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Time – Frequency Analysis Technique for Fault Investigation on Power System Transmission Lines

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ABSTRACT:
This paper explainsapplication of signal processing model for detection of fault on power system transmission line. The transmission line under consideration is a 100Km, 50Hz and 330kV transmission line. The power line is simulated in Matlab to obtain the symmetrical and unsymmetrical fault parameters. The S – Transform mathematical expressions are modeled in Matlab and connected to the Simulink transmission line circuit for detection of the faults. The results obtained when the S – Transform is applied to the transmission line produced current mesh grid plots which shows that the fault current is far greater than the No fault current and that window width is no more constant but varied to illustrate harmonics disturbances or faults occurrence on the transmission line.
KEYWORD: *S – Transform, Power System, Transmission Lines, Frequency Domain, Time Domain, Signal Analysis*

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I. INTRODUCTION

It is an inevitable fact that faults occurs on the power system transmission lines. These faults must be detected, located, classified for record purposes and finally cleared to avoid damage of the network. Symmetrical and unsymmetrical faults occur on the lines and various methods have been implemented for determination of the line conditions, type of fault that occurred and the point at which the fault occurred.

Among these methods are signal analysis methods (Laplace, Fourier, Fast Fourier, Wavelet and Stockwell) Transforms have been in use for fault diagnosis on the electric power lines.

Fourier Transform contains information about the spectral components in time series, but cannot detect the time distribution of different frequencies.

Therefore, Fourier Transform is not suitable for a large class of practical problem since its time – domain state can provide information about the time of distribution of signal, but when in frequency – domain cannot provide the time distribution of the frequency of the signal. Hence,time – frequency domain technique capable of providing both time and frequency of distribution the signal suffices.

Among the various forms of Fourier Transforms, the Short Time Fourier Transform (STFT) is frequently used as a time – frequency tool for analysis of signals. But it cannot provide the progressive distribution of signal dynamics very well especially for a non – stationary signal such as voltage or current signals because of its limitations of fixed window width.

To overcome the limitation of fixed window width in STFT application, the Wavelet Transform (WT) is used. WT is good at extracting information from both time and frequency domain, but sensitive to noise, this provide enormous result [1].

Since the development of Stockwell Transform(S – Transform), it has been widely used in the various applications ranging from geophysics, oceanography, atmospheric physics, medicine, hydrogeology and many engineering disciplines such as mechanical and electrical engineering [2].

S – Transform can be used to find out both time and frequency information with proper time and frequency resolution respectively which contain fault information about the transmission line [1].

In this paper, a comparative analysis of the application of S – Transformfor the detection of fault on theEnugu – Nsukka 330kV and IEEE 9Bus Transmission Line Networktransmission line is performed.

II. METHODOLOGY

A. Generalized S – Transform

This is an extension of Short Time Fourier Transform (STFT) and Wavelet Transform (WT). It overcomes the limitations of STFT and WT. It is a multi-resolution spectral analysis tool which is based on a moving and scalable localizing Gaussian window [1].

S – Transform of a basic continuous signal such as electric current i(t) of a transmission line is defined by equation (1).

$$S(f,\tau) = \int_{-\infty}^{\infty} i(t) g(f, \tau - t) e^{-j2\pi ft} dt \qquad 1$$

But,

$$g(f,\tau) = \frac{|f|}{\sqrt{2\pi}} e^{-(\frac{t^2}{2\rho^2})} \qquad 2$$

Where equation (2) is called the Gaussian modulating function.

$$\rho = \frac{1}{(|f|)} 3$$

Equation (3) is called the standard deviation

$$S(f,\tau) = \int_{-\infty}^{\infty} i(t) \left(\frac{|f|}{\sqrt{2\pi}}\right) (e^{-\left(\frac{(\tau-t)^2 f^2}{2}\right)}) e^{-j2\pi ft} dt \qquad 4$$

Combining equations (1) & (2), we obtain equation (4)

Where f denotes the frequency of the signal t and τ both represent time of distribution of signals.

$$S(f,\tau) = \sum_{m=0}^{N-1} I\left(\frac{m+n}{NT}\right) G(m,n) \left(e^{\left(\frac{2\pi mij}{N}\right)}\right) 5$$

But,

$$G(m,n) = e^{\frac{-2\pi^2 m^2 \alpha^2}{n^2}} 6$$

Where,

n = 0, 1, 2, …, N – 1

j = m = 0, 1, 2, …, N – 1 and

N = Number of Samples of signals.

