The Study of Deficiency of IEC Flickermeter Regarding the Interharmonic-Caused Voltage Flicker

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***Abstract*—The bad power quality may cause the machine malfunction or the damage of the machine. Therefore, the IEC 61000-4-15 is proposed by International Electrotechnical Commission for voltage flicker measurement. Moreover, the short-term flicker severity and long-term flicker severity are defined to estimate the level of voltage flicker. However, the IEC standard cannot measure the voltage flicker caused by interharmonics. The flicker caused by the interharmonic frequency higher than 102Hz and lower than 18Hz cannot be evaluated because the bandpass filter of IEC standard will filter them out. In the study, a series of filters are built for the interharmonic components, and the short-term flicker severity value will be calculated based on the envelope of the voltage fluctuation obtained by the half-wave RMS method.**

***Index Terms*—IEC 61000-4-15, interharmonic, half-cycle RMS value, band pass filter bank**

I. Introduction

FLICKER is an extremely annoying phenomenon for human eyes. The reasons of voltage flicker is that the voltage waveform fluctuated by the high-power load devices which are electric arc furnaces, welders, compressors and motors. The strongly voltage fluctuating will cause the light flicker, it is called voltage flicker. The fluorescent lamp is sensitive to voltage fluctuation among this illumination equipment. If the fluctuation frequency is in a range perceptible, the light flicker will be observed by human eyes. As a result, the voltage flicker has been considered in power quality studies. International Electrotechnical Commission has been published the IEC 61000-4-15 that be able to measurement and evaluation of the voltage flicker and it is the most widely used standard for voltage flicker measurement [1], [2]. The IEC flickermeter processes voltage signal as input and outputs flicker indices P_{st} and P_{lt} that are the short-term (10-min) flicker severity and long-term (over 2-hours) flicker severity.

Voltage flicker and interharmonics have an inherent relationship. If the voltage waveform signal contains single interharmonic component or more, the voltage will be fluctuating [3], [4]. It is because the frequency of interharmonic is not an integral multiple of the fundamental frequency. Therefore, the peak and rms value will be variations by interharmonics. The one reasons of causing interharmonic source is the cycloconverter (i.e. variable frequency devices). The interharmonic also occurs in pairs [5]. For example, one pair of interharmonics frequency is symmetry in fundamental frequency of 60- Hz in 110V/60Hz system. This paper will analyze the deficiency of IEC flickermeter and find a method for improve this deficiency. In this paper, the flicker study only considered the interharmonic component.

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II. Voltage Flicker Measuring Approach According to IEC 61000-4-15 Standerd

Fig. 1 shows the procedure of flicker measurement according to the specification defined in IEC 61000-4-15 standard.

Block 1 contains a voltage adaptor and a calibration checking circuit. The aim of the block is to make the input voltage signal to permissible range of the flickermeter.

Block 2 is square modulation from input signal by squaring the output signal of block1. Furthermore, the physical meaning of this block is to simulate the behavior of a lamp.

Block 3 is composed of a cascade of two filters and a measuring range selector. The first filter is band-pass filter. The band-pass filter eliminates the dc component, and it consist of a first-order high-pass filter which cutoff frequency is 0.05Hz and a six-order low-pass filter which cutoff frequency is 42Hz for 60-Hz system and 35Hz for 50-Hz system. The frequency range of 0.05Hz to 42Hz is based on human eyes sensation that outside of the range of the frequency cannot perceive light flicker for most people. The second filter is weighting filter that the weighting value equals one at 8.8Hz.

Block 4 is composed of a squaring multiplier which squares the output of weighting filter and a first-order low-pass filter which simulates the brain response of the cumulative probability distribution of the amplitude of the instantaneous flicker sensation. By the statistical analysis, P_{st} and P_{lt} can be obtained. P_{st} = 0.7 is the critical value which the light flicker can be perceived. P_{st}

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< 0.7 is that most of people cannot perceive flicker phenomenon.

P_{st} > 0.7 is that most of people can perceive flicker persistence of vision. The output of this block is called Instantaneous Flicker Level (IFL).

