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# The New Detection Algorithm for the Grid Accessing Voltage Wave Fluctuation of High Power EPS

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**Abstract:** Due to its high power, the grid accessing of large Emergency Power Supply (EPS) would cause the fluctuation and flicker of the voltage, which have to be detected and controlled. This paper analyzed and compared some current detection algorithms and proposed a new algorithm for detecting voltage wave elimination of matrix type. In MATLAB, the newly proposed algorithm is analyzed through simulation. The simulation result shows that this algorithm can effectively detect the voltage fluctuation and flicker. It gets rid of not only the filter in traditional algorithm but also the influence of direct current component and doubling frequency component. The superiority of this algorithm can be better embodied when it is applied in multi-frequency signals. The calculation of this new algorithm is simple and fast. The final data is relatively fewer and can be easily realized in DSP, which greatly and effectively improves the real-time detection of large EPS voltage wave.

**Key words:** EPS power, voltage fluctuation, elimination of matrix type, detection

## INTRODUCTION

With the increasing demand of power and the incapacity of grid power supply, power failure occurs from time to time. In order to keep the balance between surplus power and the power shortage in power consumption peak times, a lot of large EPS power is applied. As large EPS power has big power, when it is accessed into the grid, it will lead to some power quality problems such as the fluctuation and flicker of the voltage (Li and Sun, 2006; Fengjuan, 2006). On the other hand, when a large EPS power controller is connected into grid voltage, as there is disturbance in grid, it will send incorrect controlling signals to IGBT. As a result, it is hard to regulate and control the inverter output voltage. Therefore, it becomes particularly important to detect and control the accessed voltage fluctuation and flicker of the large EPS power. This paper focused on the detection of the grid accessing voltage fluctuation and flicker of large EPS power.

At present, there are many detection methods for accessing voltage fluctuation. The top three frequently used detection methods (Shiping and Guiying, 2008) are square demodulation detection, rectification demodulation detection and effective value detection. Additionally, modern detection methods includes Fourier transform, Wavelet transform (Zhaojing and Wenhui, 2001; Mingde and Zhigang, 2011; Sharma and Agarwal, 2012), Hilbert transform (Zhiqun *et al*., 2004), instantaneous reactive power theory (Xiaopu *et al*., 2009; Ge and Song, 2011), Kalman filter technology, minimum of absolute value of state estimation (Jiasheng *et al*., 2012), Teager power operator technology, Genetic algorithm technology (Shanghua *et al*., 2004; Xiaohua, 2007) etc. Because square demodulation detection is suitable for stand-alone by using the method of digital signal processing to form a new flicker instrument, therefore, we use square demodulation detection on the IEC recommended flicker instrument (Lixia *et al*., 2005). Based on the square modulation detection algorithm recommended by IEC, this paper proposed an analyzing method which can detect amplitude signals without filtering.

## ANALYSIS ON ALGORITHM PRINCIPLE

**Comparison analysis on various algorithms:** For the three classical detection algorithms mentioned in Literature (Shiping and Guiying, 2008), no matter which demodulation method can detect the amplitude-modulated wave. In order to remove DC component and doubling frequency component but remain amplitude-modulated wave, effective value detection has an average effect and can be easily affected by fundamental wave voltage and

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fundamental frequency. When going through the integrator, reference voltage $U_0 = A^2/2$ should be subtracted. But it is impossible that there is no DC component. Therefore, it is still necessary to block DC and filter wave. For square demodulation detection and rectifier demodulation detection, strict low pass filter or band pass filter should be designed to properly filter DC, power frequency and power frequency harmonic wave and remain the amplitude-modulated wave. It is suitable to use artificial circuit to realize rectification detection.