However, the discretized form of the S – Transform is given by equation (5).

According to [3][5], S – Transform of a signal generates S – Matrix in output in which the row matrix defines the value of the frequency and the column matrix define the value of the time.

The size of the S - Matrix depends on number of samples of the signals.

B. S – TRANSFORM APPLICATION FOR TRANSMISSION LINE FAULT DETECTION

Considering equation (6), the trigonometric function can be applied here for determination of the implementation of the signal discrete value [4].

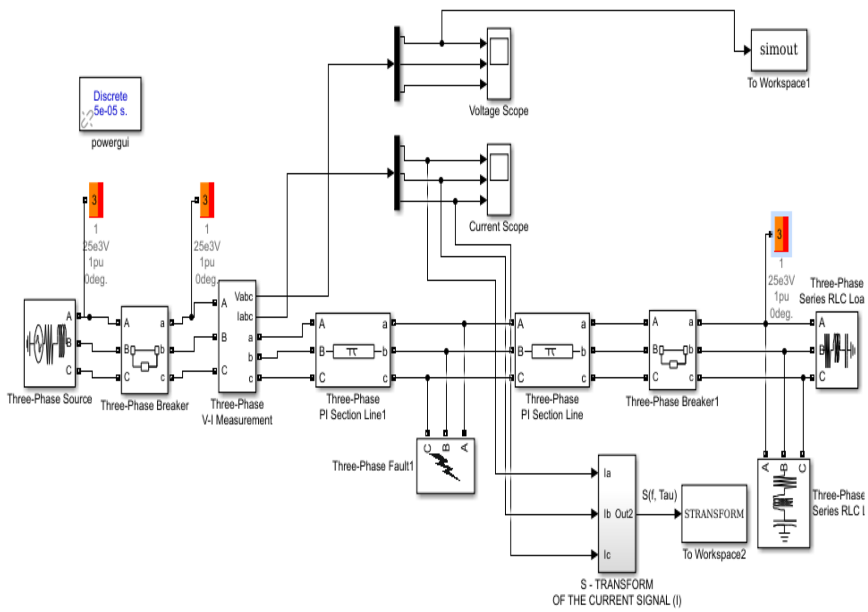

Figure 1: Enugu - Nsukka330kVTransmission Line

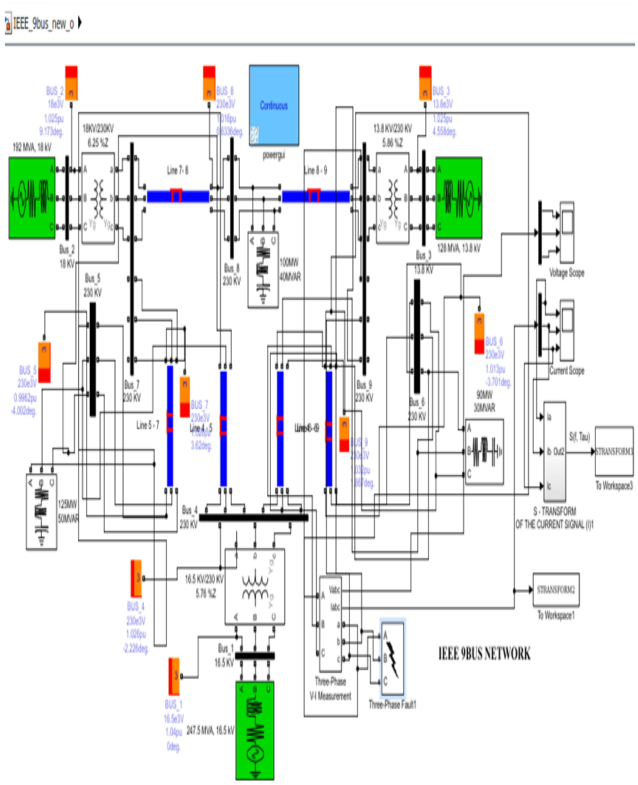

Figure2:IEEE 9Bus System Network

$$I_P = \frac{2}{3}\left(i_a + i_b e^{\frac{2\pi^2 m^2 \alpha^2}{n^2}} + i_c e^{-\frac{2\pi^2 m^2 \alpha^2}{n^2}}\right) \qquad 7$$

$$I = I_P \sin(nwt + \varphi) 8$$

Equation (7) is the discrete value of the current signal while equation (8) is the phase version of the discrete current signal.

