S-Transform based Power Quality Analysis

F Khan, G Durga Prasad, Rayudu Srinivas*

Department of Electrical and Electronics Engineering

Aditya College of Engineering and Technology

Surampalem, Andhra Pradesh

Email: farazkhan786fz@gmail.com, durgaprasadgaanta10@gmail.com, srinivasrayudu245@gmail.com

Abstract: This paper provides an analysis of S-transform and different variants of S-transform and its application in power quality disturbance analysis in power system. Simulation results were provided in this paper.

Keywords:S-transform, Power quality, disturbance

Introduction

Power quality is one of the most important issue in power system. The nonlinear loads connected to power system draw nonlinear and harmonic current which creates power quality disturbance in the power system. There are several type of power quality disturbances such as sag, swell, interruption etc. It's very difficult to acquire such signals therefore, different mathematical formulation is available which replicate the power quality disturbance signal.

Signal processing techniques are widely used for detection and classification of power quality disturbances in power system. Transform domain functions are widely used signal processing techniques. S-transform is one of the widely used transform domain signal processing technique which is widely used [1,2]. There are variety of S-transform algorithms available in literature [3] which is used for power quality disturbance detection and protection aspects [4]. Fractional S-transform is outlined in [5]. Generalized discrete S transform is provided in [6]. Different variants of S-transform is provided in [7-9].

This paper provides a study of S-transform based processing aspect of power quality disturbance signal.