In Literature (Zhaojing and Wenhui, 2001), the detection algorithm of wavelet transform is proposed. Its fundamental principle is to replace the low pass filter in traditional synchronous demodulator with wavelet multi-resolution signals decomposition filter which can detect the envelop signal of voltage flicker and the sudden change time of voltage flicker signal. This method is effective for detecting fluctuation signals which include one or two or above kinds of frequency. But the sync signal and carrier signal should be of the same phase and frequency. What's more, the frequency should be strictly fractioned. In order to improve the accuracy of the power focused wavelet base, we usually take Db4 wavelet. It has 4 arc converters and frequency in the center is high, which makes it easy to extract a wide frequency range of transient signal and inhibit the interfusion of low frequency carrier. With eight filter coefficient, the calculation amount of fast wavelet transformation is smaller.

The Hilbert-Huang Transformation (HHT) detection put forwarded in literature (Zhiqun *et al*., 2004) is a kind of non-stationary signal processing method, that is, HHT method can be used to detect typical power quality disturbance signals related to time-domain analysis. For example, voltage flicker and fluctuation signals. This method is composed by two parts: Empirical mode decomposition method (EMD) and Hilbert transform. Firstly, we make use of EMD to extract signal's Intrinsic Mode Function (IMF) component. Then to Hilbert transform IMF for instantaneous frequency and amplitude. This method has the advantage of wavelet multi-resolution, which enables us to analyze signals from two aspects: time domain and frequency domain so that we can precisely detect the time, frequency and amplitude information of sudden change, non-stationary harmonic wave and voltage flicker signals. Meanwhile, it overcomes the difficulty of extracting wavelet base from wavelet transform and the signal decomposition is based on the signal's own properties, so that it has good local characteristics.

The detection method proposed in literature (Xiaopu *et al*., 2009) is based on instantaneous reactive power theory. Its fundamental principle is as follows. If the single-phase voltage signals delay 60°, we can get the three-phase voltage, then replace the three current with three phase voltage. We can take advantage of the reactive power theory to calculate the instantaneous active and then calculate the voltage signal envelope.

**New algorithm principle:** If you intend to make valid detection of the voltage fluctuation and flicker, the top priority is to extract fluctuation signals precisely. As a usual, we regard fluctuation voltage as amplitude-modulated wave which takes power frequency rated voltage as carrier and the voltage's amplitude is modulated by the voltage fluctuation component whose frequency range from 0.05 to 0.35 Hz. For the simplicity of analysis and do not break generality, the instantaneous expression of the power frequency voltage u (t) is written as (Xiaohua, 2007):

$$u(t) = A[1 + \sum_{i=1}^{n} m_i \sin(\Omega_i t + \psi_i)] \sin(\omega t + \theta) \qquad (1)$$

In this expression, A is the amplitude of the power frequency carrier voltage, ω is the angular frequency of it, $m_i$ is the ratio between the amplitude and the carrier amplitude of amplitude-modulated wave i, $\Omega_i$ is the angular frequency of amplitude-modulated wave i, $\psi_i$ is the epoch angular of amplitude-modulated wave i, θ is the epoch angular of power frequency carrier voltage.

When doing research on the voltage fluctuation detection, we can assume that the voltage to be measured only has the modulation of one certain single frequency's amplitude wave to power frequency carrier. Then the instantaneous expression for the to be measured voltage signal u(t) with voltage fluctuation is:

$$u(t) = A[1+m \sin(\Omega t)] \sin(\omega t+\theta) \qquad (2)$$

In this expression, m is the ratio between the voltage amplitude and the carrier amplitude of the amplitude-modulated wave, which represents the amplitude-modulated wave's controlling degree by modulating signals. Ω is the angular frequency of the amplitude-modulated wave voltage.

First, we detect the carrier wave in sample signals and according to the test results we send reverse carrier signals to offset the carrier waves in the original signals (Li *et al*., 2010; Xiaohua, 2007). Then process the remaining signals in two ways. According to the And Angle formula principle, the two processed signals minus each other and the influence of fundamental carrier frequency cancels each other out. In this way the detection of amplitude modulated signals can be realized. The overall frame diagram is shown in Fig. 1. Different from filtering wave in frequency level, this method gets a satisfying result by analyzing from another perspective.