Block5 performs the statistical classification of the instantaneous flicker sensation and computes the phenomenon. P_{st} > 1 is that the flicker causes extremely uncomfortable in people.

The P_{st} value of flicker of production by the power system or power equipment produces the must be $1\pm5\%$ by specific magnitude that conform to IEC standard.

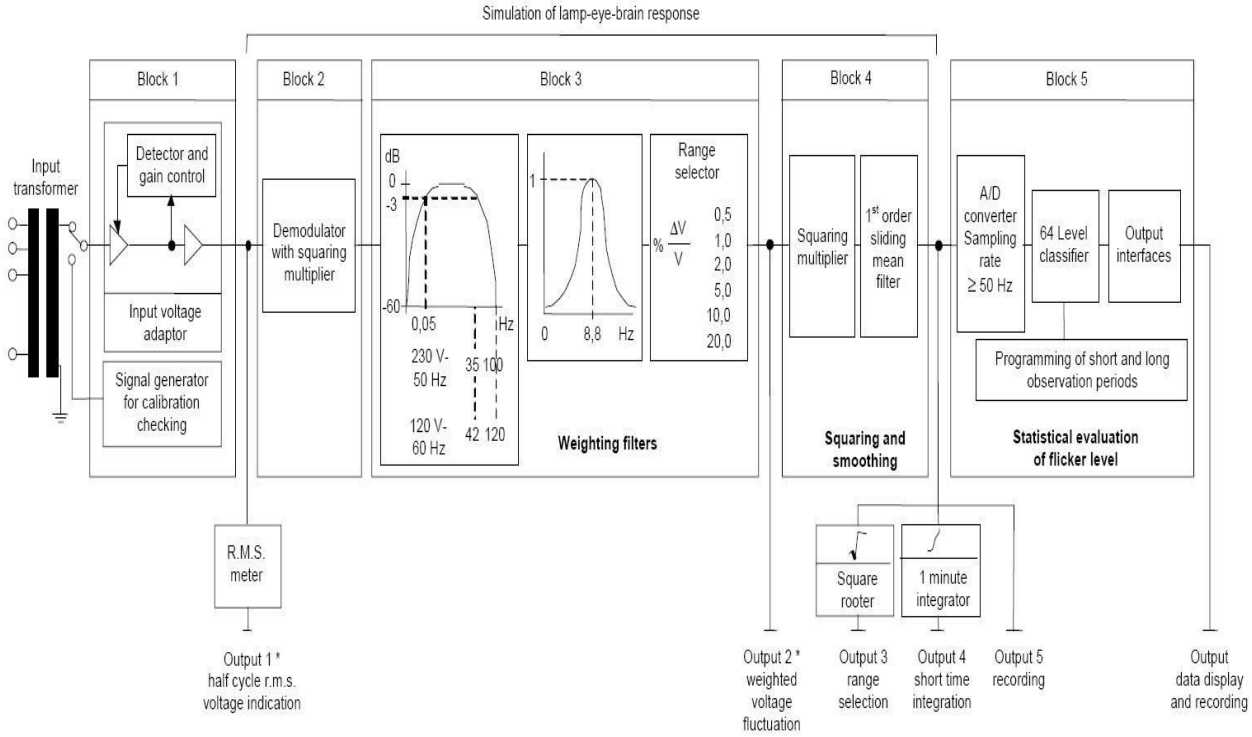

Figure 1. The diagram of IEC flickermeter.

III. Harmonic-Caused Flicker and the Deficiency of IEC Flickermeter

There are many inverter and converter used in electronics industry. One of reasons cause interharmonic is that the cycloconverter [6], [7].

The flicker source with interharmonic frequency can be expressed as

$$v(t) = V_1[\sin(2\pi f_1 t) + m\sin(2\pi f_{ih} t)] \quad (1)$$

where V_1 ,f_1 , m and f_{ih} , are the fundamental peak magnitude, fundamental frequency, interharmonic magnitude and frequency, respectively. For an interharmonic pair, the voltage waveform with two interharmonic components can be expressed as

$$v(t) = V_1[\sin(2\pi f_1 t) + m_1\sin(2\pi f_{ih1} t) + m_2\sin(2\pi f_{ih2} t)] \quad (2)$$

where m1, m2, fih1 and fih2 are the interharmonic relative magnitude and interharmonic frequency of the 1st and 2nd interharmonic components, respectively. Furthermore, interharmonic-caused flicker waveform has a potential characteristic, as shown in Fig. 2.

