

Flicker Source Detection Methods Based on IEC 61000-4-15 and Signal Processing Techniques – A Review

M. Silsüpür and B.E. Türkay

Abstract—Flicker is one of the major power quality event. The effect of flicker disturbance has been seen in the power distribution networks nowadays. Voltage variations so called flicker mainly brings negative effects human eye, but also it brings some malfunctions and misoperations to the sensitive electrical equipments. In order to provide proper corrective measures for flicker, the first step is precisely detection of flicker source. Therefore, this paper gives a review of flicker source detection methods based on IEC 61000-4-15 flickermeter and signal processing methods like Fast Fourier Transform (FFT), Wavelet Transform (WT) and Hilbert-Huang Transform.

Index Terms—Flicker, flicker source detection, signal processing for power quality disturbances.

I. INTRODUCTION

FLICKER can be described as an amplitude modulation (AM) of the voltage which has a modulation frequency 0,5 Hz to 35 Hz. It is also defined in the standard IEC 61000-4-30 as impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time [1]. The light flicker or so called voltage flicker comes out due to the fluctuation of voltage.

Arc furnaces, welding machines, generators like wind turbines and variable frequency drives (VFDs) are accepted as voltage flicker generating sources. The effect of the each source to the flicker contribution depends on the frequency and the magnitude of the voltage fluctuation. The frequency and the magnitude of flicker can be defined by a flicker meter.

The measurement of flicker is described in the IEC 61000-4-15 standard. This measurement is based on a flicker meter. This meter has a continuous voltage signal input and outputs of instantaneous flicker sensation (P_{inst}) and a discrete flicker severity called as short term flicker (P_{st}) [2]. The measurement method defined in IEC 61000-4-15 is not sufficient for flicker source detection. Therefore, various methods based on signal processing techniques has been presented in the literature for source detection. In this paper, a review of flicker source detection methods based on IEC 61000-4-15 and signal processing techniques are presented.

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II. DETECTION METHODS BASED ON IEC 61000-4-15

The measurement method defined in the IEC standard can be given by the following block diagram.

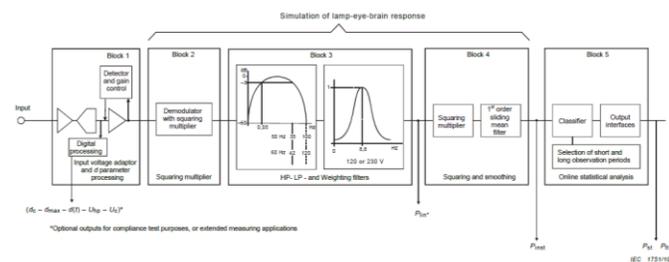


Fig. 1. Block diagram of the IEC flickermeter [2]

Block 1 (input voltage adaptor) contains a voltage adapting circuit that scales the input mains frequency voltage to an internal reference level. The purpose of block 2 (squaring multiplier) is to recover the voltage fluctuation by squaring the input voltage. Block 3 (weighting filters) is composed of a cascade of two filters. The first low-pass filter eliminates the double mains frequency ripple components of the demodulator output. The high pass filter (first order, -3 dB at $0,05$ Hz) can be used to eliminate any d.c. voltage component. The second filter is a weighting filter block that simulates the frequency response of the human visual system to sinusoidal voltage fluctuations of a coiled filament gas-filled lamp. Block 4 (squaring and smoothing) is composed of a squaring multiplier and a first order low-pass filter. The output of block 4 represents the instantaneous flicker sensation. Block 5 (On-line statistical analysis) performs an on-line analysis of the flicker level, thus allowing direct calculation of significant evaluation parameters [2].

The IEC standard mentions about sinusoidal and rectangular voltage changes. For a rectangular and sinusoidal voltage change, voltage modulations can be given by the following formulas

$$v(t) = V \sin(2\pi ft) \left\{ 1 + \frac{1}{2} \frac{\Delta V}{V} \text{signum}[\sin 2\pi f_f t] \right\} \quad (1)$$

$$v(t) = V \sin(2\pi ft) \left\{ 1 + \frac{1}{2} \frac{\Delta V}{V} \sin(\sin 2\pi f_f t) \right\} \quad (2)$$

where f is the power system fundamental frequency, $\frac{\Delta V}{V}$ is the relative voltage change and f_f is the flicker frequency. Rectangular and sinusoidal voltage change waveforms are given in Fig. 2. and Fig. 3., respectively.

