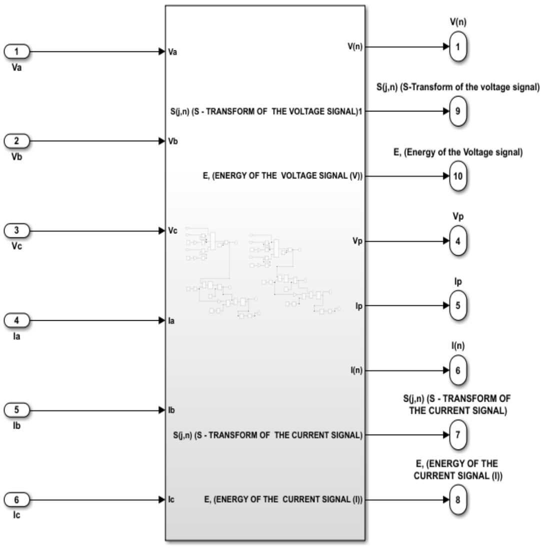
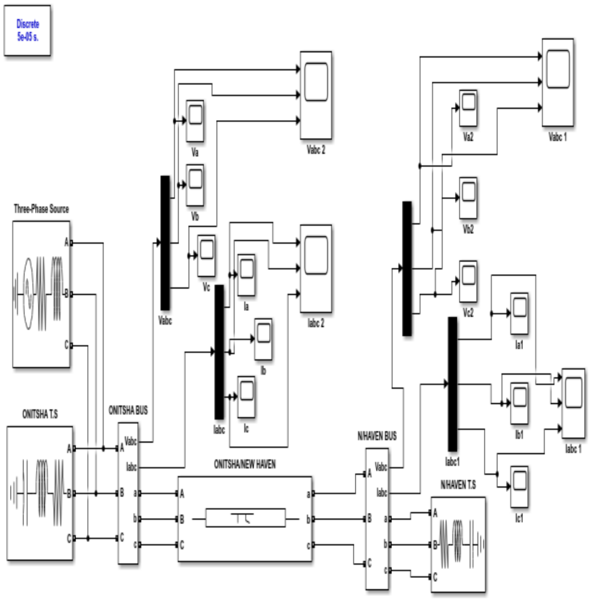


Figure 1.15: Complete Discrete S -Transform Model for the Computation Voltage and Current Signal Conditions

Figure 1.15 is a subsystem containing the Matlab/Simulink model for computing discrete values of pre-fault and fault voltage and current. Additionally, it includes energy models for voltage and current signals as well as the S-Transform fault detection model.

The voltage-current measurement block in Matlab/Simulink is connected to the inputs of the S-Transform fault detection model to extract the phase voltage and current signals. Each of the models in the S – Transform fault detection system is linked to the input signals. They calculate the values of their voltage and current signal and provide the results. In chapter four, their findings are tallied



appropriately.

Figure 1.16: Modelled Simulink diagram of the Onitsha to New-Haven transmission line network

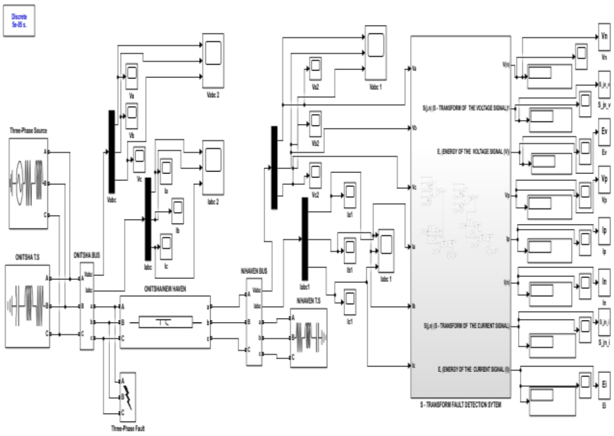


Figure 1.17: S – Transform Model Connected to the Case Study Transmission Line for Pre-fault and fault Voltage and Current Computation