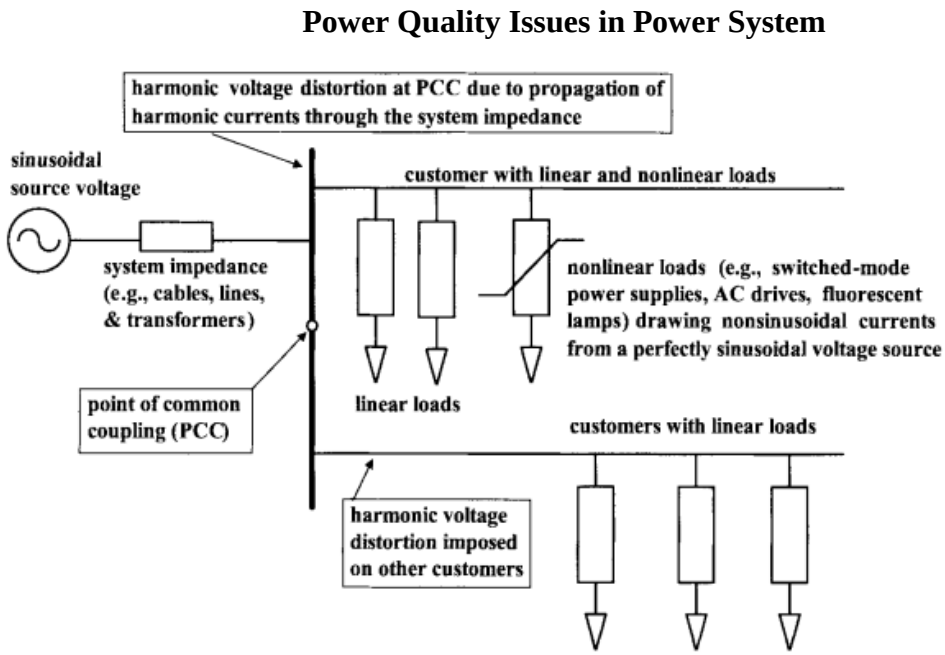


Figure 1: Power quality issues in power system

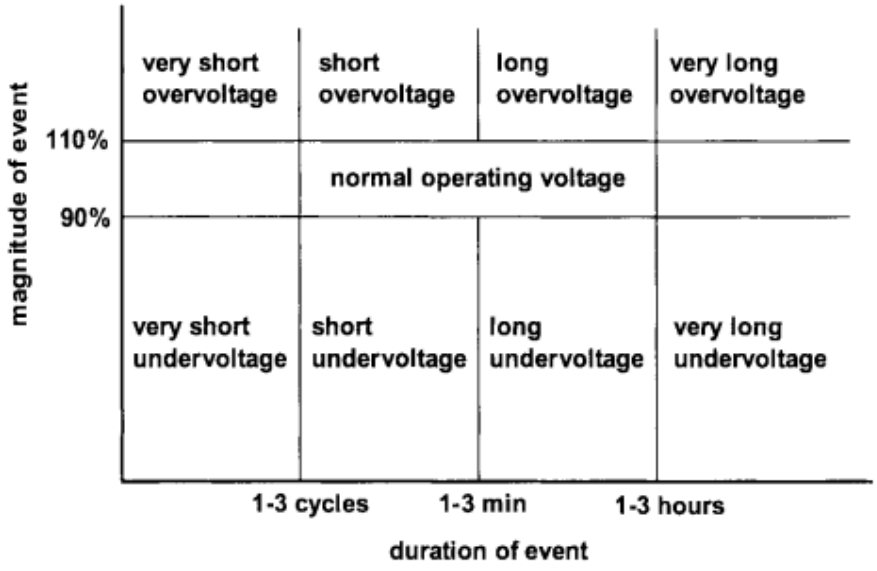


Figure 2: Different type of power quality disturbance

Figure 1 illustrates the concept of power quality disturbance in a power system. Power quality disturbances occur due to nonlinear load drawing nonlinear and harmonic current in the power system at the point of common coupling (PCC). Different type of nonlinear loads are switched mode converter, rectifier, florousent lamp, AC drives etc. Figure 2 illustrates the time duration of power quality disturbances. Though the time duration of power quality disturbances are low, the amplitude is high enough.

S-Transform: Theory

S-transform of a signal $x(t)$ can be represented as

$$S(\tau, f) = \int_{-\infty}^{\infty} x(t) w(\tau - t) e^{-j2\pi ft} dt \quad (1)$$

Window function is a scalable Gaussian window

$$w(t, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{t^2}{2\sigma^2}} \quad (2)$$

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

Eq(1) can be written as

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

$$S(\tau, f, \beta) = \int_{-\infty}^{\infty} x(t) w(\tau - t, f, \beta) e^{-j2\pi ft} dt \quad (5)$$

$$\int_{-\infty}^{\infty} w(\tau, t, \beta) dt = 1 \quad (6)$$

S-transform can be written as

$$S(\tau, f) = \int_{-\infty}^{\infty} H(\alpha + f) e^{\frac{-2\pi^2\alpha^2}{f^2}} e^{i2\pi\alpha\tau} d\alpha \quad (7)$$

The discrete Fourier transform can be written as

$$H\left[\frac{n}{NT}\right] = \frac{1}{N} \sum_{k=0}^{N-1} h[kT] e^{-\frac{i2\pi nk}{N}} \quad (8)$$

$$S\left[jT, \frac{n}{NT}\right] = \sum_{m=0}^{N-1} H\left[\frac{m+n}{NT}\right] e^{-\frac{i2\pi^2 m^2}{n^2}} e^{\frac{i2\pi mj}{N}}, n \neq 0 \quad (9)$$