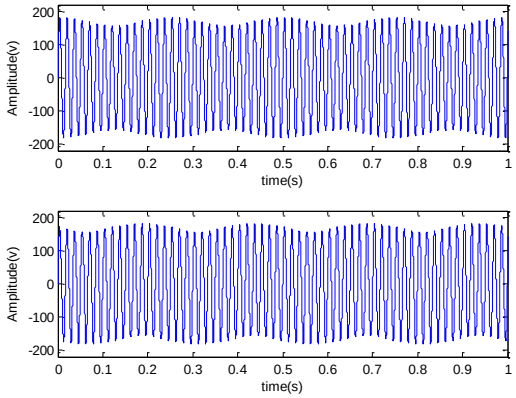

Figure 2. Voltage waveforms with 15% interharmonic-magnitude at 64Hz (top) and 124Hz (bottom) by using MATLAB software

If the interharmonic frequency is closest odd harmonic order, the upper and lower envelopes swell on positive and negative direction respectively and simultaneously. If the harmonic frequency is closest even harmonic order, the envelope changes as a sinusoidal form. In addition, the signal interharmonic-caused flicker near the odd order harmonic (i.e. 60Hz, 180Hz, 300Hz, etc.) can result in significant rms voltage deviation. As shown in Fig. 3, it is

a pair-interharmonic waveform with 10% magnitude at 60±4 Hz. It's voltage fluctuation is obviously observed. An effective way for this is that set of a series band pass filter bank. The aim of this filter is to separate the different frequency components of pair of interharmonic. The separated component will calculated rms value respectively, the individual will be summed up. The schematic diagram is shown in Fig. 4.

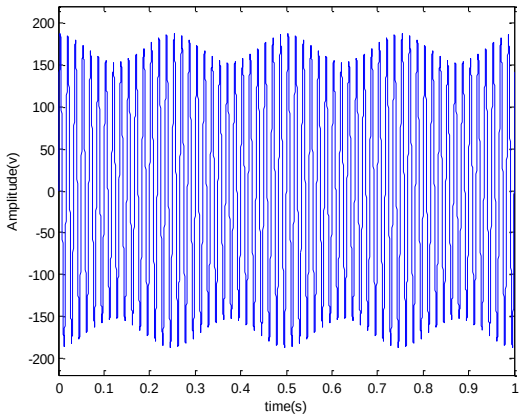

Figure 3. Pair-interharmonic waveform with 10% magnitude at 60 4Hz.

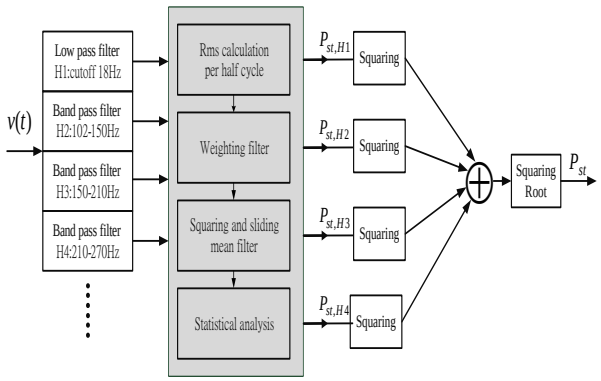

Figure 4. The proposed method to distinguish interharmonic of actual voltage frequency and its P_{st} value calculation.