Firstly, detect the carrier wave's frequency ω, amplitude A, phase angle θ in signals and send out a reverse signal through the signal generator:

$$q(t) = A\sin(\omega t+\theta) \quad (3)$$

Subtract expression 3 from expression 2, offset the fundamental wave component and get:

$$p(t) = u(t)-q(t) = mA\sin(\Omega t)\sin(\omega t+\theta) \quad (4)$$

Then process expression 4 from two ways. φ is arbitrary constant.

- **Way 1:** Multiply expression 4 with cos (ωt+θ+φ), then we get:

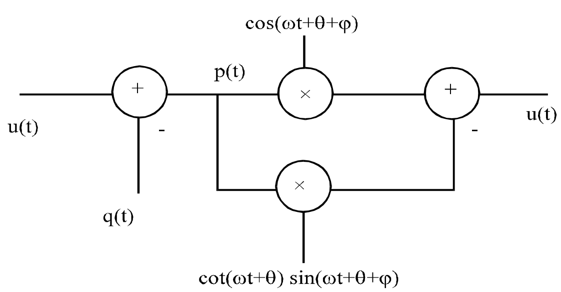


Fig. 1: Overall frame diagram

$$p(t)*\cos(\omega t+\theta+\varphi) = mA\sin(\Omega t)\sin(\omega t+\theta)\cos(\omega t+\theta+\varphi) \quad (5)$$

- **Way 2:** Multiply expression 4 with cot(ωt+θ) sin(ωt+θ+φ), then we get:

$$mA\sin\Omega t\cos(\omega t+\theta)\sin(\omega t+\theta+\varphi) \quad (6)$$

Deduct expression 6 from expression 5, we get:

$$\begin{aligned} & mA\sin\Omega t\sin(\omega t+\theta)\cos(\omega t+\theta+\varphi)- \\ & mA\sin\Omega t\cos(\omega t+\theta)\sin(\omega t+\theta+\varphi) \\ & = mA\sin\Omega t[\sin(\omega t+\theta)\cos(\omega t+\theta+\varphi)- \\ & \cos(\omega t+\theta)\sin(\omega t+\theta+\varphi)] \\ & = mA\sin\Omega t\sin(\omega t+\theta-\omega t-\theta-\varphi) \\ & = mA\sin\Omega t\sin(-\varphi) \end{aligned} \quad (7)$$

We can get from expression 7 that this method not only omits the filter but also gets rid of the influence of DC component and doubling frequency component in square demodulation detection. This algorithm can better show its superiority when it is in multi-frequency amplitude signals.

## SIMULATED VERIFICATION AND ANALYSIS

In order to testify the validity of this algorithm, this algorithm was tested and analyzed in MATLAB R2009. In simulation experiment, we set 311 V to A, 50 Hz to ω, 0.1 to m, 5 Hz to Ω, π/3 to φ and 0 to θ. Figure 2 is the simulation diagram of the to be measured voltage u(t) and p(t), which produce voltage fluctuation. Figure 3 is the voltage fluctuation signal wave form of p(t), u(t) and the pre-added voltage with DC component. Figure 4 is the simulation diagram of voltage fluctuation detection. In

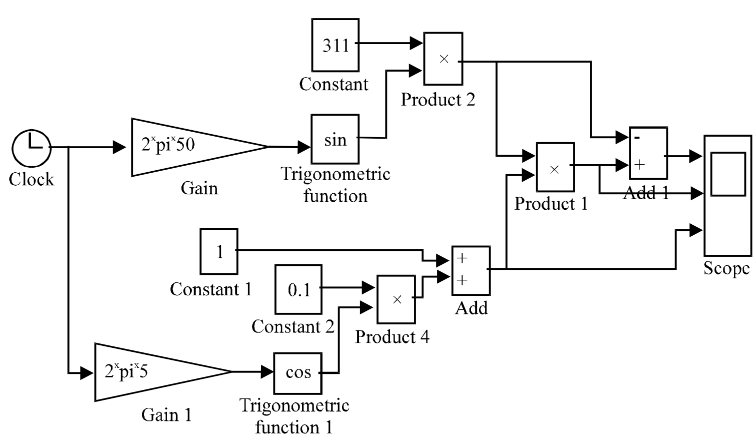


Fig. 2: The simulation diagram of u(t) and p(t)