RESULTS AND DISCUSSIONS .IV

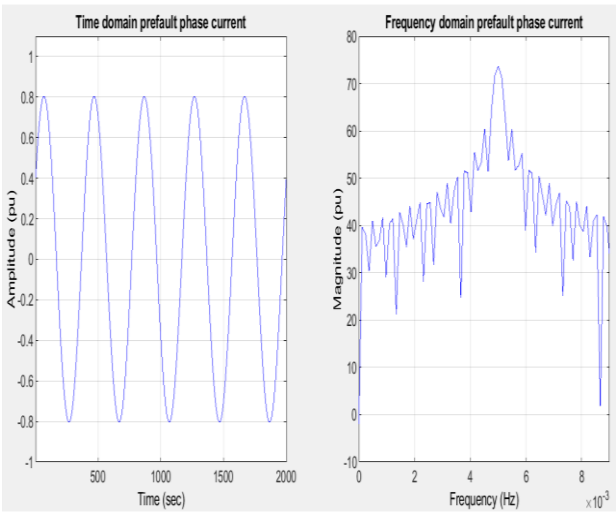


Figure 2.11: Time and Frequency Domain Onitsha – New Haven 330kV Transmission Line Pre-fault Current Waveform

A time and frequency domain graph shows how a signal changes over time and frequency. A frequency domain graph compares how much of a signal is contained inside each frequency band over a range of frequencies to a time domain graph, which depicts how a signal evolves over time. Figure 2.11, the amplitude of the time domain pre-fault phase current when the s-transform is applied is about 0.8pu. The frequency domain prefault frequency domain prefault phase current magnitude of 75pu.

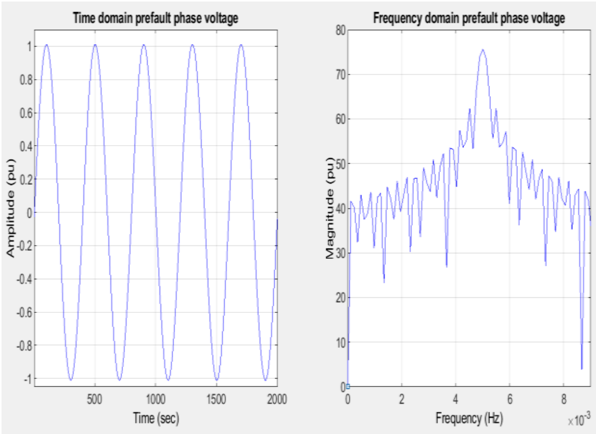


Figure 2.12: Time and Frequency Domain Onitsha – New Haven Transmission Line Pre-fault Voltage Waveform

In figure 2.12, the time domain of the pre-fault phase voltage which shows the time dependent value of the voltage. When the S-transform was applied, the highest voltage amplitude is 1pu, while the highest frequency domain which shows the frequency magnitude of the pre-fault phase voltage is 75pu.

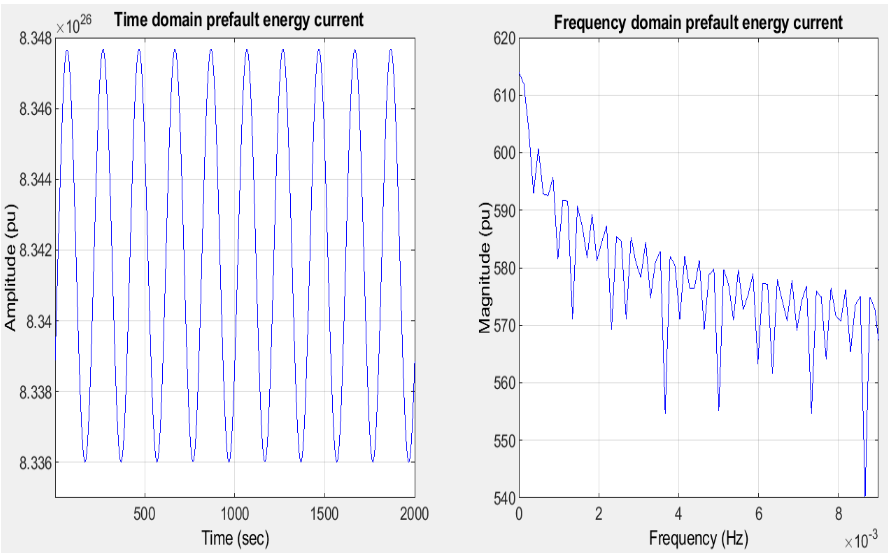


Figure 2.13: Time and Frequency Domain Onitsha – New Haven Transmission Line Pre-fault Energy of Current Waveform.