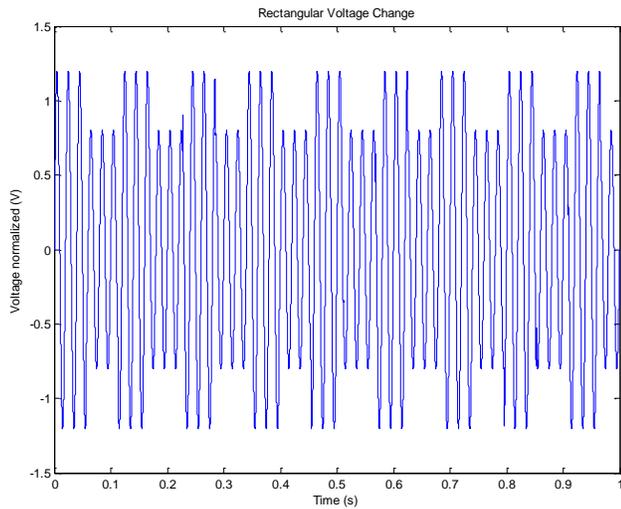


Fig. 2. Rectangular Voltage Change

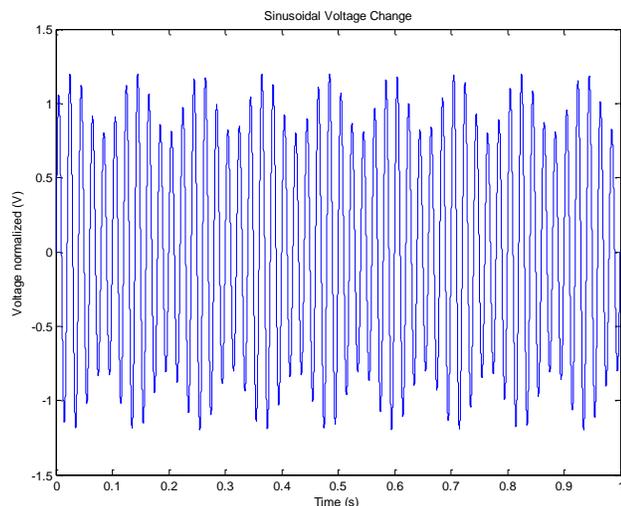


Fig. 3. Sinusoidal Voltage Change

IEC standard defines the flicker level considering only voltage value and the effect of current variations is not taken into account in the meter. Therefore, the outputs of flickermeter is not sufficient for source detection. Besides voltage value, some other parameters like current and power are required for source detection.

A flicker source detection method based on IEC standard has been given by Axelberg et al in [3] and [4]. The authors proposed a method based on Flicker Power (FP). Besides to the voltage signal, the current signal is applied to a flickermeter simultaneously and FP is obtained according to the following equation.

$$p_{\pi}(t) = (m_{u\pi}(t)) \cdot (m_{i\pi}(t)) \quad (3)$$

$$FP = \frac{1}{T} \int_0^T p_{\pi}(t) dt \quad (4)$$

Where $m_{u\pi}(t)$ and $m_{i\pi}(t)$ filtered voltage and current signals respectively, and $p_{\pi}(t)$ is instantaneous flicker power.

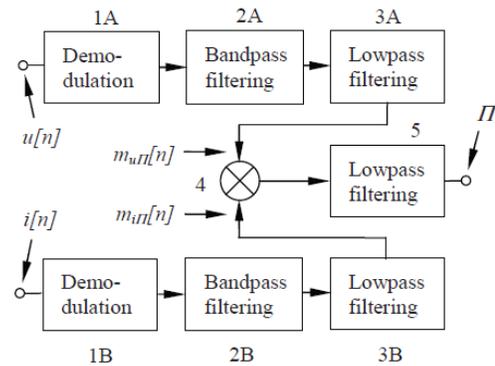


Fig. 4. Signal flow diagram of the proposed method [4]

The source detection is obtained according to the sign of the FP. From the measurement point of view, a positive sign of FP means a flow from the network to the load (downstream) while a negative sign of FP means a flow from load to the network (upstream).