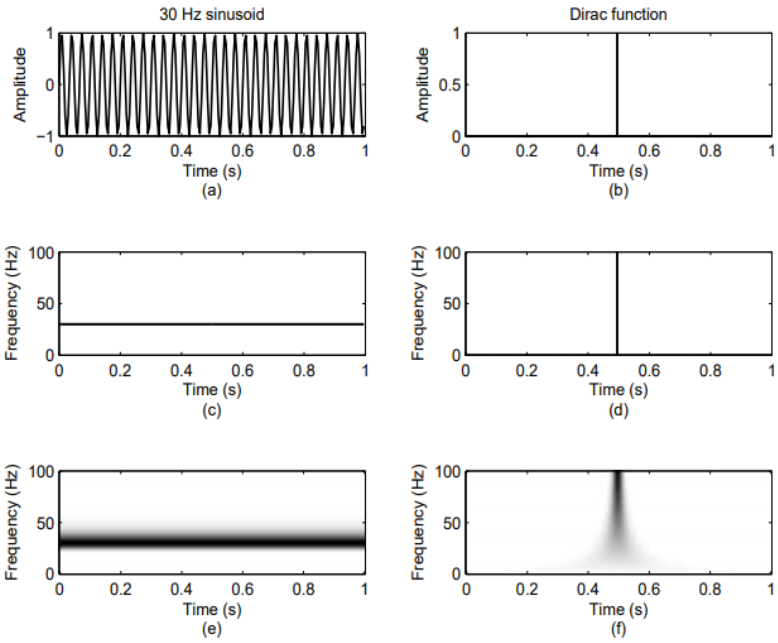


Figure 3: Time-frequency representation of signal

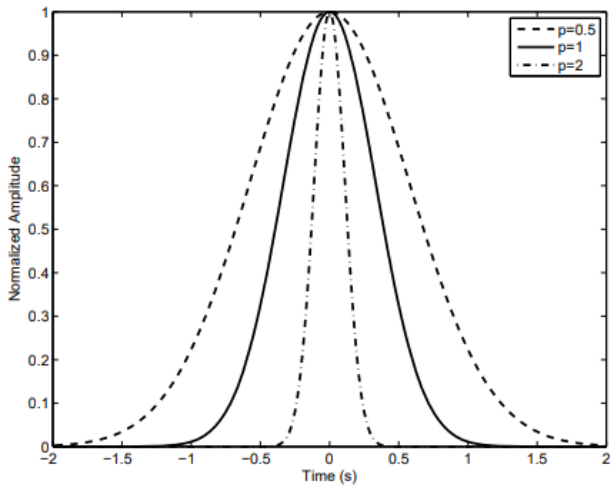
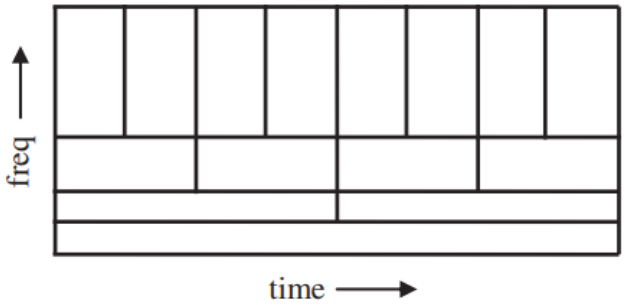


Figure 4: Normalized gaussian window for varying width of p

Fast discrete S-transform is one of the variants of discrete S-transform which uses different form of scaling windows as illustrated in Figure 5.