The time frequency domain of pre-fault energy current amplitude in time domain in figure 2.13 is about 8.348e26 while in time domain amplitude is 615pu.

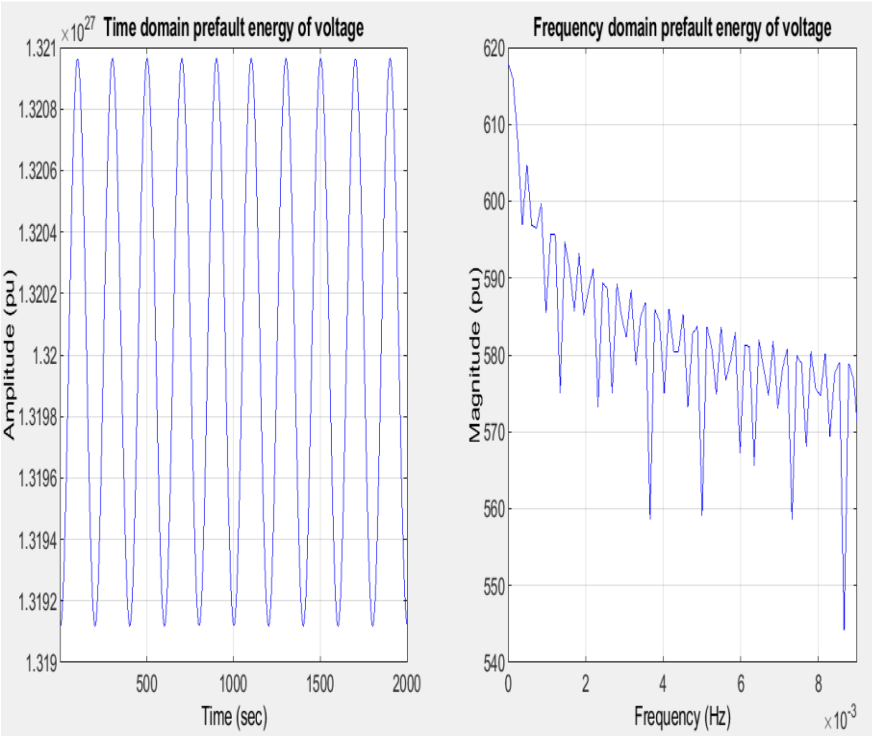


Figure 2.14: Time and Frequency Domain Onitsha – New Haven Transmission Line Pre-fault Energy of Voltage Waveform.

The Onitsha – New Haven transmission line time and frequency domain energy of the voltage waveform in figure 2.14 shows the time composition of the pre-fault energy voltage to be 1.321e27 pu whereas the frequency domain magnitude is about 619pu when the S-transform was applied.

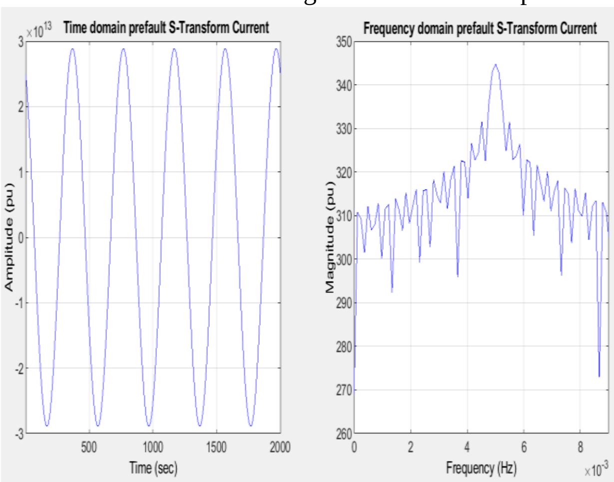


Figure 2.15: Time and Frequency Domain Onitsha New Haven Transmission Line Pre-fault S-Transform Current Waveform. In figure 2.15, the S-Transform pre-fault current waveform amplitude in time domain is about 3e13pu while the frequency magnitude in the frequency domain is about 345pu.