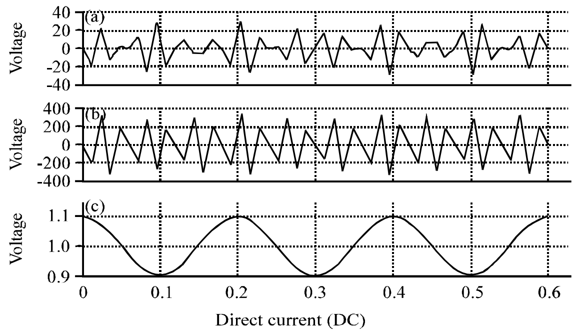


Fig. 3(a-c): The waveform of (a) p(t), (b) u(t) and (c) The pre-added voltage with DC component

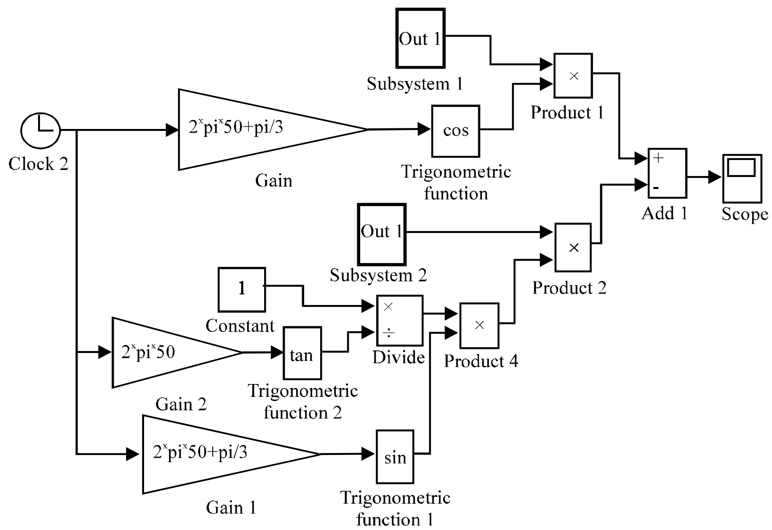


Fig. 4: The simulation diagram of voltage fluctuation detection

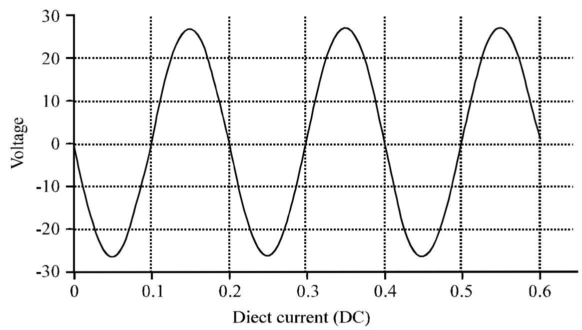


Fig. 5: The voltage fluctuation signal of the detection

this figure, module out 1 is the sub-module of p(t). Figure 5 is the voltage fluctuation signal of the detection. From this figure, we can get that the detected voltage fluctuation is nearly the same as the pre-added, except for different amplitudes. From Fig. 4 we can see that this method not only omits filter but also gets rid of the influence of the DC component and doubling frequency component in square demodulation detection.

To further illustrate the effectiveness and superiority of this algorithm, we also made simulation research in the circumstance of multi-frequency

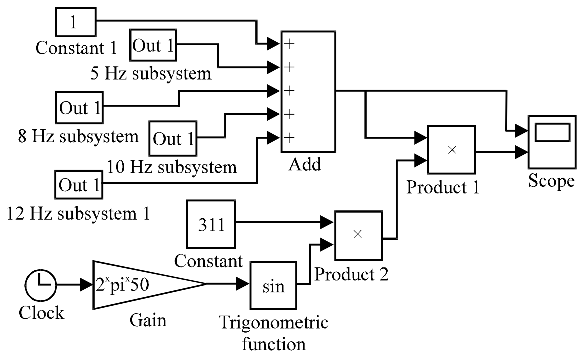


Fig. 6: The simulation diagram of voltage fluctuation u(t) with several different frequencies

