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Voltage Flicker Real-time Detection Based on Recursive Degree Method

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Abstract

Traditional flicker detection methods accurately extract the amplitude envelope as the premise, the complexity of large amount of computation. This paper presents a new real-time detection of voltage flicker method, analysis method with recursive frequency carrier signal frequency; use of the adjacent three-point sampling data, the frequency carrier signal frequency, sampling frequency voltage flicker waveform obtained by the current envelope size. Of harmonic pollution by noise or flicker between the signals, the low-pass filtering results are not affected. Simulation results show that: The method to directly detect flicker signal, the process is simple, computational load and real time, tracking performance, with a certain anti-noise and inter-harmonic interference suppression capability, suitable for real-time detection of voltage flicker.

Keywords: voltage flicker, recursive analysis, real-time detection, envelope detection, low-pass filter

1. Introduction

With the development of industrial technology, a large number of non-linear impulse load into the power grid, causing rapid changes in power demand. The resulting voltage fluctuations will not only interfere with the public power grid, but will seriously affect the power network operation of various electrical equipment, such as flashing lights, control equipment malfunction, the motor speed fluctuation [1-3]. For enterprises, equipment level, a large number of computer systems based on high degree of automation control equipment and electrical equipment have been put into use, the increasingly high demand for power quality, or even a fraction of a second abnormal can result in huge losses. Complex structure of the grid, load diverse nature, in particular, is located in the mountains many storm, when power loss of pressure, grounding, short circuit accident, large motor starting and the electric shocks and other factors, caused voltage fluctuations or flicker, ranging from affect the normal production; while in production disruptions, resulting in economic losses can not be ignored [3]. It is necessary for voltage fluctuation and flicker monitoring and suppression, and get accurate, detailed parameters of voltage fluctuation and flicker are its most important prerequisite for proper treatment.

Voltage fluctuation and flicker from the national standard GB12326-2000, voltage fluctuation is the voltage of each half cycle rms value of fundamental changes or a continuous series of changes. When the voltage fluctuations in the frequency of 0.5 ~ 35Hz, the volatility is the person most aware of incandescent illumination frequency, the "flicker." Because most electrical equipment sensitivity to voltage fluctuations is far less than the incandescent lamp, the flash becomes harmful levels of voltage fluctuations measured by the evaluation index [1]. Flicker of light intensity fluctuations are human subjective sensation, that perceived by the human visual voltage fluctuations caused by changes in light [4], flicker value may be understood as a certain frequency, waveform and intensity of these three elements dominated comprehensive assessment of the level of voltage fluctuations and use continue for some time that the statistical results.

The most commonly used at home and abroad flicker detection methods: squared detection, RMS rectified detection method and detection method, these three methods of measuring devices in the simulation easier to implement and does not apply to time-varying frequency of voltage fluctuations and multi-signal detection [5]. Direct application of FFT

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requires a lot of flicker detection sampling data, large amount of computation. To reduce the computing time, the first extraction of the signal amplitude envelope, and then use FFT amplitude modulation and frequency of testing, but the inherent FFT spectral leakage can not be avoided, the sampling process in the FFT [6] put forward by leaps and bounds in the sampling method to reduce errors caused by spectral leakage, but the envelope extraction time longer. Will apply to time-varying signal detection is not sensitive to noise and wavelet transform [7-9] for flicker detection, the choice of wavelet function test results. Application of Hilbert method [10-12] fast flicker envelope extraction, the use of wavelet denoising or the mathematical morphological filter to remove noise and high harmonics, practice the complexity of computing for a long time. The use of blind signal separation [13] extract the envelope, to solve the overdetermined equations estimated flicker amplitude, reduction of noise. It was also suggested to detect by predicting voltage flicker, such as rotational invariance techniques (ESPRIT) [14], Kalman filter [15], adaptive neural network [16] and other methods. Similarly, the forecasts which need a lot of calculations, these methods are hindered real-time detection of voltage flicker in the direction of development.