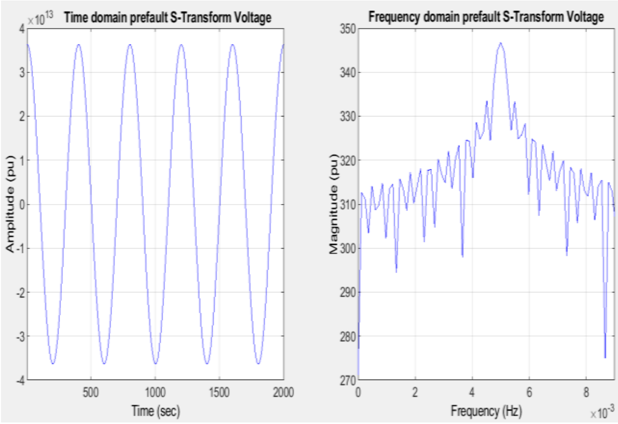


Figure 2.16: Time and Frequency Domain Onitsha – New Haven Transmission Line Pre-fault S-Transform Voltage Waveform

The S-transform pre-fault voltage waveform from figure 2.16 shows the amplitude of the voltage when the s-transform is applied in time domain to be 3.9e13pu. The frequency domain pre-fault S-transform voltage magnitude is 349pu.

Table 2.2: Time & Frequency Domain Pre-fault Voltage and Current Computation at No Fault Condition

S/N	S-Transform parameters	Time domain (pu)	Frequency domain (pu)
1	V_p	1	75
2	I_p	0.8	75
3	E_v	1.321e27	619
4	E_i	8.348e26	615
5	$S - T_v$	3.9e13	349
6	$S - T_I$	3e13	345

Where

V_p = discretized voltage
I_p = discretized current
E_v = energy of voltage
E_i = energy of current
V_p = discretized voltage
$S - T_v$ = Stockwell transform of the voltage
$S - T_I$ = Stockewell transform of the current

Signals in the time domain (T) depend on the amount of time it takes for them to occur. But the quantity and size of the spectrum affect the frequency-domain (s).

According to Mohammed (2013), time and frequency domain signals are the most signals in practice and that in many applications of signal processing, the frequency content of the signals contains the most relevant and discrete information. Thus various mathematical transform are used to analyze those signal processes. High frequency current and voltage waves are present in the transmission line along with additional waveform analysis factors including reactance, resistance, capacitance, admittance, and conductance.