If a voltage signal contains one or more interharmonic component, the flicker evaluation could be wrong if on the basis of IEC flickermeter. The equation (1) through the block 2 can be expanded as

$$v^2(t) = \frac{1}{2}V_1(1+m^2) - \frac{1}{2}V_1^2\cos(2\pi\cdot 2f_1) - \frac{1}{2}V_1^2 m^2\cos(2\pi\cdot 2f_{ih}t) + V_1^2 m\cos(2\pi\cdot(f_1 - f_{ih})t) - V_1^2 m\cos(2\pi\cdot(f_1 + f_{ih})t) \quad (3)$$

It can be seen that there are five term formula by squaring signal, which dc, , and will must filter out. Only the component left into the block 3 of flickermeter.

$$f_{flicker} = |f_1 - f_{ih}| \quad (4)$$

If this component over then 42Hz of range of band pass filter (i.e. f_{ih} > 102Hz), it will also eliminated by the filter. The flicker severity index will not evaluate accurately by the other procedures. But there are some literature shown that the non-incandescent lamps will appear flicker phenomenon. So a method which can evaluate interharmonic-caused flicker must be found out.

IV. Half-Cycle RMS Method and Bandpass Filter Nank

It is explained in the last section, the component which interharmonic frequency over then 102Hz will eliminated by band pass filter due to the square modulation. A novel method that called half-cycle RMS can solve the problem. The envelope of flicker signal can be obtained that need not be through block 2 of IEC flickermeter. The main key to obtain the envelope is that calculate the rms value (i.e. root-mean-square) per half cycle of voltage waveform. For example, one-cycle voltage waveform consists of 256 points, then half-cycle have 128 points. The first point of voltage envelope of flicker signal is built by calculated rms value of 1 to 128 points. The second point is determined by calculated rms value of 2 to 129 points. The envelope can input through band pass filter and next procedure of IEC flickermeter.

V. Experimental

The experimental way implemented by MATLAB and LabVIEW software. It can be individualy performed. The actual voltage simulation is shown in Fig. 5. The proposed method in this paper has been simulated by MATLAB software and compared with the actual voltage simulation. The experimental results for 60Hz < f_{ih} < 102Hz is shown in Table I. It can be seen that the deviation of P_{st} value is allowable for 20Hz < f_{ih} < 102Hz.

TABLE I. The Experimental Results for Range of 60Hz to 102Hz for One-Interharmonic

fi(Hz)	60+f (Hz)	Magnitude (%)	HIOKI	Proposed method
			Pst value	Pst value
12	72	0.417	0.713	0.716
13	73	0.469	0.712	0.717
14	74	0.528	0.713	0.717
15	75	0.592	0.713	0.717
16	76	0.66	0.712	0.717
17	77	0.734	0.712	0.718
18	78	0.811	0.712	0.718
19	79	0.892	0.712	0.718
20	80	0.977	0.712	0.718
21	81	1.067	0.712	0.719
22	82	1.16	0.712	0.719
23	83	1.257	0.712	0.720
24	84	1.359	0.712	0.720
25	85	1.464	0.711	0.721
33.333	93.33	2.57	0.707	0.731
40	100	4.393	0.7	0.744

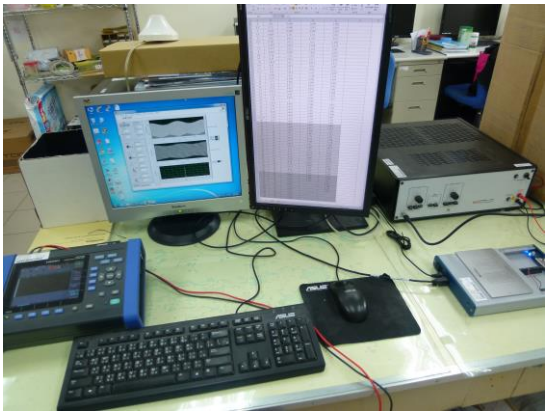

Figure 5. The simulation architecture waveform.

VI. Conclusion

According the IEC 61000-4-15 standard, the frequency of interharmonic component if less than 18Hz, will be filter out by band pass filter of IEC flickermeter. Therefore, the half-cycle RMS and band pass filter bank have proposed in this paper. It can be seen that the proposed method can process the voltage flicker caused by interharmonic in experimental results. It is helpful to produce a novel IEC flickermeter for interharmonic-caused flicker.

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