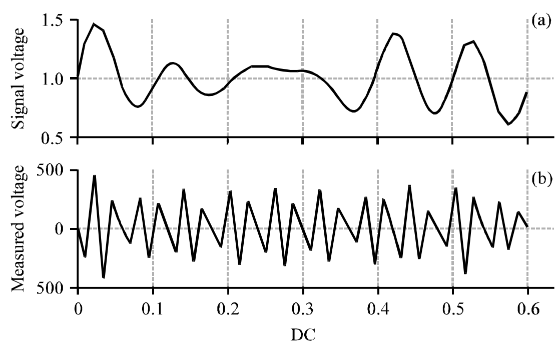


Fig. 7(a-b): The waveform of (a) The pre-added multi-frequency amplitude signal voltage fluctuation and (b) The measured voltage u(t)

amplitude signal, that is, the voltage fluctuation which has several different frequencies. Therefore, expression 7 would convert into:

$$A\sum_{i=1}^{n} m_i \sin\Omega_i t \sin(-\varphi) \tag{8}$$

In the simulation research, four voltage fluctuation signals are added. Their frequencies are 5, 8, 10 and 12 Hz and the m value for they are 0.1, 0.15, 0.2, 0.05. For simplify of the process, 5, 8, 10 and 12 Hz voltage fluctuation signals will be produced to build a subsystem. Figure 6 is the simulation diagram of voltage fluctuation u(t) with several different frequencies and out 1 is separately the subsystem modules of four different frequency voltage fluctuation signal. Figure 7 is the waveform of pre-added multi-frequency amplitude signal voltage fluctuation and the to be measured voltage u(t). Figure 8 is the simulation diagram of detected voltage fluctuation by using the detecting algorithm proposed in this paper. Figure 9 is the detected voltage fluctuation

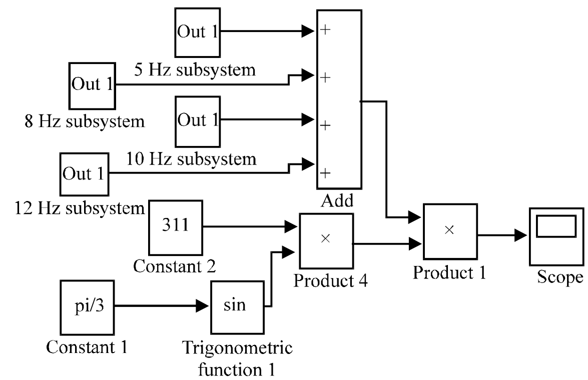


Fig. 8: The simulation diagram of detected voltage fluctuation

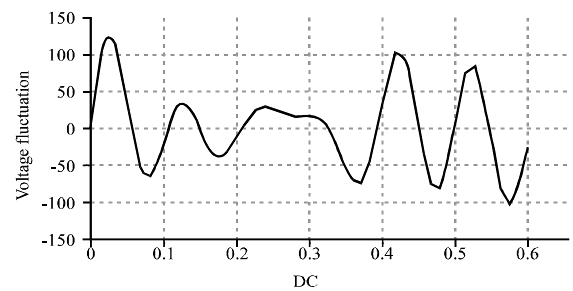


Fig. 9: The detected voltage fluctuations

signal. From this figure, we can see the signal detected in Figure 9 is nearly the same with the pre-added voltage fluctuation which has several different frequency signals in Figure 7.

## CONCLUSIONS

In voltage fluctuation detection, the algorithm proposed in this paper works easily and quickly. The data got from calculation is small in amount and high in accuracy. It gets rid of not only filters but also the influence of DC component and doubling frequency in square demodulation detection (Xiaoli, 2004). In the detection of voltage fluctuation with several different frequencies, this algorithm has more advantage. It is very suitable for the detection of voltage fluctuation and flicker in shore power grid accessing.

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