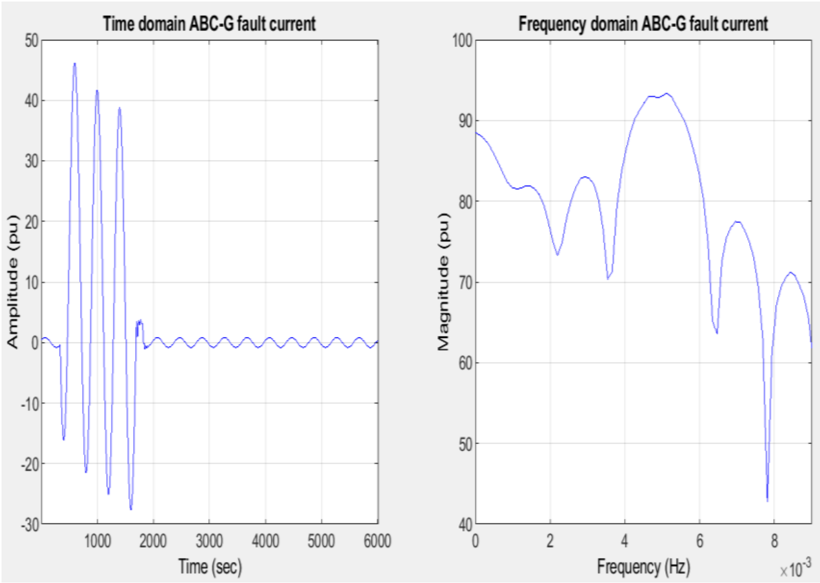


Figure 2.17: Time and Frequency Domain Onitsha – New Haven Transmission Line ABC-G Fault Current Waveform

The time domain of the three phase ABC-G phase current fault in figure 2.17 show the amplitude of the time domain to be 45pu at the time of the three phase to ground fault occurrence and after the fault was cleared at about 2000 seconds, it maintained its original amplitude. The frequency domain of the ABC-G fault phase current magnitude is about 95pu.

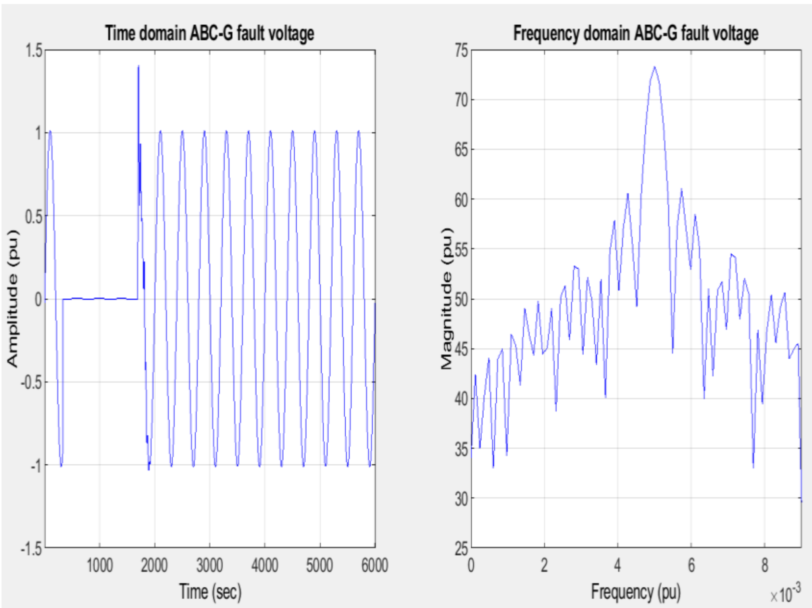


Figure 2.18: Time and Frequency Domain Onitsha – New Haven Transmission Line ABC-G Fault Voltage Waveform

Figure 2.18 shows the time domain ABC-G fault phase voltage amplitude to be about 1pu. The amplitude dropped to zero (0) when the fault occurred indicating that there is fault, later it retained its original amplitude value of 1pu after the fault was cleared. The frequency domain magnitude of the ABC-G fault phase voltage is 74pu.

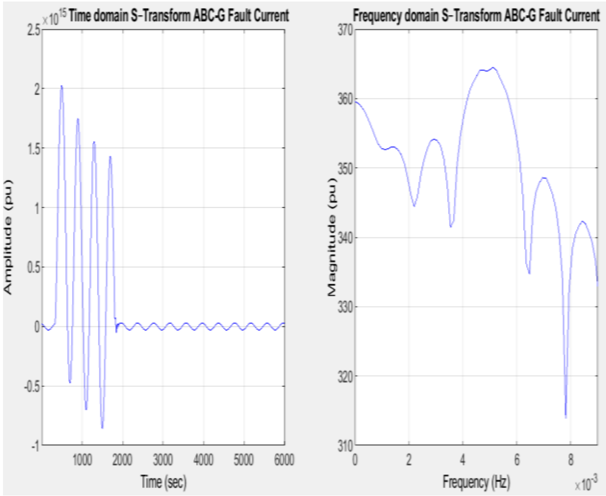


Figure 2.19: Time and Frequency Domain Onitsha – New Haven Transmission Line S–Transform ABC-G Fault Current Waveform

The time domain S-transform ABC-G fault current amplitude from figure 2.19 to be about 2e15pu and the frequency domain S-transform ABC-G fault current magnitude about 365pu.

