Time-Frequency Analysis Method in the Transient Power Quality Disturbance Analysis Application

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ABSTRACT: *This paper use the methods of S transformation to test the starting time, the end of the time, frequency and amplitude characteristics of common transient power quality signal disturbance. Through error analysis and simulation show that this method can accurately determine the disturbance occurred time and duration, and the identification and determination of disturbance can be simple and intuitive. It has the practical value and realistic significance to power quality signal interference analysis.*

Keywords: S Transformation, Power Quality, Voltage Sag, Time-frequency Analysis CLC Number, TM712

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1. Introduction

With the development of science and technology and national economy, the demand of electric power's user is increasing, the requirement of power quality is higher and higher at the same time. Good power quality is undoubtedly favorable for the operation of electrical equipment, and the bad power quality of electric power system operation will produce adverse effect. The day when Modern science and technology are highly developed, because of massive application of power electronic technology and computer as a representative of all kinds of digital electronics equipment and communications equipment such as power wide application of sensitive equipment, makes the power quality problem attract more and more extensive attention and concerns. So, improve the power quality have important significance to power grid safety and economic operation, guarantee the quality of industrial products and the normal scientific experiments and reduce energy consumption etc.

Power quality problems include the steady state and transient power quality of electric power quality. But the transient power quality problems become the main problems which affecting the quality of electric energy in recent years. Similar to the problems voltage dip of transient power quality can make the computer system suddenly cause data loss, contact pressure loss tripping or low voltage protection start trip, automatic controller (programmable logic controller, frequency conversion governor) sudden failure, it still can cause power of large area blackout when serious. The research of transient power quality disturbance signal identification's detection and classification is of great significance to understand the transient power quality disturbance, further evaluation and management of power quality problems, and then construct the perfect power quality monitoring and analysis system.

2. The Principle of S Transform

S transform is a reversible local timefrequency analysis method, the idea is the development of the CWT and STFT. The signal *x*(*t*)*' s* S transform $S(\tau, f)$ are defined as follows:

$$S(\tau, f) = \int_{-\infty}^{\infty} x(t) w(\tau - t, f) \exp(-2\pi i f t) dt$$

$$w(\tau - t, f) = \frac{|f|}{\sqrt{2\pi}} \exp\left[\frac{-f^2(\tau - t)^2}{2}\right]$$

Among them $w(\tau - t, f)$ is Gaussian Window, τ is the parameter which confine the Gaussian Window in the *T*. It can be seen from the type, *S* transformation is different from the short Fourier transform in the height and width of the Gaussian window changes along with the frequency, thus, it overcome the defects of short Fourier transform window's height and width in a fixed number. Signal *x* (*t*) can rebuild well from its *S* transformation $S(\tau, f)$ to inverse transformation

$$x(t) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} [S(\tau, f) d\tau] \exp(2\pi j f t) df$$

S transform is a new type of timefrequency analysis method developed by combination of continuous wavelet transform and short Fourier. The result of S transform can be displayed by the 3 d drawing - timefrequency diagram, 2 d contour map-timefrequency isoline and gray image, or intercepted a profile with 2 d curve - the amplitude frequency characteristic curve and amplitude envelope to express. The results contain rich signal characteristic information. Making full use of S transform time-frequency analysis results, which will be helpful to analyze transient power quality disturbance signal accurately.

3. Transient Power Quality Mathematical Model

Transient power quality problems mainly include pulse type of transient power quality problems and oscillation of transient power quality problems. The pulse transient power quality problem refers to the voltage, current, or both in steady development situation, cause the sudden, non - work frequency and single direction (positive or negative polarity) the nature of the change. Oscillation of transient power quality problem refers to the voltage, current, or both in steady state conditions occur suddenly, frequency and polarity and negative polarity changes in two aspects. This paper studies the analysis of the main processes of transient power quality problems - voltage drop of the mathematical model.

Voltage sag is the situation of power frequency voltage or current situation of the RMS reduce to 0.1 pu~0.9 puÿand the duration between 0.5 cycles to 1 min of transient power quality problems. Power system transmission and distribution line fault, start the heavy load, or large capacity motor can cause the voltage dip easily. The mathematical model of voltage dip can be expressed in formula (4)

$$u(t) = \begin{cases} \sin(\omega t + \theta_1) & t < t_1, t > t_2 \\ a\sin(\omega t + \theta_2) & t_1 \le t \le t_2 \end{cases} \quad 0.1 < a < 0.9$$

Among them $\omega = 2\pi f = 2\pi * 50 rad/s$, t_1 and t_2 are the start time and end time of disturbance respectively θ_1 and θ_2 are the phase before the disturbance and after the disturbance. Simulation of voltage waveform has been shown in figure 1.

