

Voltage Fluctuation and Flicker Monitoring System Using LabVIEW and Wavelet Transform

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Abstract—The paper puts forward a method which uses wavelet multi-resolution analysis to extract characteristics of voltage flicker, establishes the arithmetic model of voltage fluctuation and flicker, and it can detect the amplitude modulation waveform of the voltage flicker, and examine abrupt-change time, frequency, and amplitude of the amplitude modulation waveform. A voltage fluctuation and flicker monitoring system based on virtual instrument was developed, where the wavelet transform was applied to virtual instrument by using the MATLAB script node in LabVIEW. The evaluation indices of short-term flicker severity were obtained by using statistic sorting algorithms. Sensation level weighted filter, Square multiplier and first order low pass filter were designed.

Index Terms—flicker, voltage fluctuation, wavelet transform, frequency

I. INTRODUCTION

The application of large power and impact loads, such as large capability arc furnaces, spot welding machines and compressors, etc, had made the voltage fluctuation and flicker occurred frequently in the power system. They brought a lot of disadvantages to daily life and industry. For example, lighting equipments flicker, control unit misoperation, motor fluctuation and so on. It is very important to develop a monitoring system of voltage fluctuation and flicker in order to improve and eliminate their influence.

There are three main methods of monitoring the voltage fluctuation and flicker around the world, they are half-wave virtual value, square demodulation and full-wave rectification. But all these methods are not suitable for the time-variable voltage flickering signal detection and time-frequency analysis. Nowadays, the detection method recommended by IEC has been widely considered as an international standard for voltage fluctuation and flicker monitoring, but it can't attain qualified accuracy in voltage fluctuation or flicker

analysis because it's square demodulation method. This paper puts forward a method for measuring voltage fluctuation and flicker based on wavelet transform, which can not only extract the feature of the voltage flicker and examine the frequency and the amplitude of the voltage fluctuation, but also detect the moment when the voltage flicker occurs. The key technologies and hardware of the system are stated below.

II. THE HARDWARE OF THE SYSTEM

The voltage fluctuation and flicker monitoring system based on wavelet transform was developed by using the virtual instrument technology. The hardware structure of the virtual instrument is shown as Figure 1, the system consists of sensors, signal conditioning circuits, transfer boards, data acquisition (DAQ) and computer. The sensors are HYH-SB-13-U voltage sensor and HYH-SB-13-I current sensor. The signal conditioning circuit which revises error of sensor caused by individual difference, is an in-phase enlarge proportion amplifier composed of LM324. The transfer board is made by us. The data acquisition is PCI-6023E. a product of NI company, it has 16 channel single, 8 channel difference analogy input, 12 bit precision, 200KS/s sampling frequency, $\pm 0.05V$ to $\pm 10V$ input range.

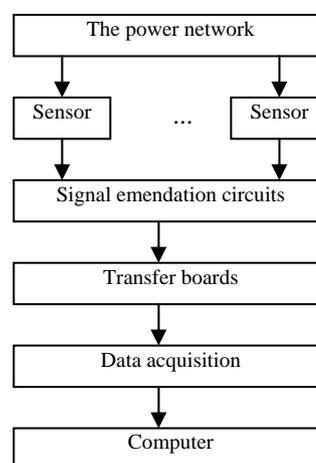


Figure 1. The hardware of virtual instrument

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III. THE ARITHMETIC MODEL OF MONITORING VOLTAGE FLUCTUATION AND FLICKER

Many electrician equipments can not work properly because of the voltage fluctuation and flicker. Generally speaking, the fluorescent lamp and television are far less sensitive to voltage fluctuation than incandescent lamp. Almost all build lighting has large number of incandescent lamp. Therefore, if the voltage fluctuation can't influence the fluorescent lamp and television, it won't cause incandescent lamp flicker. So, the operating condition of incandescent lamp can be regarded as the standard to decide whether the voltage fluctuation is acceptable or not where the flicker can simply be comprehended as the sense to incandescent lamp.