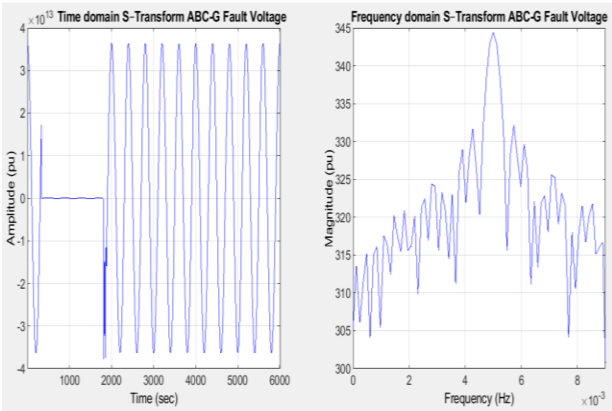


Figure 2.20: Time and Frequency Domain Onitsha – New Haven Transmission Line S–Transform ABC-G Fault Voltage Waveform

Figure 2.20 shows the time domain ABC-G S-transform fault voltage amplitude to be 3.9e13pu before the fault occurred. At about 450 seconds when the fault occurred the amplitude in the time domain dropped to zero and later returned to its original form after the fault was cleared. The frequency domain magnitude of the S-Transform ABC-G fault voltage is 345pu.

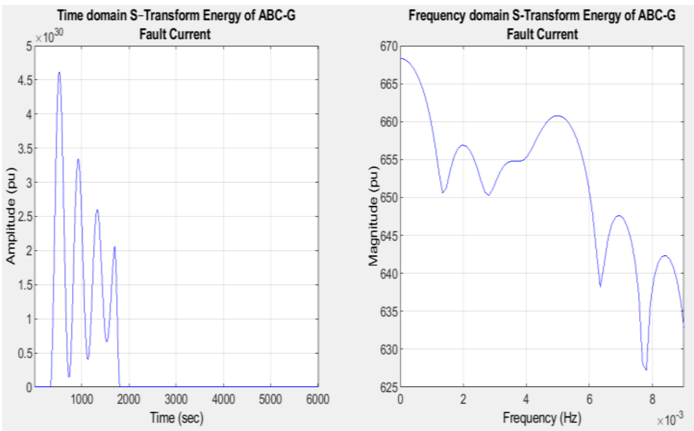


Figure 2.21: Time and Frequency Domain Onitsha – New Haven Transmission Line S–Transform Energy of Fault Current Waveform

Figure 2.21 which shows the time and frequency domain of the Onitsha-New Haven transmission line S-transform Energy of the fault current waveform. It shows that the amplitude of the energy of the current in time domain is 4.6e30pu and the frequency domain magnitude is about 669pu.

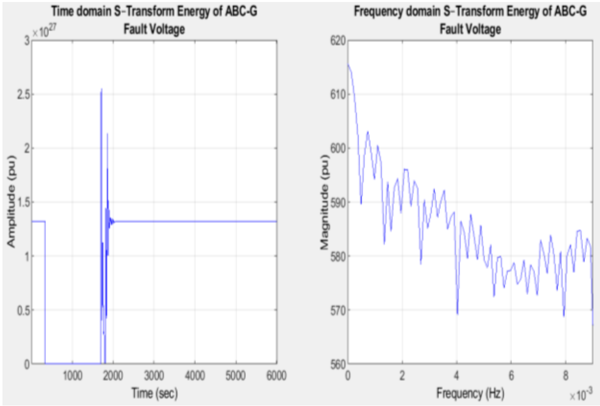


Figure 2.22: Time and Frequency Domain Onitsha – New Haven Transmission Line S–Transform Energy of Fault Voltage Waveform

The Time and Frequency Domain of the Onitsha – New Haven Transmission Line S – Transform Energy of Fault Voltage Waveform is shown in figure 2.22 above. The amplitude of the voltage is about 2.5e27pu in the time domain. The voltage magnitude dropped to zero (0) at the time when the fault occurred and the waveform was restored to its original position when the fault was cleared. It also shows the frequency domain to have about 615pu in magnitude.