4. Transient Power Quality Detection Process

The determination of disturbance moment, disturbance duration and approximate type of disturbance can be achieved for transient power quality disturbance signal changes according to the *S* transform modulus matrix .The detection process is as follows:

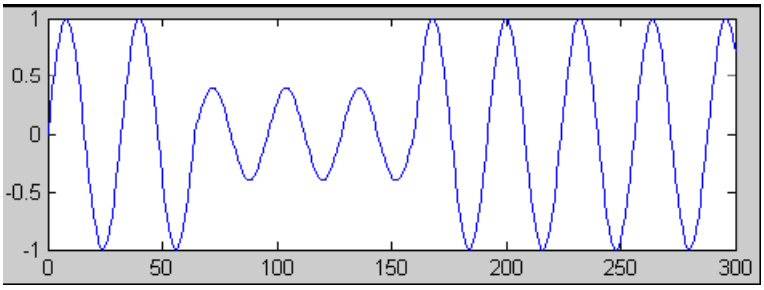


Figure 1. Simulation diagram of voltage sag

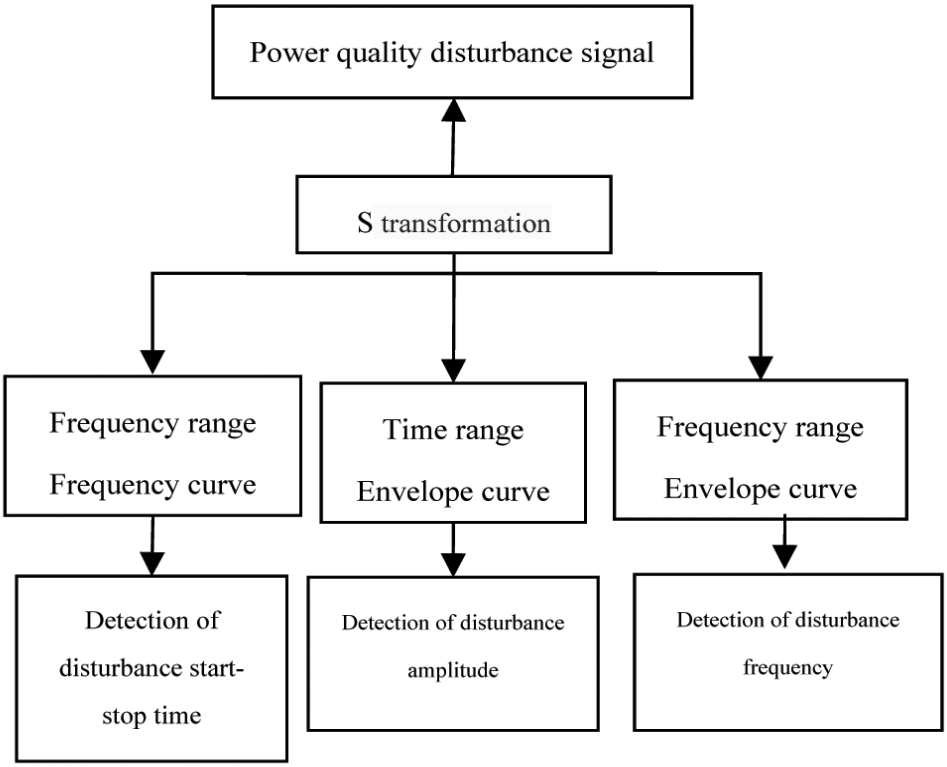


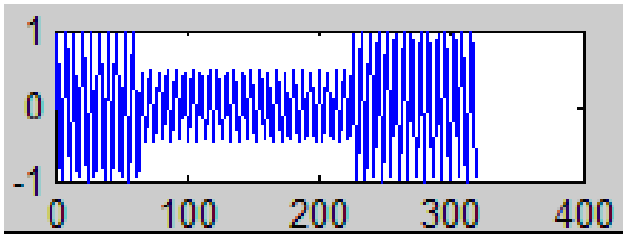
Figure 2. Detection of transient power quality process

5. The Simulation Analysis

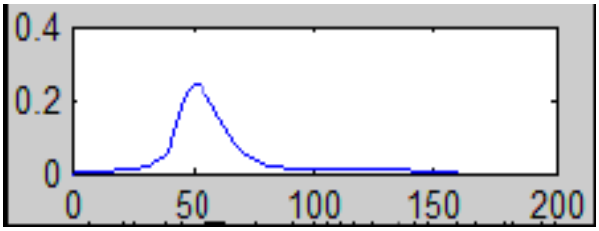
For signals like voltage dip, voltage swell, voltage interruption, pulse transient and low frequency oscillation, it is wise to choose the appropriate sampling frequency and sampling time for better simulation result. The simulation signal for use is 50 Hz ac power frequency ac signal. Use the theory of S transform analysis of the algorithm for simulation of transient power quality disturbance signal. All kinds of transient power quality disturbance signal characteristics of S transform test simulation shows as follow.