The authors in [5], presented a method based on both the sign and the magnitude of FP. The flow diagram of this method is the same as described in figure 4. The envelope demodulation is used instead of square demodulation in the flickermeter.

Poormonfaredazimi et al proposed a new demodulation technique based on coherent phase detector for FP calculation [6].

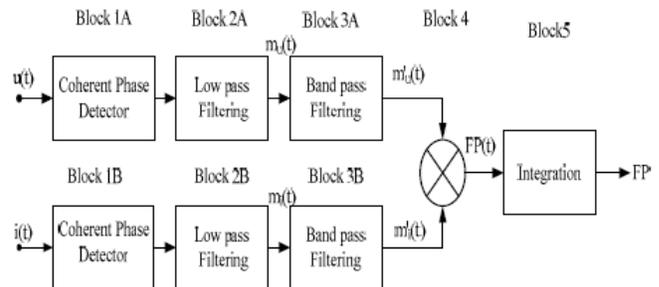


Fig. 5. Proposed block diagram for flicker power calculation [6]

A new FFT based demodulation technique in the IEC flickermeter is suggested by Jamaludin et al [7]. The aim of this technique is estimating the flicker envelope without producing additional low frequency components.

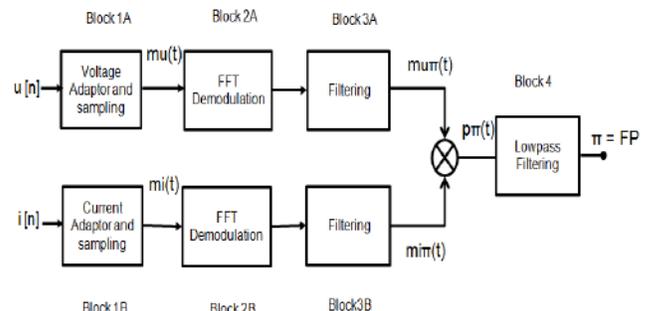


Fig. 6. The proposed flicker power algorithm based on FFT demodulation [8]

The authors in [9], developed an algorithm to detect the flicker sources with minimum number and placement of the measurement devices. Voltage and current signals taken from the measurement devices are used to calculate the FP.

A method based on flicker energy has been given in [10]. If the sign of flicker energy is positive, the flow direction is downstream and vice versa.

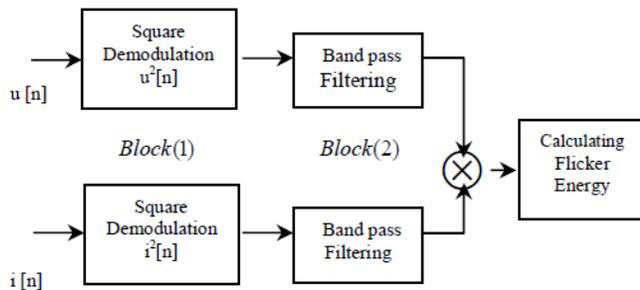


Fig. 7. Signal flow diagram of measurement method [10]

Shao et al developed a source location and flicker disturbance responsibility method by considering voltage at Point of Common Coupling (PCC) [11]. According to the simple distribution system given in Fig. 8., U_{PCC} is calculated with respect to fluctuating load impedance as follows

$$U_{PCC}(t) = \left| \frac{Z(t)}{Z_s + Z(t)} \right| U_s \quad (5)$$

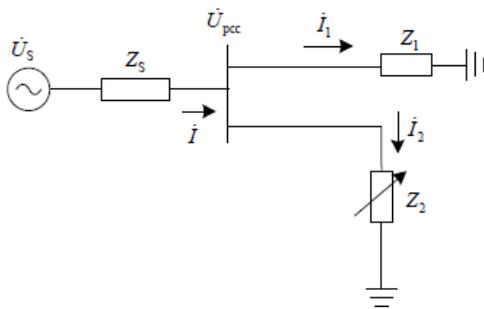


Fig. 8. A simple distributed system [11]

For the calculation, only one load impedance is considered as a fluctuating load while the others are not fluctuating and U_{PCC} values are calculated accordingly. U_{PCC} values are then used as inputs of the IEC flicker meter and flicker disturbance responsibility of each load is calculated.