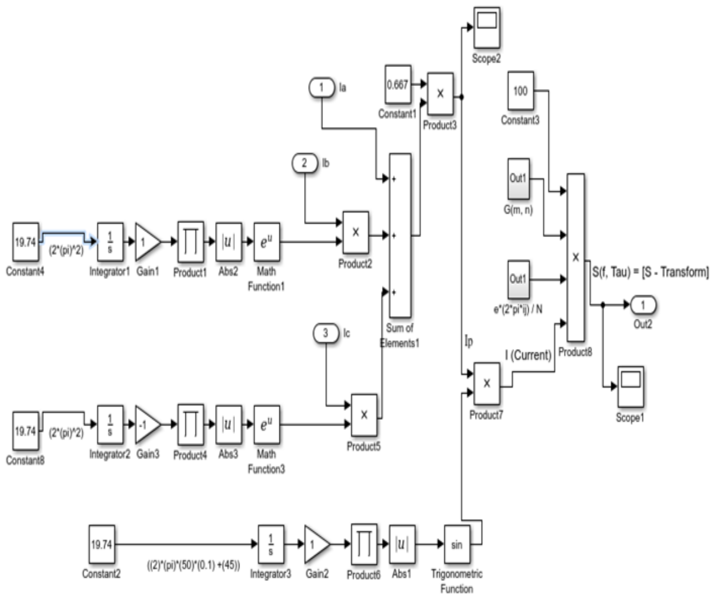

Figure 3: S – Transform Model for the fault detection

Equations (5), (6), (7) and (8) are modeled in the Matlab environment to obtain figure (2).
Symmetrical and Unsymmetrical faults are simulated and their point of occurrence determined by this technique.

III. RESULTS AND DISCUSSION

The results of the simulation of the model for symmetrical and unsymmetrical faults are shown in mesh-grid and spectral waveforms.
The model is also tested on the 14 – bus IEEE network to compare with and validate the test results obtained for a 330kV transmission line model figure (1).

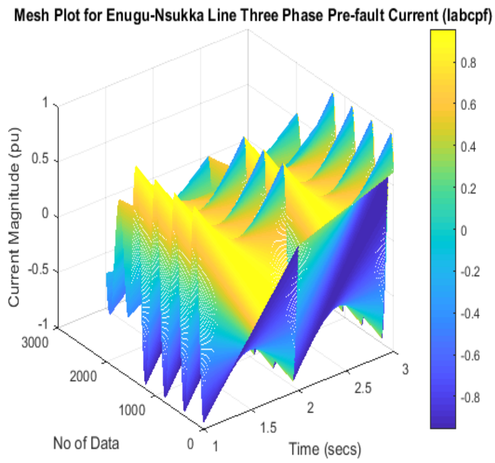

Figure 4: Mesh Plot Three Phase Pre-Fault Current ($Iabc_{pf}$) for 330kV Enugu - Nsukka Transmission Line

Here, pre-fault mesh current plot show three basic colour bands which are blue, yellow and green. These colour bands represent the magnitude of Ia, Ib and Iccurrent signals respectively.
According to the colour band, the position of a colour on the waveform determines its unit magnitude. Thus, figure 4 show that Ib has the highest magnitude (0.8pu) followed by green colour (line C) with 0.4pu. Blue colour (Ia) has a magnitude almost equal to Ibbut slightly greater that Ib [5][6].