Table 2.3: Time & Frequency Domain fault Voltage and Current Computation at Three Phase (ABC) Fault Condition

S/N	S-Transform Parameters	Time Domain (pu)	Frequency Domain (pu)
1	Vp	0	74
2	Ip	45	95
3	Ev	0	615
4	Ei	4.6e30	669
5	S-Tv	0	345
6	S-Ti	2e15	365

Table 2.3 which shows a tabulated result of the Time & Frequency Domain fault Voltage and Current Computation at Three Phase (ABC) Fault Condition. It is seen from the above table that frequency domain magnitude of the current is higher than that of the voltage counterpart at the occurrence of a three phase ABC fault.

V. CONCLUSION

This study introduces the new simplified signal processing technique which bridges the gap created by the complex and abstract nature of the fundamental signal processing techniques. It has been able to develop and implement a fault detection model based on Stockwell Transform (S - Transform) for fault detection on the any transmission line. This fault detection model is developed, implemented using mathematical modeling and simulation approaches in Matlab environment. Considering the performance of the model, the output results obtained and the difficulties encountered, it was that, the model produced time – and frequency – domain waveforms and spectrum diagrams respectively. These diagrams illustrates the faulty conditions of the transmission line and the low and large magnitude S – Transform parameters (voltage and current) respectively against that of no faults are evidence that fault occurred and were detected on the transmission line. Further studies on this work will be very useful especially in the areas of classification and location of fault in power system generation, transmission and distribution and other engineering discipline. Also, the method can be combined with the artificial intelligence (artificial neural network, genetic algorithm, swam optimization, support vector machines, radial basic functions etc.) to solve some problems in power system protections, power system planning and optimization, stability analysis and other engineering areas.

REFRENCES

[1] Ameen, M. G. (2008). Automatic classification and characterisation of Power qualitiy events. IEEE Trans. On Power Delivery, 23(4), 2417-2425.
[2] Lin Yun, X. X. (2013). Time-frequency Analysis Based on the S-transform. International Journal of Signal Processing, Image Processing and Pattern Recognition, 6(5), 245-254. Retrieved from http://dx.doi.org/10.14257/ijsip.2013.6.5.22

[3] Madhavi, C. B. (2013, November). Transmission Line Protection Using Wavelet Transform. International Journal of Engineering Research & Technology (IJERT), 2(11), 2169-2176.

[4] Moussa, A. M.-G.-S. (2004). Hardware – software structure for on-line power quality assessment. in Proc of the 2004 ASME/IEEE Joint, 147-152.

[5] Neha Agarwal, O. P. (2016). Detection of Power System Faults in the Presence of Linear Loads Using Stockwell Transform. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE), 11(5), 37-45.

[6] Neha, K. S. (2016). Power System Faults: A Review. INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) CMRAES, 4(2), 1-2.

[7] Nor, M. A.-A. (2010, October). Fault analysis of Multiphase Distribution Systems Using Symmetrical Components. IEEE Trans. On Power Delivery, 25(4), 2931-2939.

[8] Pratik, W. R. (2016). Analysis of Different Types of Faults in Power System Using S-Transform. National Conference on Innovative Trends in Science and Engineering (NC-ITSE'16). 4, pp. 26-28. IJRITCC.

[9] Srividya, T. A. (2013). Identifying, Classifying Power Quality Disturbances Using Short Time Fourier Transform & S-Transform. Weekly Science, 1(1), 2321-7871.

[10] Tirnovan, R. C. (2019). Advanced techniques for fault detection and classification in electrical power transmission systems: An overview. Conference: 2019 8th International Conference on Modern Power Systems (MPS).