Altintas et al proposed a flicker contribution tracing method based on individual reactive current components of multiple electric arc furnaces at PCC [12]. Voltage drop on the source impedance by considering individual reactive current is calculated and then it is given as an input to IEC flickermeter. P_{st} values for each EAF is then calculated and flicker contribution is obtained.

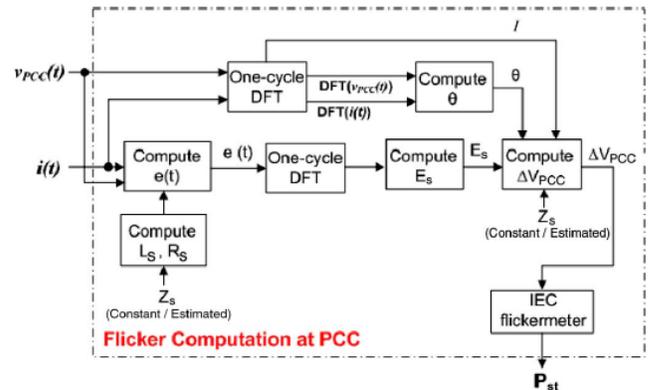


Fig. 9. Computation of flicker at the PCC with the proposed method [12]

The authors suggested a spectral decomposition based approach for flicker evaluation of electric arc furnaces in [13]. In the suggested method, voltage resulted from this approach is applied to IEC flicker meter and flicker severity is calculated.

III. DETECTION METHODS BASED ON SIGNAL PROCESSING TECHNIQUES

As mentioned above FFT technique is mainly used for flicker measurement. Beside the FFT technique, various signal processing techniques like Wavelet Transform (WT) and Hilbert-Huang Transform are used. These techniques can be used individually or hybrid manner (e.g. combination of FFT and WT).

Wavelet representation of voltage flicker has proposed in [14] and [15]. By using Multi Resolution Analysis [MRA], flicker calculation, detection and assessment are given.

In order to prevent the leakage effect of FFT algorithm, the authors introduced a hybrid algorithm by using FFT and WT [16].

Since increasingly usage of WT in the analysis, it is essential to detect which wavelet is suitable for required application. In [17] it has been provided a comparison between Daubechies orthogonal wavelet (DOW) and nonorthogonal cardinal spline wavelet (NCSW) from the computation cost point of view. It is figured that DOW is better than NCSW. The authors proposed a method based on Wavelet Packet Transform (WPT) to selection of suitable mother wavelet for harmonic and interharmonic measurements. Discrete Meyer (dmey) family is seen that dmey is suitable [18]. In [19], Gauss wavelet family for Continuous Wavelet Transform (CWT) has presented as suitable to sag detection. Wavelet function selection for sag, swell, transient, flicker and harmonic has proposed and Biorthogonal Bior3.9 family is selected by Vega et al [20]. The authors introduced best wavelet selection method based on Discrete Wavelet Transform (DWT) coefficient energy [21]. Biorthogonal wavelet has been selected as most suitable for sag, swell, transient, flicker and harmonic identification. In [22], it has been suggested to calculate the percentage energy of the wavelet coefficients at each level of DWT and compare to the percentage estimated energy of each harmonic component. In [23], selection of the most suitable mother wavelet among the

Gaussian, Morlet, Shannon, and complex wavelet families used in CWT for harmonic measurement has investigated and based on the minimum percentage error Gaussian has been selected as the most suitable. The authors suggested a method based on minimum energy deviation in each level of DWT [24]. It has been pointed out that Daubechies db10 mother wavelet is the most suitable for reformulating power components definitions contained in the IEEE Standard 1459-2000 and harmonic analysis [25-27]. In [28], the authors investigated different mother wavelets like Discrete Meyer (dmey), Daubechies 10 (db10) & Daubechies 7 (db7), Symlet 8 (sym8) and Coiflet 5 (coif5) for power system harmonic by considering IEEE Standard 1459-2000 with the help of energy criteria and is pointed out that Daubechies db7 is most suitable for harmonic analysis. The author proposed a method to track the impedance of fluctuating load by using Daubechies db5 wavelet function

in DWT [29].