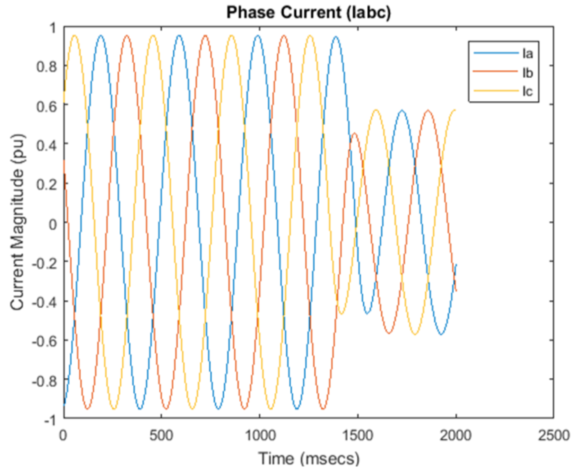

Figure 5: Enugu - Nsukka330kVTransmission Line Pre-Fault Current Waveform

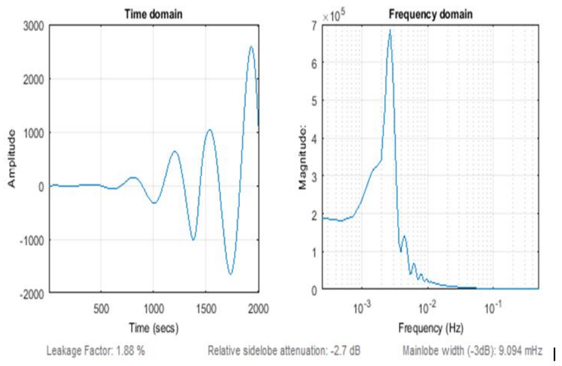

Figure 6: 330kV Enugu - Nsukka Transmission Line S – Transform Pre-Fault Current Waveform

Figure 6is Time – Frequency - domain pre-fault current signal waveform obtain when S – Transform is applied. It shows that, the highest T-domain current signal amplitude which is synonymous with the fault condition of the three phase line is 2500 units with time 1800msecs. While in S – domain (frequency), it shows 6.8e5 units with 9.094 mHz.

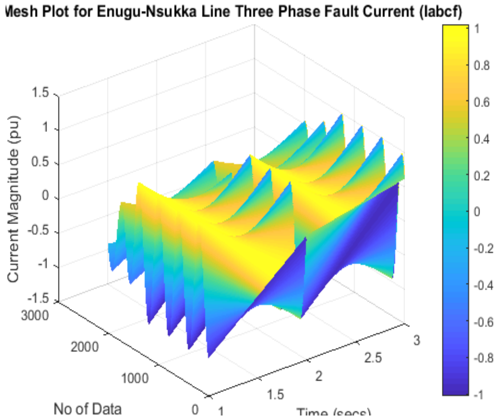

Figure 7: Mesh Plot Three Phase Fault Current ($Iabc_f$) for 330kV Enugu - Nsukka Transmission Line

Considering Figure 7, blue and yellowcolours (Ia and Ib) respectively has the same magnitude which is -1.0 and1.0pu respectively. While green (Ic) is below their mark with 0.48pu from the according to the band.

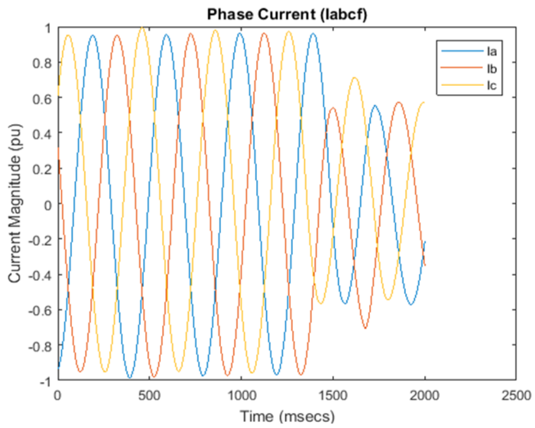

Figure 8: Enugu - Nsukka330kV Transmission Line Three Phase (LLL) Fault Current Waveform

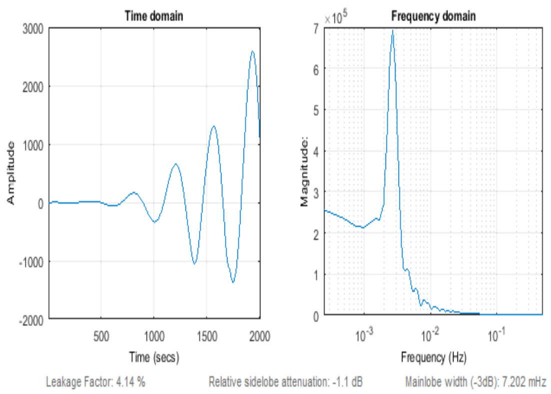

Figure 9:330kV Enugu - Nsukka Transmission Line S – Transform Three Phase Fault Current Waveform

Figure 9 is Time – Frequency - domain three phase fault current signal waveform obtain when S – Transform is applied. It shows that, the highest T - domain current signal amplitude which is synonymous with the fault condition of the three phase line is 2500 units with time 1800msecs. While in S – domain (frequency), it shows 7.0e5 units with lesser frequency distribution window width of 7.202mHz compared with its pre - fault with larger window width frequency of 9.094mHz.