Voltage flicker amplitude contains the flicker frequency, amplitude and phase information, so the traditional voltage flicker signal detection must first extract the envelope, and through the FFT, Pisarenko harmonic decomposition methods such as estimation, calculation complexity, and envelope extraction speed and accuracy of test results of flicker. This paper presents a new real-time detection of voltage flicker method, using a recursive method to find frequency carrier signal frequency (ie fundamental frequency); use of the adjacent three-point sampling data, the frequency carrier signal frequency, sampling frequency obtained by the current-voltage flash variable size. This method does not require a large number of sampling data, computational load, fast, straightforward implementation process, and there is robust and is estimated to high accuracy. For harmonic pollution with flicker between the signals, the test results are not affected. The method is to avoid the Fourier (FFT) domain spectral leakage, the entire sub-barrier effect and non-wave phenomenon. Simulation results show that: The method designed for flexible, easy to use, can be engineered to detect flicker in real time.

2. F Voltage Flicker Model and Real-time Detection Algorithm

2.1. Detection Algorithm

Voltage flicker is the amplitude of grid voltage fluctuations caused by changes, voltage fluctuations often seen as the voltage of the carrier frequency (50Hz or 60Hz), the RMS voltage by the voltage fluctuation amplitude modulation components as [17]. Therefore, interpretation of the instantaneous value of the voltage-type is writed as:

$$\begin{aligned} u(t) &= A(1+m\cos(2\pi f t+\phi))\cos(2\pi f_0 t+\phi_0) \\ &= a(t)\cos(2\pi f_0 t+\phi_0) \end{aligned} \tag{1}$$

Where: A is the amplitude of the voltage-frequency carrier; f_0 is voltage frequency for the carrier frequency; m is the amplitude of the voltage amplitude coefficient; f is the amplitude voltage frequency, ϕ_0 voltage for the initial phase of the carrier frequency, ϕ wave voltage for the early AM Beginning phase. Flicker measurement is the detection of type (1) the carrier frequency in the time-varying amplitude envelope a (t). General voltage fluctuations in the frequency f range 0.05 ~ 35Hz, amplitude of the carrier frequency m the range of voltage amplitude A, 0 ~ 10% [18]. Carrier frequency is fundamental here.

2.2. The Real-time Detection Algorithm for Voltage Flicker

Frequency carrier frequency f_0 is detected, by the (1) the sampling frequency is f_s, The sampling period $T_s = \dfrac{1}{f_s}$; $\alpha = 2\pi f_0 T_s$, $\theta_n = 2\pi f_0 n T_s + \phi_0 = n\alpha + \phi_0$; Sampled signals:

$$u(n) = a(n)\cos(n\alpha+\phi_0) \tag{2}$$

Adjacent three operations:

$$\begin{aligned}&u^2(n)-u(n-1)u(n+1)\\&=[a^2(n)-a(n-1)a(n+1)]\cos^2(n\alpha+\phi_0)\\&+a(n-1)a(n+1)\sin^2(\alpha)\end{aligned} \quad (3)$$

In (9) assumed $a^2(n)=a(n-1)a(n+1)$, then:

$$a(n)=\frac{\sqrt{u^2(n)-u(n-1)u(n+1)}}{|\sin(\alpha)|} \quad (4)$$

By the formula: 1) robustness, the calculation does not divide, even if the signal does not affect the zero-crossing operator results. 2) rapid response capability, the algorithm also uses only three samples adjacent to the signal, you can quickly track changes in the envelope.

3. Recursive Analysis of Voltage and Frequency Detection of the Carrier Frequency

3.1. Recursive Analysis

Recursive analysis is a nonlinear dynamic analysis method; it is based phase space reconstruction, reflecting the recovery after the chaotic attractor has a law. Different nature of the state of the signal characteristics of the track not the same as, and in the recurrence plot (Recurrence Plot RP) of the structure is different [19-21]. Thought algorithm described as follows:

1) Select the appropriate time delay τ and embedding dimension m, the one-dimensional reconstruction of nonlinear time series, the resulting dynamic system is as follows:

$$X_i=(x(i),x(i+\tau),...,x(i+(m-1)\tau)) \quad (5)$$

More than one-dimensional time series that is re-pose-dimensional phase space trajectory, from the perspective of dynamical systems to achieve a recovery in the high dimensional space attractor.

2) Calculate the phase space rows X_i, columns X_j, and the distance between vectors:

$$S_{ij}=\left\|X_i-X_j\right\| \quad (6)$$

Which $\|x\|$ expressed the Euclidean norm.