The human brain nerve needs a limited memory time to perceive illumination fluctuation. People will not perceive illumination fluctuation if it is higher than some certain frequency. The visual feeling of human eye and brain to the illumination fluctuation are (as statistics): to the incandescent lamp with 230V, 60W, the frequency range perceivable is from 1Hz to 25Hz approximately, the flickering sensitive frequent range is from 6Hz to 12Hz approximately, the most sensitive frequency to the sine modulated wave with illumination fluctuation at 8.8Hz, the frequency range perceivable can not surpass 0.05Hz to 35Hz.

The flicker is the subjective feeling when we staring an incandescent lamp and it has some relationship with the brain. So we need to set up a mathematic model that simulates the light-eye-brain process, then count and deal with the waveform just gotten. Nowadays, the detection method recommended by IEC has been widely applied to detect the voltage flickering.

A. The Detection Method Recommended by IEC

Since the flicker is due to voltage fluctuation, the first step of monitoring voltage flicker is to extract component of voltage fluctuation from signal.

By analyzing the amplitude modulation waveform of single frequency to the modulation power frequency carrier wave. The instantaneous value of a voltage can be expressed as:

$$u(t) = A(1 + m \cos \Omega t) \cos \omega t \tag{1}$$

Where A is the amplitude of the power frequency carrier wave and ω its angle frequency, m the amplitude of the amplitude modulation waveform and Ω its angle frequency.

Figure 2 shows diagram of flicker meter recommended by IEC. IEC uses square demodulation method.

Square demodulation method:

$$u^2(t) = \frac{A^2}{2} \left(1 + \frac{m^2}{2} \right) + mA^2 \cos \Omega t + \frac{m^2 A^2}{4} \cos 2\Omega t + \frac{A^2}{2} \left(1 + \frac{m^2}{2} \right) \cos 2\omega t + \frac{m^2 A^2}{8} \cos 2(\omega + \Omega)t + \frac{m^2 A^2}{8} \cos 2(\omega - \Omega)t + \frac{mA^2}{2} \cos(2\omega + \Omega)t + \frac{mA^2}{2} \cos(2\omega - \Omega)t + \dots \tag{2}$$

Band pass filter: band pass filter with 0.05~35Hz is used to filter the weight of direct current and power Frequency, the amplitude modulation waveform(weight of voltage fluctuation) is extracted, so

$$A^2 v(t) \approx mA^2 \cos \Omega t \tag{3}$$

Where error is $\frac{m^2 A^2}{4} \cos 2\Omega t$, double frequency weight of the amplitude modulation waveform.

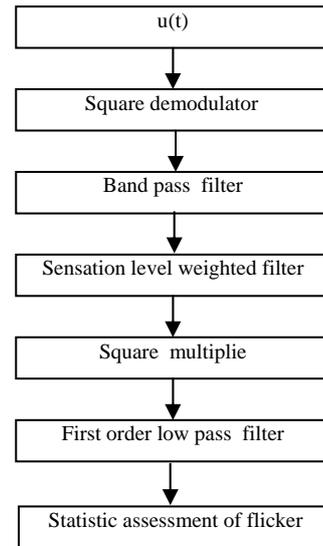


Figure2. Diagram of flicker meter recommended by IEC

But as to the square demodulation used to amplitude modulation waveform detection, its main drawback is that amplitude modulation waveform contains the multiples component of frequency of modulation volute signal, and can not detect the moment when the voltage flicker occurs.

B. the arithmetic model of monitoring voltage fluctuation and flicker based on the wavelet transform

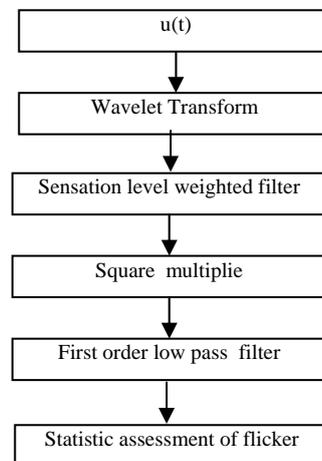


Figure 3. The arithmetic model of voltage fluctuation and flicker

Here we construct an arithmetic model of monitoring voltage fluctuation and flicker based on the wavelet transform as shown in Figure 3.