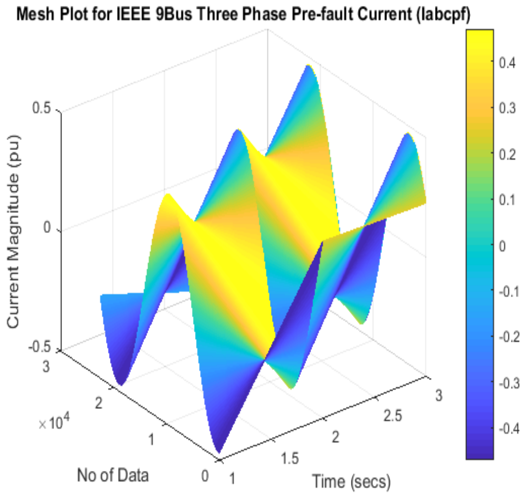

Figure 10: Mesh Plot Three Phase Pre-Fault Current ($Iabc_{pf}$) for 230kV IEEE 9Bus System Transmission Line

Here in figure 10, blue and yellow colours (Ia and Ib) respectively has the magnitude of 0.5pu and0.4pu respectively. While green (Ic) is below their mark with 0.2pu according to the colourband [5][6].

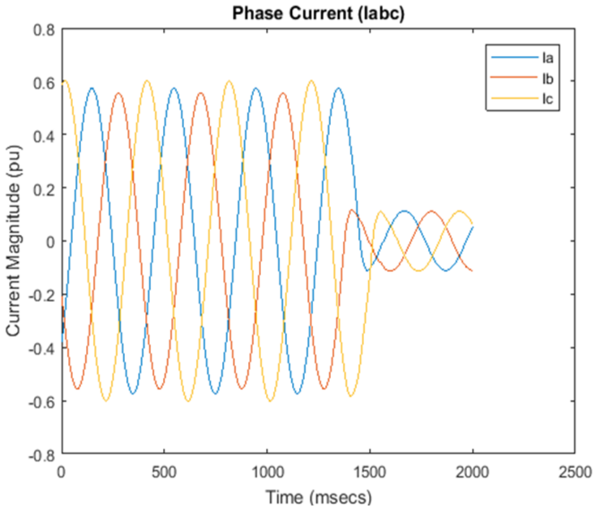

Figure 11:IEEE 9Bus System Pre-Fault Current Waveform

In figure 11, all the three lines have almost equal current magnitude of 0.6pu.

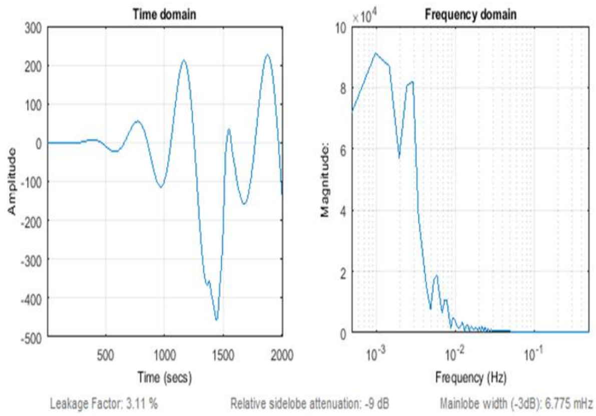

Figure 12:S – Transform IEEE 9Bus System Pre-Fault Current Waveform

Figure 12 shows that, the highest T - domain current signal amplitudeis 210 units with time 1800msecs. While in S – domain (frequency), it shows 9.0e4 units with frequency distribution window width of 6.775mHz.

Figure 9 show that the two colours, blue (Ia) and green (Ib) are almost at the same point with fault current of 0.58pu on the waveform, but with yellow (Ic) approaching near them.

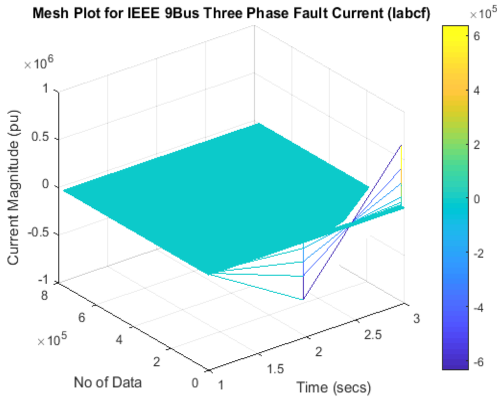

Figure 12: Bar Plot Three Phase Fault Current ($Iabc_f$) for 230kV IEEE 9Bus System Transmission Line

Considering Figure 12, the sea green colour is as a result of large number of data of the three phases with same values. The blue and yellow (Ia and Ib) respectively are almost at same point which is 6.0e5pu. While green (Ic) is below their mark with -2.0e5pu.