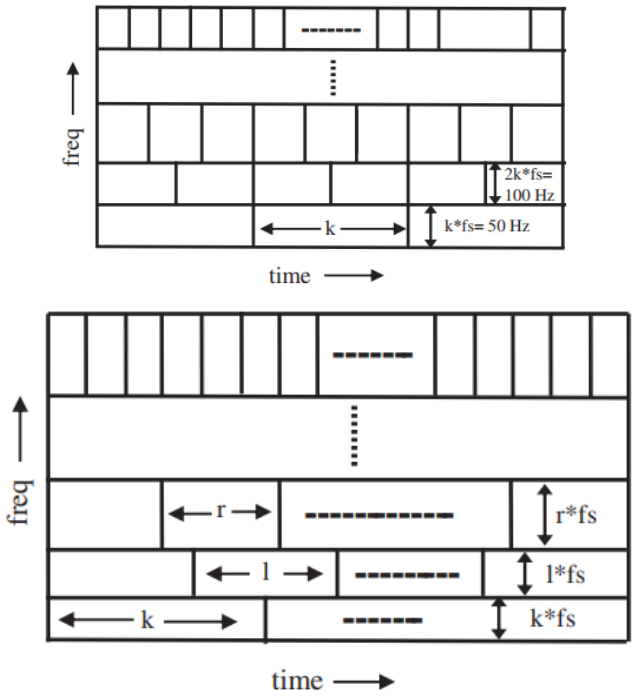


Figure 5: (a) Dydaic scaling, (b) Power signal scaling and (c) automatic scaling

Simulation Results

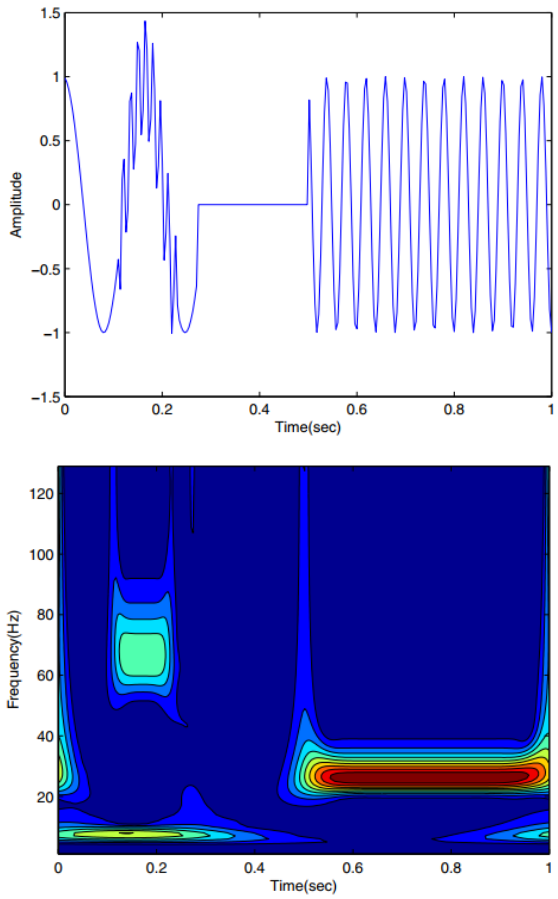


Figure 6: Time-frequency representation of a PQ signal

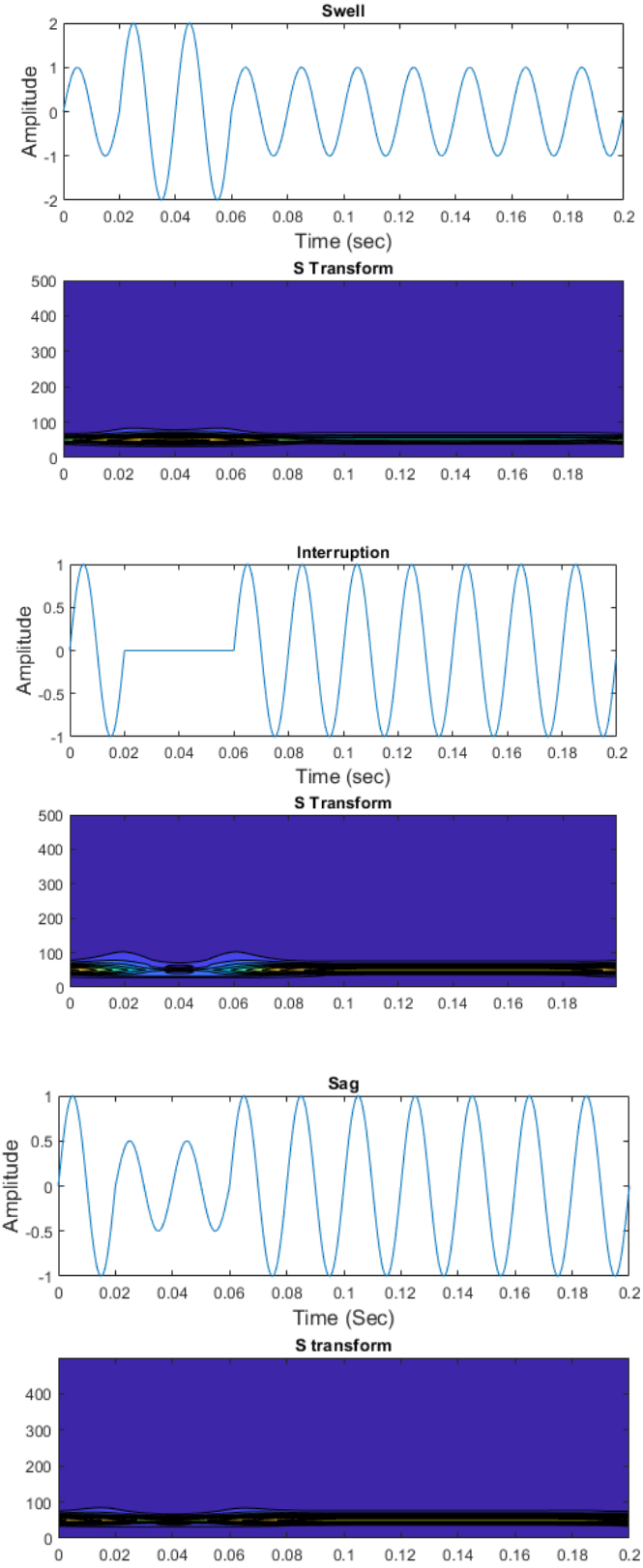


Figure 7: S-transform of swell, interruption and Sag power quality disturbances

Figure 6 and Figure 7 shows S-transform representation of different power quality disturbance signals. Figure 8 shows the time complexity of different S-transform techniques