By means of the wavelet transform, we can extract the amplitude modulation waveform, get the accurate time when the voltage flicker occurs and stops, and count the frequency and amplitude of voltage fluctuation. For the amplitude modulation waveform $v(t)$ of the voltage flicker carrying about amplitude and frequency of voltage flicker, after obtaining the multi-resolution representation of the voltage flicker signal each weight of the signal is obtained in different band, since the voltage flicker signal is low-frequency, then feature of flicker is available by extracting its low-frequency band information only.

The sensation level weighted filter simulates the frequency response of human eyes to the incandescence lamps influenced by sine volute fluctuation. The square multiplier simulates the non-linearity sense process of eye-brain. The first order low pass filter uses integral function to average the smoothness, and simulates the nonlinear and memory effect of human brain nerve to reflect vision. The output is waveform of instantaneous flicker sensation level $S(t)$. Short-term flicker severity Pst can be attained through statistical calculation of $s(t)$.

IV. WAVELET TRANSFORM AND THE PROGRAM DESIGNING

A. Wavelet transform

Suppose $\psi(t) \in L^2(R)$ and its Fourier transform is $\hat{\psi}(\omega)$. Let $\hat{\psi}(\omega)$ be under the admissible condition, that is then

$$C_\psi = \int_R \frac{|\hat{\psi}(\omega)|^2}{|\omega|} d\omega < \infty \tag{4}$$

The continue wavelet transform of signal $x(t)$ is given by

$$WT_f(a, \tau) = \langle x(t), \psi_{a,\tau}(t) \rangle = \frac{1}{\sqrt{a}} \int_R x(t) \psi^* \left[\frac{t-\tau}{a} \right] dt \tag{5}$$

Where $WT_f(a, \tau)$ is wavelet transform coefficient, a is scale factor and τ is translation factor. Reconstruction formula is as follows:

$$x(t) = \frac{1}{C_\psi} \int_0^{+\infty} \frac{da}{a^2} \int_{-\infty}^{+\infty} WT_f(a, \tau) \frac{1}{\sqrt{a}} \psi \left[\frac{t-\tau}{a} \right] dt \tag{6}$$

To minimize the redundancy of the wavelet transform coefficient, a and τ in wavelet function

$\psi_{a,\tau}(t) = \frac{1}{\sqrt{a}} \psi \left[\frac{t-\tau}{a} \right]$ could be defined at some discrete value, that is

$$a = a_0^m \quad a_0 > 0, m \in Z$$

Discrete wavelet function $\psi_{a_0^j, k\tau_0}(t)$, corresponding to $\tau = ka_0^j \tau_0$, is given by

$$\psi_{a_0^j, k\tau_0}(t) = a_0^{-\frac{j}{2}} \psi \left[a_0^{-j} (t - ka_0^j \tau_0) \right] = a_0^{-\frac{j}{2}} \psi \left[a_0^{-j} t - k\tau_0 \right] \tag{7}$$

Therefore, discrete wavelet transform is expressed as, then

$$WT_f(a_0^j, k\tau_0) = \int x(t) \psi_{a_0^j, k\tau_0}^*(t) dt \tag{8}$$

$$j = 0, 1, 2, \dots, k \in Z$$

On the basis of multi-resolution analysis Mallat has established wavelet decomposition and reconstruction, fast algorithm which is called as Mallat algorithm. According to Mallat algorithm, the construction of wavelet function is regarded as the design of filter coefficient[1][2], thus we can obtain the fast wavelet transform algorithm.

Suppose $C_0(n)$, the discrete approximation of the transient signal $x(t)$ under the condition of the zero-scale, is known, and we can substitute $x(n)$ for the sampling sequence $C_0(n)$, that is

$$C_0(n) = x(n) \quad n = 0, 1, \dots, N-1$$

Where $N = 2^J, J \in N$.

The sequence $C_0(n)$ can be decomposed as a approximation coefficient sequence $C_1(n)$. detail coefficient sequence $d_1(n)$ and approximation one $C_1(n)$, decomposing the latter can result in a new wavelet detail coefficient sequence and approximation one. In the same way, decomposing it may result in a new wavelet detail and approximation one with the scale j , the former is rich in the higher frequent component, while the latter rich, in the lower frequent component.

The concrete expression is as follows:

$$d_j(n) = \sum_k c_{j-1}(2n-k)g(k) \tag{9}$$

$$c_j(n) = \sum_k c_{j-1}(2n-k)h(k) \tag{10}$$

Where h denotes low-pass filter and g high-pass filter.