In [30], the authors suggested a flicker measurement method based on Orthogonal Hilbert-Huang Transform.

IV. RESULTS

The sign of the flicker power and interharmonic power have been used for source detection with the help of IEC 61000-4-15 flickermeter. In addition to the IEC flickermeter, various methods based on signal processing techniques are presented in the literature. WT is mainly used for flicker source detection methods. In WT analysis, selecting the most suitable mother wavelet family or wavelet function is important. Therefore, the comprehensive analysis about flicker source detection methods and wavelet families are presented in Table I and Table II.

TABLE I
FLICKER SOURCE DETECTION METHODS BASED ON IEC FLICKERMETER AND SIGNAL PROCESSING TECHNIQUES

Reference	Detection Method	Source Detection
Axelberg et al. [3], [4]	IEC Flickermeter	Sign of Flicker Power (+) or (-)
Axelberg et al. [5]	IEC Flickermeter (Envelope Demodulation)	Sign of Flicker Power (+) or (-)
Poormonfaredazimi et al. [6]	IEC Flickermeter (Coherent Demodulation)	Sign of Flicker Power (+) or (-)
Jamaludin et al. [7], [8]	IEC Flickermeter (FFT Demodulation)	Sign of Flicker Power (+) or (-)
Moaddabi et al. [9]	IEC Flickermeter	Sign of Flicker Power (+) or (-)
Payam et al. [10]	IEC Flickermeter	Sign of Flicker Energy (+) or (-)
Shao et al. [11]	PCC Voltage and IEC Flickermeter	Flicker Contribution Responsibility
Altıntaş et al. [12]	Reactive Current Component and IEC Flickermeter	Flicker Contribution Responsibility
Köse et al. [13]	Flicker Measurement by Spectral Decomposition	-
Zheng et al. [14]	Wavelet Transform	Maximum Flicker Magnitude
Chen et al. [16]	Continuous Wavelet Transform and FFT	-
Zhenguo et al. [29]	Wavelet Transform	Change of Impedance

TABLE II
PQ DISTURBANCES & WAVELET FAMILIES

Reference	Parameters to be measured or detected	Method	Suitable Wavelet Family
Morsi et al. [18]	Harmonic and Interharmonic	Wavelet Packet Transform	Discrete Meyer (dmey)
Faisal et al. [19]	Voltage Sag	Continuous Wavelet Transform	Gauss wavelet
Vega et al. [20]	Sag, Swell, Transient, Flicker and Harmonic	High Pass Decomposition Filter	Biorthogonal Bior3.9
Vega et al. [21]	Sag, Swell, Transient, Flicker and Harmonic	Wavelet Coefficient Energy	Biorthogonal
Morsi et al. [22]	Harmonic	Wavelet Coefficient Energy	Daubechies db10
Srivastava et al. [23]	Harmonic	Minimum Percentage Error	Gaussian
Morsi et al. [24], [25]	Power Components acc. To IEEE Standard 1459-2000	Minimum Energy Deviation	Daubechies db10
Apetrei et al. [26]	Harmonic	Discrete Wavelet Transform	Daubechies db10
Morsi et al. [27]	THD, TIF, CF	Wavelet Packet Transform	Daubechies db10

V. CONCLUSION

This paper gives a review of flicker source detection methods based on IEC 61000-4-15 and signal processing techniques. The flicker power and interharmonic power are

used as to detect the flicker source by considering the sign of the power. If the sign is negative the source is located downside (upstream) with respect to measurement point and if the sign is positive, it is upside (downstream). Signal processing techniques especially Wavelet Transform is

mainly used for flicker calculation.

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