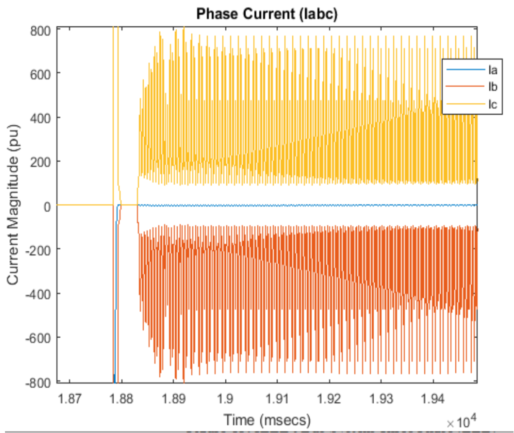

Figure 13:IEEE 9Bus System Three Phase (LLL) Fault Current Waveform

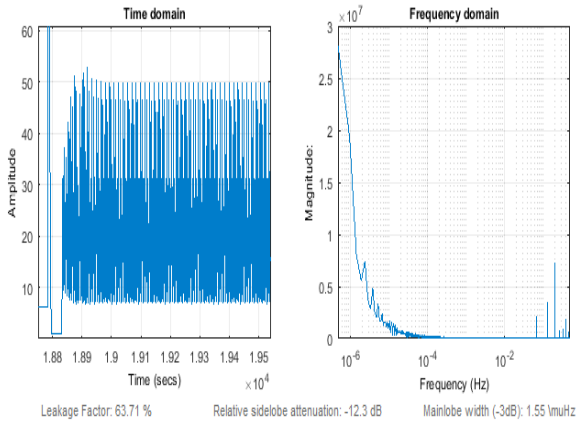

Figure 14: S – Transform IEEE 9Bus System Three Phase (LLL) Fault Current Waveform

Figure 14show that, the highest T - domain current signal amplitude is above 60 units with time 1.88e4msecs. While in S – domain (frequency), it shows 2.75e7 units with lesser frequency distribution window width of 1.55muHz compared with its pre - fault with larger window width frequency of 6.775 mHz.

With the results of figures 4 to 14, it is clear that, the results obtained when S – Transform model is applied to IEEE 9Bus System is more clear and accurate than that of 330kV Enugu – Nsukka since the its fault current magnitude obtained is far larger than that of pre – fault.

However, fault due to the presence of fault on the transmission line is above the magnitude of the pre - fault current signal and as such we conclude that fault has been detected on the line. The IEEE 9bus system network is used to validate the method and test results obtained.

IV. CONCLUSION

This paper explained the method of fault detection on power system transmission lines. The current signals were extracted from the receiving ends of the two transmission line networks and were fed into theirMatlab/Simulink mathematical modeled S – Transform simultaneously for the detection of symmetrical faults conditions of the lines.

The S – Transform was able to show clear waveform of the symmetrical fault with clear varying window width unlike the STFT in both Time and Frequency domain. It also shows its ability in managing and reducing the noise effects on the line current signal [5][6].

REFERENCE

[1]. Hsiang N. Y. '' The Tutorial on S – Transform''. Graduate Institute of Communication Engineering. National Taiwan University, Tapei, Taiwan, ROC.
[2]. Pratik W. C., Ranindra K. M., Mohammad Z. ''S – Transform Application for Fault Analysis on Transmission Line''. National Conference on Innovative Trends in Science and Engineering. Vol. 4, Issue 7, Pg 26 – 28.
[3]. Ashrfin M. R., Gharehpetin G. B. and Gholamghasemi M. *'' Application of S – Transform for Differential Protection of Power Transformer''*. International Journal of Computer and Electrical Engineering. Vol. 4, No 2, April 2012.
[4]. Yanwei W. *''Efficient Stockwell Transform with Application to Image Processing''*. University of Waterloo, Ontario, Canada, 2011.
[5]. Samantaray S. R., Panigrahi B. K. and Dash P. K. *''High Impedance Fault Detection in Power Distribution Network Using Time - Frequency Transform and Probabilistic Neural Network''*. National Institute of Technology Rourkela, Feb. 26, 2009.
[6]. Kedarnath S., Aurobinda R. *''Comparison of ICA and WT with S – Transform Base Method for Removal of Ocular Artifact from ECG Signals''*. J. Biomedical Science and Engineering. Vol. 4, Pg. 341 – 351. May, 2011.

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