By decomposing $x(t)$, the discrete approximation and detail with different resolution are available, then we can analyze the signal at will[3]. While decomposing the signal step by step, the number of the data containing the wavelet detail coefficient and approximation would reduce half each time[4], Thus signal will be decomposed with multi-scale j from 1 to J . So, the entire signal space

is divided into different scale space, each corresponds to a different frequency space[5].

With the separation of the different frequency band in the signal, making use of wavelet transform coefficients with different frequency band to reconstruct the wave form belonging to different frequent band, the signal feature can be analyzed and extracted better[6][7].

B. The program designing and experiment results

1. The selection of wavelet functions

It is pivotal for wavelet apply to choose wavelet function, and still under research. Now, there are some different wavelet functions, such as Harr, Daubechies, Coiflets, and Symlets. For a certain signal, the analysis effect is different by using different wavelet function, because different wavelet functions have different characteristic in orthogonality compact support, smoothness and symmetry. Haar wavelet is commonly used in theory research because it's discontinuity and the defect of local property in frequency domain. Daubechies wavelet has been applied widely since it is sensitive for non-stationary signal. Because Daubechies wavelet has characteristics of orthogonality, compact support, and fast arithmetic, so Daubechies wavelet is very suitable for detecting oddity of signal. Thus Daubechies wavelet was selected to analyze voltage fluctuation and flicker.

2. The program designing

The program designing of monitoring voltage fluctuation and flicker based on wavelet analysis can be realized by mixed programming of MATLAB and LabVIEW. This paper discusses how to apply wavelet toolbox of MATLAB to LabVIEW so as to enhance function of signal analysis without Signal Processing Toolset, in development environment of LabVIEW, we link MATLAB script program by using MATLAB node, realize call of wavelet function, steps :

(1)Carry through handle Function →Mathematics →Formula Palette, choose right MATLAB script server, and put it to flow chart edit area. When running script node, will call MATLAB script server. Because LabVIEW uses ActiveX technology to implement MATLAB script nodes, they are available only on windows[8].

(2) Right click MATLAB script node frame edge ,in shortcut menu click Add Input and Add Output option so as to add input and output variable of MATLAB script frame ,choose proper types of variable.

(3)Input MATLAB function to MATLAB script frame

Use wavedec(), wavelet decomposition function and wrcoef(), wavelet reconstruction function of Matlab toolbox to deal with the signal containing amplitude modulation waveform. The wavelet decomposition level is 6. The flow chart of monitoring voltage fluctuation and flicker is as Figure 4 shows.

3. Experiment results

Suppose that the input voltage signal is sine waveform with the amplitude being 220V and the frequency being 50Hz and voltage flicker with the amplitude and the frequency being 28V and 6Hz respectively occurs at t=0.1s, the sampling frequency is 3200hz. signal

sequence in sub-band (0~25Hz) is available by using the wavelet DB5 decompose $u(t)$ to six scale, then, the amplitude modulation waveform of the voltage flicker is reconstructed by the signal sequence ,the frequency and amplitude of the voltage fluctuation and the moment at which the voltage flicker occurs is detected.