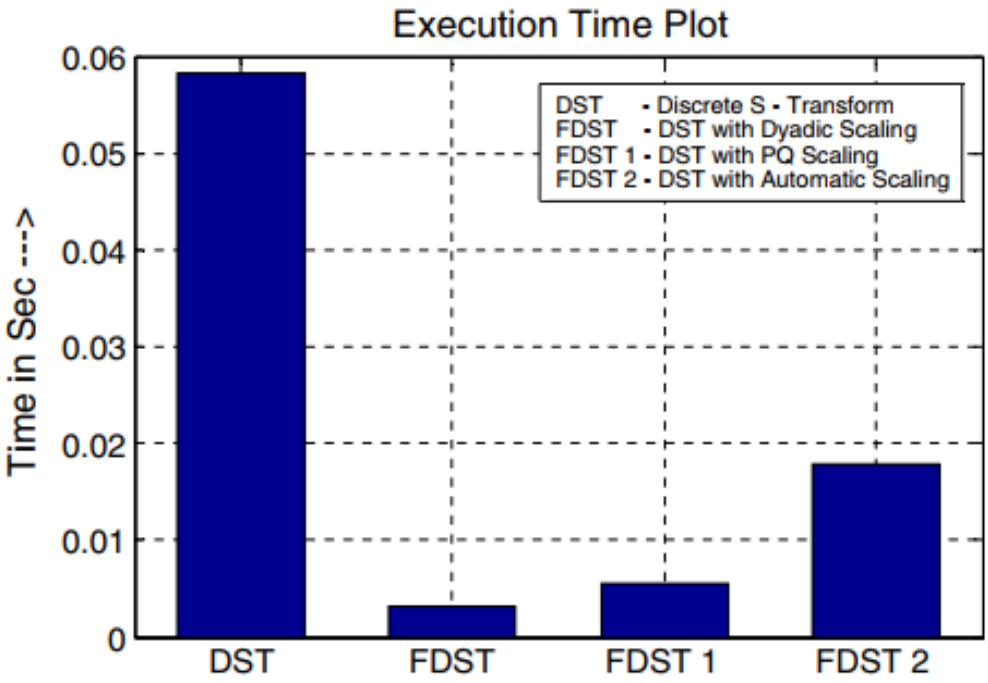


Figure 8: Execution time plot for different variants of S-transform

Conclusion

This paper provides a study of different S-transform techniques for power quality disturbance signal. Mathematical formulation of different S-transform techniques have been provided as well as simulation results have been provided.

Acknowledgement

The authors are thankful to the research mentors of "Accendere Knowledge Management Services Pvt Ltd", CL Educate Limited for their help in this paper.

Reference

1. RG Stockwell, L Mansinha, R P Lowe, "Localization of the complex spectrum: The S transform," IEEE Transactions on Signal Processing, vol. 44, no. 4, Apr. 1996, pp. 998-1001.
2. C Robert Pinnegar, Lalu Mansinha, "The S-transform with windows of arbitrary and varying shape," Geophysics, vol. 68, no. 1, 2003, pp. 381-385

3. P Ramesh Babu, P K Dash, S K Swain, S Sivanagaraju, “A new fast discrete S-transform and decision tree for the classification and monitoring of power quality disturbance waveforms,” International Transactions on Electrical Energy Systems, 2013,
4. Krishnananda K R , P K Dash, “A new real-time fast discrete S-transform for cross-differential protection of shunt-compensated power systems,” IEEE Transactions on Power Systems, vol. 28, no. 1, Jan 2013, pp. 402-410
5. Sunil Kumar Singh, “The fractional S-transform on spaces of Type S,” Journal of Mathematics, 2013
6. Yusong Yan, Hongmei Zhu, “The generalization of discrete stockwell transforms,” Proc. 19th European Signal Processing Conference, 2011, pp. 1209-1213.
7. Sitanshu Sekhar Sahu, Ganapati Panda, Nithin V George, “An improved S-transform for time-frequency analysis,” Proc. IEEE International Advance Computing Conferemce, 2009
8. U Battisti, L Riba, “Window dependent bases for efficient representation of the Stockwell transform,” Applied and Computational Harmonic Analysis, 40, 2016, pp. 292-320.
9. Robert A Brown, Richard Frayne, “A fast discrete S-transform for biomedical signal processing,” 30th Annual Interntational IEEE EMBS Conference, 2008, pp. 2586—2589