We use MATLAB to detect the voltage sag waveform of S transform as shown in figure 3 and figure 4ÿamong them $t_1 = 64$, $t_2 = 224$, $a = 0.3$, $\theta_1 = \theta_2 = 0^o$

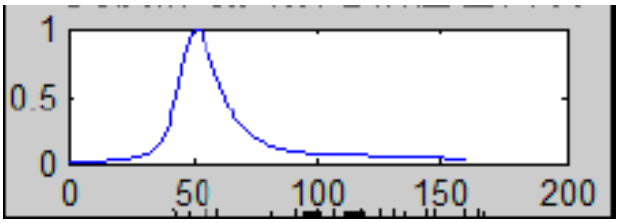
As shown in figure 3 and 4, voltage sag after S transformation, In time the isoline of sag occurrence will appear at a sharp peaks, the sag point of isoline will appear a sharp peak in time, at the end of the dropping point there is also a sharp peaks. Detected the two peaks' happened time can accurately positioning disturbance and duration time.



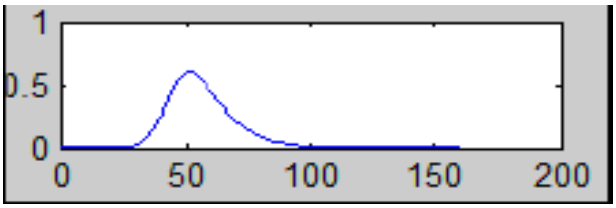
(a) Voltage sag signal



(b) S transform spectrum



(c) S transform maximum amplitude spectrum difference curve



(d) S transform frequency amplitude curve

Figure 3. S transform detection of voltage sag time-frequency information statistical graph

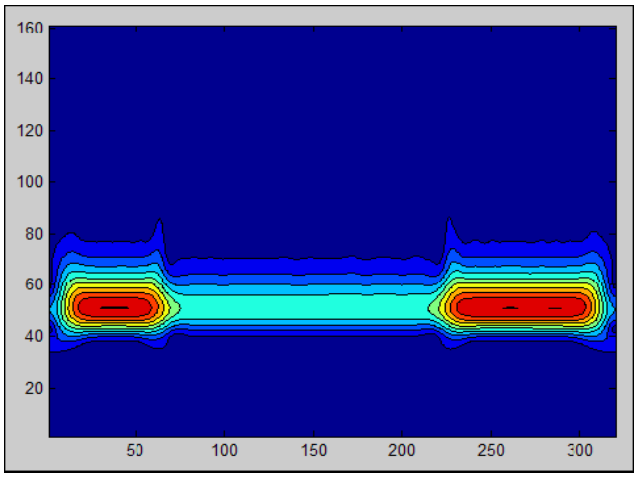


Figure 4. S transform time frequency analysis chart

Disturbance type	Theoretical value	Detection value	Error/%	Theoretical value	Detection value	Error/%
Sag	0.105	0.106	0.1	0.200	0.204	0.4

Table 1. S transform the disturbance signal error detection

Contrasting the actual value and test values of sag signal and established in table 1.It can be seen from the table that the relative error is small, and can realize all kinds of rapid and accurate detection of power quality disturbance signal, provides a effective method of timefrequency analysis for power quality problem, can accurately detect the signal of the mutant moments, so as to calculate the duration of the disturbance. Also, disturbance signal get the frequency and amplitude curves, time amplitude envelope curve and frequency amplitude envelope curve through S transformation, which intuitively reflect the characteristics of disturbance signal information, Through the information of these characteristics which through S transformation can effec tively determine the type of power quality disturbance, and provided important help for the real-time performance detecting.

6. Conclusion

Through the application of S transform time-frequency isoline, amplitude frequency characteristics curve, amplitude envelope and 3 d grid t, we can have a contrast test analysis for voltage sag. Time-frequency analysis result is ideal, but verified that make full use of S transform each result is more accurate, more convincing than single time-frequency analysis.

1. In this paper the S transform detection scheme can detect disturbance faster, using the time-frequency diagram analysis perturbation type, Determine different S ransform results combination to test can achieve rapid detection speed according to the type.

2. The result of the S transform from each side directly shows the multiple features of the disturbance, with the most accurate results of S transform to detect the characteristic, not only realize the rapid detection but also reached a satisfactory accuracy.

3. This paper use the S transform to detect the disturbance, extraction of characteristic information is comprehensive, high accuracy, and also has the ability to resist noise, can used as the fault diagnosis, online testing and monitoring applications later to provide accurate judgment and the beneficial help.

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