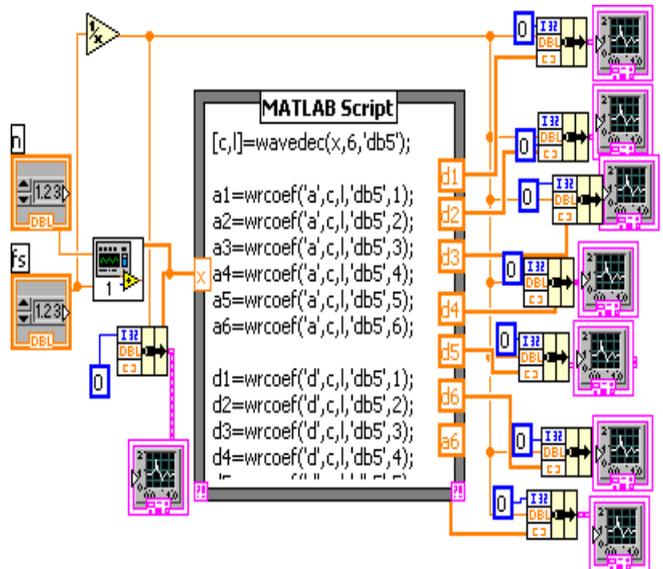


Figure 4. The flow chart of monitoring voltage fluctuation and flicker

AS shown in Figure 5, detail signal $d1 \sim d6$ and approximation signal $a1 \sim a6$ denote signals reconstructed by wavelet coefficients in corresponding band .It is very clear from the approximation signal $d2$ that the voltage flicker occurs at $t=0.1s$ and from the test that by the wavelet analysis the moment at which the voltage flicker occurs is detected exactly. According to $a6$, the frequency and the amplitude of the flicker are 6Hz and 28V respectively and they can be extracted precisely.

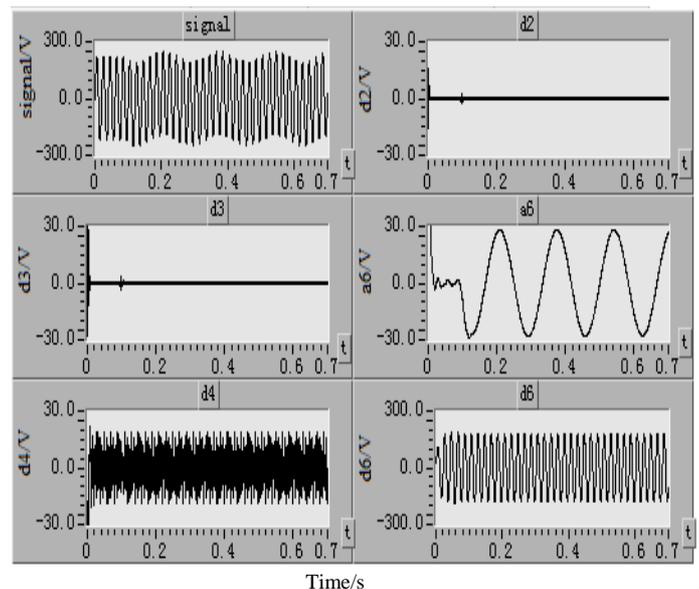


Figure 5. The simulation results of extracting feature of flicker

4. Virtual value measurement of the amplitude modulation waveform

Within the time period T, the amplitude modulation waveform can be expressed as $u(t)$. After sampling, it could be expressed as $u(n)$, $n=1,2,\dots,2^N-1$. Any time domain signal can express in weighted linear sums of wavelet function. So, $u(t)$ is

$$u(t) = \sum_{i=0}^{2^j-1} \sum_{k=0}^{2^{n-j}-1} d_j^{2i}(k) \psi_{j,k}^{2i}(t) + \sum_{i=0}^{2^j-1} \sum_{k=0}^{2^{n-j}-1} d_j^{2i+1}(k) \psi_{j,k}^{2i+1}(t)$$

$$= \sum_{k=0}^{2^{n-j}-1} d_j^0(k) \psi_{j,k}(t) + \sum_{i=1}^{2^j-1} \sum_{k=0}^{2^{n-j}-1} d_j^{2i}(k) \psi_{j,k}^i(t) \tag{11}$$

$d_j^0(k)$ is the coefficient of scaling function, $d_j^i(k)$ is the coefficient of wavelet transform. Virtual value of voltage may express in coefficient of wavelet transform of j scale.

$$\int u(t)^2 dt = \int \left[\sum_{k=0}^{2^{n-j}-1} d_j^0(k) \psi_{j,k}(t) + \sum_{i=1}^{2^j-1} \sum_{k=0}^{2^{n-j}-1} d_j^{2i}(k) \psi_{j,k}^i(t) \right]^2 dt$$

$$= \sum_{i=0}^{2^j-1} \sum_{k=0}^{2^{n-j}-1} [d_j^i(k)]^2 \tag{12}$$

So, virtual value of voltage is

$$U = \sqrt{\frac{1}{2^N} \sum_{n=0}^{2^N-1} u(n)^2} = \sqrt{\frac{1}{2^N} \sum_{i=0}^{2^j-1} \sum_{K=0}^{2^{n-j}-1} [d_j^i(k)]^2}$$

$$= \sqrt{\sum_{i=0}^{2^j-1} (U_j^i)^2} \tag{13}$$

$$U_j^i = \sqrt{\frac{1}{2^N} \sum_{K=0}^{2^{n-j}-1} [d_j^i(k)]^2} \tag{14}$$

U_j^i is Virtual value of voltage in frequency band of j node, when decomposition scale of wavelet is j.