3) Recursive calculation of the value

$$R_{ij}=\Theta\left(\varepsilon-S_{ij}\right) \quad (7)$$

Where, ε is the critical distance, $\Theta\left(x\right)$ is said step (Heaviside) function, $\Theta(x)=\begin{cases}0 & x\le 0\\1 & x>0\end{cases}$。Nodes use the phase space can be described from two-dimensional graphics on the internal dynamics of nonlinear time series matrix of the mechanism, the recurrence plot (RP). $R_{ij}=1$ is corresponding position at the time that the black point, $R_{ij}=0$ is white point when you said, RP is through the black point and figure point to describe the white graphics to reflect the time series.

Figure 1 shows the main part of the periodic signal $f(t)=\sin(8\pi t)$ on the diagonal of the RP maps, lower figure for the white noise signal RP. Figure from the RP point of view it is clear periodic signals, because the white noise is stationary, white noise figure of the black spots RP, evenly covered with white spots, time series have become unpredictable. Above analysis, RP map can directly reflect clearly the dynamic features of the system qualitatively describes the system of non-steady-state phenomenon, and from the perspective reveals the dynamics of phase space trajectories of the run.

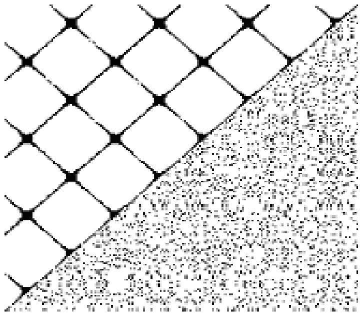

Figure 1. Effect of different recursive signal (RP) Diagram

3.2. Carrier Frequency Voltage and Frequency Detection

In order to quantitatively from a statistical point of view of signal analysis, in the recurrence plot is introduced based on the number of signals to be measured recursion. The main diagonal straight line parallel to the R_ε = 0 we call recurrent points:

$$D_\varepsilon(k) = \sum_{i=1}^{N-k} R_{i,i+k} \qquad k = 1,2,\cdots,N-1 \tag{8}$$

Its size reflects the strength of the system periodically. In the voltage flicker signal processing, we take the embedding dimension m = 1, time delay τ =0, Sampling frequencyfs(Hz), Frequency carrier signal in order to avoid access to the frequency multiplier and a half there, can give the approximate frequency range of the carrier frequency [f_1,f_2]Hz, $ks = [\frac{f_s}{f_2}], \quad ke = [\frac{f_s}{f_1}]$, [。] Rounding.

$$D_\varepsilon(k_0) = \max\{D_\varepsilon(k) \quad k = ks, ks+1, \cdots, ke\} \tag{9}$$

The frequency carrier frequency (ie fundamental frequency):

$$f_0 = \frac{f_s}{k_0} \tag{10}$$

4. Experimental Evaluation

In all of the following test signals, take it to the sampling frequency fs = 1000Hz, number of samples N = 1000, recursive method to calculate the critical frequency from the carrier frequency $\varepsilon = 0.1STD(u), STD$ is standard Variance. The following are multiple flicker frequency, amplitude and frequency dependent amplitude changes, including noise pollution and is harmonic pollution between the experimental detection of flicker.

4.1. Signal Frequency Flicker Measurement

Set with multiple signal frequency flicker signal:

$$u(t) = (1 + 0.1\cos(2\pi \frac{50}{3} t + \frac{\pi}{6}) + 0.075\cos(2\pi 10t + \frac{\pi}{4})$$
$$+ 0.05\cos(2\pi \frac{50}{7} t))\cos(2\pi 50t + \frac{\pi}{3})$$
$$= a(t)\cos(2\pi 50t + \frac{\pi}{3}) \qquad (11)$$
$$Where: a(t) = 1 + 0.1\cos(2\pi \frac{50}{3} t + \frac{\pi}{6})$$
$$+ 0.075\cos(2\pi 10t + \frac{\pi}{4}) + 0.05\cos(2\pi \frac{50}{7} t)$$

Figure 2 (a) multi-source voltage flicker frequency modulation waveform. Figure 2 (b) envelope of this paper the true value of the flicker with real-time detection assay values and Figure 2 (c) envelope of error.