Table I shows experiment results of different frequency modulation waveform.

TABLE I.
EXPERIMENT RESULTS OF DIFFERENT FREQUENCY MODULATION WAVEFORM

Frequency(Hz)	Virtual value(V)		
	Theoretical value	Measured value	Error
6	19.802	19.806	0.004
8	19.802	19.809	0.007
12	19.802	19.795	0.007

V. REALIZATION OF SENSATION LEVEL WEIGHTED FILTER

The simulation of human eye's frequency choose characteristic can use the transfer function IEC recommended:

$$K(s) = \frac{K\omega_1 s}{s^2 + 2 \cdot \lambda s + \omega_1^2} \times \frac{1 + \frac{s}{\omega_2}}{(1 + \frac{s}{\omega_3})(1 + \frac{s}{\omega_4})} \tag{15}$$

$K=1.74802$, $\lambda=2\pi \times 4.05981$, $\omega_1=2\pi \times 9.15494$, $\omega_2=2\pi \times 2.27979$, $\omega_3=2\pi \times 1.22535$, $\omega_4=2\pi \times 21.9$.

The transfer function is a weighted filter which center frequency is 8.8Hz. Converting expression (15) to z domain system function.

$$H(z) = \frac{\sum_{k=0}^4 b_k z^{-k}}{1 + \sum_{k=1}^4 a_k z^k} \tag{16}$$

Then transform it to difference equation as

$$y(n) = \sum_{k=0}^4 b_k x(n-k) + \sum_{k=1}^4 a_k y(n-k) \tag{17}$$

$a_1=-3.548754$, $a_2=4.714548$, $a_3=-2.77601$, $a_4=0.610325$, $b_0=-0.009351$, $b_1=0.00329$, $b_2=-0.018373$, $b_3=-0.00032$, $b_4=0.009022$.

VI. SQUARE MULTIPLIER AND FIRST ORDER LOW PASS FILTER

Square multiplier is Square arithmetic for output of sensation level weighting filter

The transfer function of first order low pass filter is

$$K(s) = \frac{K}{0.3s + 1} \tag{18}$$

$K=63.7864$

Converting it to z domain system function

$$H(z) = \frac{0.26471(1 + z^{-1})}{1 - 0.9917z^{-1}} \tag{19}$$

Then transform it to difference equation as

$$y(n) = 0.26471x(n) + 0.26471x(n-1) + 0.9917y(n-1) \tag{20}$$

We can get waveform of S(t) from above-mentioned arithmetic, then can obtain short-term flicker severity Pst

VII. SHORT-TERM FLICKER SEVERITY

For the voltage fluctuation caused by random changing load, such as arc furnaces, we need not only to inspect the max voltage fluctuation, but also to inspect the statistical result of voltage fluctuation in a long period (at least 10 minutes). The short-term flicker severity Pst

is a statistical calculation result which shows whether the flicker is strong or weak. The method is: Firstly, take $S(t)$ within 10 minute, draw the curve cumulate probability (CPF) of $s(t)$. The formulation of Pst as follows:

$$P_{st} = \sqrt{0.0314P_{0.1} + 0.0525P_1 + 0.0657P_3 + 0.28P_{10} + 0.08P_{50}} \tag{19}$$

Where $P_{0.1}, P_1, P_3, P_{10}$ and P_{50} are detection units that the instantaneous flicker sensation level $S(t)$ exceed 0.1%、1%、3%、10% and 50% in 10 minute.