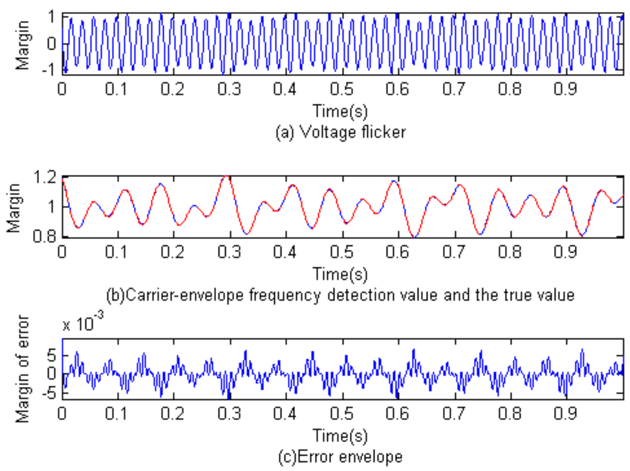

Figure 2. Real-time detection of voltage flicker envelope with invariable power frequency

4.2. Amplitude Modulation and Frequency-dependent Variable Voltage Flicker Signal Detection

Frequency carrier signal is:

$$\cos(2\pi 50t + \pi/3),$$

Superposition of the 0 ~ 250ms amplitude 0.1, frequency of 10Hz envelope; at 251 ~ 500ms superimposed amplitude 0.2, frequency of 10Hz envelope; at 501 ~ 750ms superimposed amplitude 0.2, frequency 15Hz envelope; in 751 ~ 1000ms superimposed amplitude 0.1, frequency of 10Hz envelope. Namely:

$$u(t) = a(t)\cos(2\pi 50t + \frac{\pi}{3}) \qquad (12):$$
$$a(t) = 1 + 0.1[t_0, t_1]\cos(2\pi 10t) + 0.2[t_1, t_2]\cos(2\pi 10t)$$
$$+ 0.2[t_2, t_3]\cos(2\pi 15t) + 0.1[t_3, t_4]\cos(2\pi 10t)$$

This AM signal through the amplitude change, freque0ncy change, with varying amplitude and frequency, Figure 3(a) for the amplitude and frequency changes the original signal waveform voltage flicker. Figure 3(b) envelope of this paper the true value of the flicker with real-time detection assay values and Figure 3(c) envelope of error.

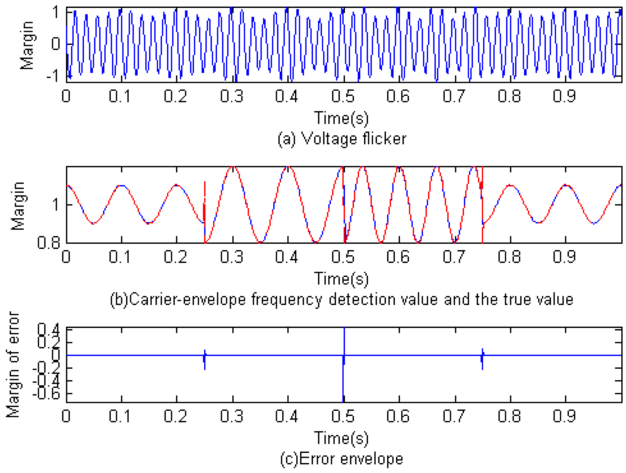

Figure 3. Real-time detection of voltage flicker envelope with variable amplitude- frequency

5. Conclusion

With the increased automation of modern enterprises, more and more demanding requirements on power quality, voltage flicker is the power supply system is one important cause of pollution hazards. This paper presents a new real-time detection of voltage flicker method. Specific performance:

1) Use a recursive method to find frequency carrier signal frequency, that is, fundamental frequency;
2) the use of the adjacent three-point sampling data, the frequency carrier signal frequency, sampling frequency according to (4) obtain the current amplitude of voltage flicker;
3)The method reflects the sensitivity of the interference signal, there is interference between the harmonics or noise, signal preprocessing to be a low-pass filter;
4) The proposed method has a low-pass filtered noise immunity;
5) the method with a low-pass filtered between anti-harmonic;
6) The method of time-varying amplitude of voltage flicker a good real-time tracking, tracking accuracy and sampling frequency, sampling frequency was significantly higher tracking;
7) The results of this method did not specify an explicit expression of the mutant signal in real time tracking;
8) The simulation results show that the proposed algorithm can effectively and accurately, in real time to extract the signal envelope for the online detection of voltage flicker.

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