The program of Calculating Pst was designed by using statistical sorting algorithm, because the instantaneous flicker sensation level $S(t)$ is discrete S sequence in equality time interval, if the sum of the time period (where the S is no less than a certain $S(x)$ is x percent of all the time period, that means S is the highest probability value within(100- x)% period of time. So the P values, $P_{0.1}, P_1, P_3, P_{10}, P_{50}$ which correspond to 0.1%、1%、3%、10% and 50% ordinate of CPF curve are the highest probability value within 99.9%、99%、97%、90%、50% of time period $S(n)$. We just need to realign $S(n)$ from smallness to bigness to find out corresponding probability highest value, then apply them to the formula mentioned above. This method is simple and accurate, doesn't need to draw the CPF curve.

VIII. EXPERIMENT RESULTS

A. Emulation results of instantaneous flicker sensation level $S(t)$

Table II indicates the simulation results of instantaneous flicker sensation level $S(t)$, the error is very lower .

B. experiment results of mixed the different frequency amplitude modulation waveforms

Suppose that the input voltage signal is sine waveform with the amplitude being 220V and the frequency being 50Hz and the amplitude modulation waveforms with the amplitude being 22V and their frequencies are 6Hz and 20Hz respectively. By the wavelet representation, the frequency of the amplitude modulation waveform can be detected exactly, though it mixes with other frequency components. According to the decomposition characteristics of the frequency field, low-frequency coefficient $a8(0\sim6.25Hz)$ and high-frequency coefficient $d7(12.5\sim25Hz)$ are available by decomposing the mixed signal to 8 scale by the wavelet DB5. Then they can be reconstructed to the waveforms indicated as Figure 6.

TABLE II.
EMULATION RESULTS OF INSTANTANEOUS FLICKER SENSATION LEVEL $S(T)$

Frequency (Hz)	Voltage fluctuation(%)		S(t)			
	Sine Wave	Rectangle Wave	Sine Wave		Rectangle Wave	
			Emulation results	Error	Emulation results	Error
5.0	0.398	0.293	0.9983	0.0017	0.9841	0.0159
7.0	0.28	0.217	0.9985	0.0015	0.9850	0.0150
8.8	0.25	0.199	0.9993	0.0007	1.0051	0.0051
9.5	0.254	0.200	1.0011	0.0011	1.0062	0.0062
10	0.262	0.205	1.0010	0.0010	1.0091	0.0091
11	0.282	0.223	1.0006	0.0006	1.0101	0.0101
12	0.312	0.246	0.9994	0.0006	1.0087	0.0087
15	0.462	0.344	0.9985	0.0015	1.0092	0.0092

TABLE III.
EXPERIMENT RESULTS OF MIXED DIFFERENT FREQUENCY AMPLITUDE MODULATION WAVEFORMS

6HZ			20HZ		
Theoretical virtual value(V)	Measured virtual value(V)	Error	Theoretical virtual value(V)	Measured virtual value(V)	Error
15.554	15.558	0.004	15.554	15.559	0.005
19.802	19.809	0.007	19.802	19.812	0.010
21.21	21.200	0.010	21.21	21.200	0.010
23.331	23.320	0.009	23.331	23.321	0.010

It can be known from the result of the test that the low-frequency coefficient a_8 shows the amplitude modulation waveform at frequency 6Hz and high-frequency coefficient d_7 the amplitude modulation waveform of frequency 20Hz. The time-frequency characteristic the of the voltage flicker is clear and distinct as shown in Figure 6 , from which the frequency and the amplitude of the amplitude modulation waveform can be extracted precisely.

Table III shows experiment results of mixed different frequency amplitude modulation waveforms.

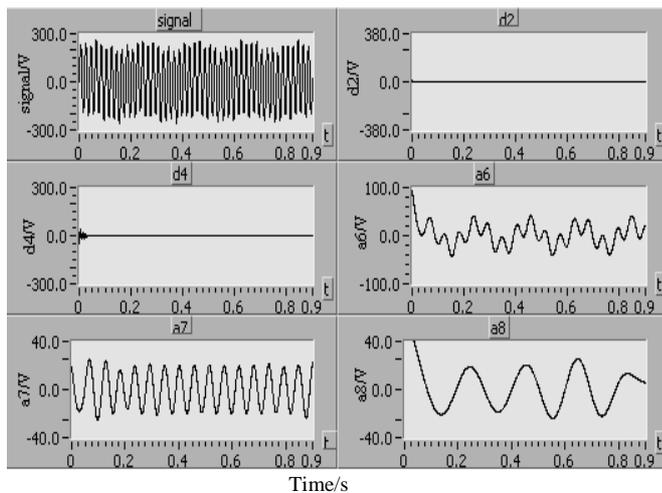


Figure 6. The simulation results.

C. experiment results of harmonic interference

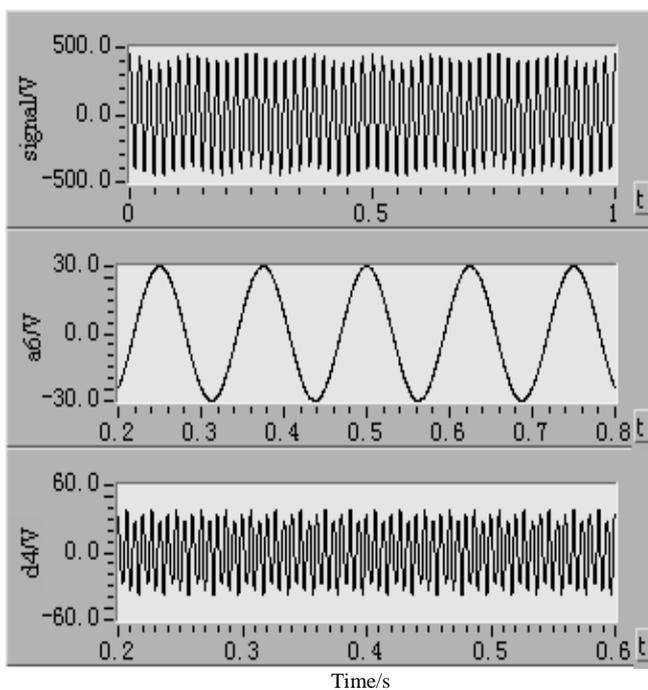


Figure7. The simulation results of extracting feature of flicker

With the increasing of non-linear load to the power system, harmonic interference has become more and more complicated, Suppose that the input voltage signal is sine waveform with the amplitude being 380V and the frequency being 50Hz and the amplitude modulation waveforms with the amplitude being 30V and their frequencies are 8Hz, third harmonic the amplitude being 38V. According to the decomposition characteristics of the frequency field, low-frequency coefficient $a_6(0 \sim 25\text{Hz})$ and high-frequency coefficient $d_4(100 \sim 200\text{Hz})$ are available by decomposing the mixed signal to 6 scale by the wavelet DB5. Then they can be reconstructed to the waveforms indicated as Figure 7.

TABLE IV. EXPERIMENTS RESULTS OF VOLTAGE FLUCTUATION AND FLICKER

Testing time	S(t)	Short-term flicker severity
2008-08-20 9:10:30	0.9837	0.6943
2008-08-20 9:10:50	0.9837	0.6943
2008-08-20 9:11:30	0.9817	0.6936
2008-08-20 9:12:30	1.0684	0.7235
2008-08-20 9:13:50	0.9823	0.6938
2008-08-20 9:15:30	0.9823	0.6938
2008-08-20 9:18:50	0.9861	0.6951
2008-08-20 9:20:30	0.9837	0.6943
2008-08-20 9:20:50	0.9837	0.6943

The voltage fluctuation and flicker monitoring system using LabVIEW and wavelet transform was applied into two typical substations. The experiments results of voltage fluctuation and flicker is shown in Table IV, and it proved that the testing system had nice interoperability, while its operation was stable and the conclusion of the tests were reliable.

IX. CONCLUSION

The voltage fluctuation and flicker monitoring system based on Wavelet Transform was developed by using the virtual instrument technology. The system consists of sensors, signal conditioning circuits, data acquisitions and computers. In the system, the arithmetic model of voltage fluctuation and flicker was established. This paper proposes a method of monitoring and analyzing voltage fluctuation and flicker based on the wavelet transform. In the system, the wavelet transform was applied to virtual instrument by using the MATLAB script node in LabVIEW, in which the signals were divided into multi-frequency bands according to the voltage flicker signal character, the feature of the flicker was extracted, frequency and amplitude of voltage fluctuation signal was gained, the moment at which voltage flicker occurs was detected. The evaluation indices of short-term flicker severity P_{st} are obtained by using statistic sorting algorithms.

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