System for Verification of Virtual Flickermeters

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Abstract – **In this paper a calibration system for verification of LabVIEW based virtual flickermeters is described. The system is designed on the base of the IEC 61000-3-3 [1] standard which set up some tests to determine whether the flickermeter response is within the defined accuracy. The virtual instrument generates a set of amplitudes and frequencies for sinusoidal and rectangular modulation signals for 230 V/50 Hz systems. These signals are the input data for the virtual flickermeter under test where the measured results for the maximum instantaneous flicker and the short-term perceptibility index should be equal to one within accuracy of ±5%.**

Keywords – **Virtual instrumentation, flickermeter, calibration system, LabVIEW**

I. Introduction

The use of industrial and consumer equipment with nonlinear characteristics, loads that need reactive power and other causes, generate repetitive or random variations of the magnitude of the power supply. These magnitude changes occurring at frequencies up to 35 Hz can give rise to an effect called lamp flicker. Flicker is an impression of unsteadiness of visual sensation induced by a light source whose luminance or spectral distribution fluctuates with time.

Before few decades the flicker problems arise not very often and in that time engineers develop empirical guidelines for determination of the flicker level that can be tolerated. These guidelines were based on a number of voltage fluctuations in minute and the percentage of the voltage fluctuation. This concept has several imperfections because it is based on approximations which simplify the complex events with one magnitude and repetition rate. Hereafter by their design, the first generation instruments were of relatively low accuracy.

In the last decade the development in the area of power-quality monitoring have been subject to large improvements, mainly caused by development in microprocessors, data storage, communication, and by the customer demands for information on power quality levels. The adoption of personal computers in the field of the power quality measurement offer great progress and flexibility. Step ahead for development of modern measurement systems is achieved by adopting the concept of virtual instrumentation. It is a methodology for realization of measurement instruments by using standard PC's, hardware data acquisition boards for signal conversions and specialized program platforms for processing and recording of the measurement results. The adoption of these tools for flicker measurements is very popular and many solutions have been reported in literature. The new generations of flicker instruments are more accurate and require calibration procedure with lower uncertainty.

This paper describes a virtual instrument used for validation testing of LabVIEW based virtual instruments for flicker measurement. The virtual flickermeter is based to IEC 61000-4-15 [2] standard. The standard defines tests for determination of the flickermeter response which should be within the defined accuracy. The virtual instrument generates a set of amplitudes and frequencies for sinusoidal and rectangular modulation signals for 230 V/50 Hz systems. These signals are the input data for the virtual flickermeter under test where the measured results for the maximum instantaneous flicker P and the short-term perceptibility index P_{st} should be equal to one within ±5% accuracy.

II. Flicker measurement

Flicker monitoring has been standardized using a meter that is completely described in IEC 61000-4-15 Standard. The system can be divided in two main parts: simulation of the lamp-eye-brain response and statistical evaluation and results. The block diagram of the digital flicker meter according to this standard is shown on Fig.1.

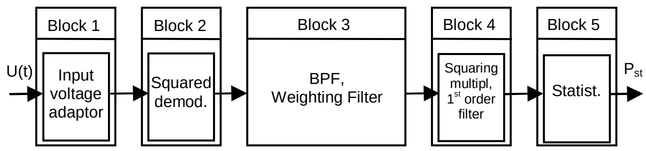

Fig. 1. Block diagram of digital flicker meter

The block 1 represents the signal conditioning circuit for filtering and attenuation of the input signal down to an appropriate reference level. The block 2 represents a squaring demodulator for reconstruction of the envelope of the voltage fluctuations, and simulation of the lamp behavior. The block 3 is a cascade of two filters. The first filter can be further divided on two filters forming a band pass filter:

- 3rd order high pass filter for DC removal with cut-off frequency of 0.05Hz,
- 6th order low pass filter with cut-off frequency of 42Hz

The second filter of block 3 is a weighting filter which simulates the frequency response of a lamp and human visual system caused by voltage fluctuations. The transfer function of this filter with maximum on 8.8 Hz is defined by the IEC 61000-4-15 Standard for 230V, 60W incandescent lamp. It is expressed with the equation:

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$$F(s)=\frac{k\omega_1 s}{S^2+2\lambda s+\omega_1^2}\frac{1+\frac{s}{\omega_2}}{(1+\frac{s}{\omega_3})(1+\frac{s}{\omega_4})} \quad (1)$$

where: $\omega_1=2\pi 9.2$, $\omega_2=2\pi 2.27$, $\omega_3=2\pi 1.22$, $\omega_4=2\pi 21.9$ and $k=1.74$, $\lambda=2\pi 4.06$.

The block 4 contains squaring multiplier and a first order low pass filter with cut-off frequency of 0.54 Hz which simulates the eye-brain response. The output of this filter corresponds to an instantaneous flicker sensation. The last block 5 is used for statistical analyzes of the measurement results over short period (10 min.) where the amplitude of the instantaneous flicker is divided in minimum 64 classes defined by IEC standard. This classification is further used for obtaining the cumulative probability function and calculation of the short-term flicker P_{st} according the relations:

$$\begin{aligned}
P_{st} &= \sqrt{0.031P_{0,1}+0.052P_{1s}+0.065P_{3s}+0.28P_{10s}+0.08P_{50s}} \\
P_{50s} &= (P_{30}+P_{50}+P_{80})/3 \\
P_{10s} &= (P_6+P_8+P_{10}+P_{13}+P_{17})/5 \\
P_{3s} &= (P_{2.2}+P_3+P_4)/3 \\
P_{1s} &= (P_{0.7}+P_1+P_{1.5})/3
\end{aligned} \quad (2)$$

III. Testing description

The testing of the flickermeter validation is made for two types of measurements, short-term flicker P_{st} and instantaneous flicker sensation P. The P_{st} response is tested with modulation signal with square wave shape, and P response is tested with both sinusoidal and square modulation signals. When these signals are the input data for the virtual flickermeter under test, the measured results for the maximum instantaneous flicker and the short-term perceptibility index should be equal to one. The maximum allowed error of the readings is ±5% according [1]. On Fig.2 a curve of equal severity (P_{st}=1) for rectangular voltage changes is given.

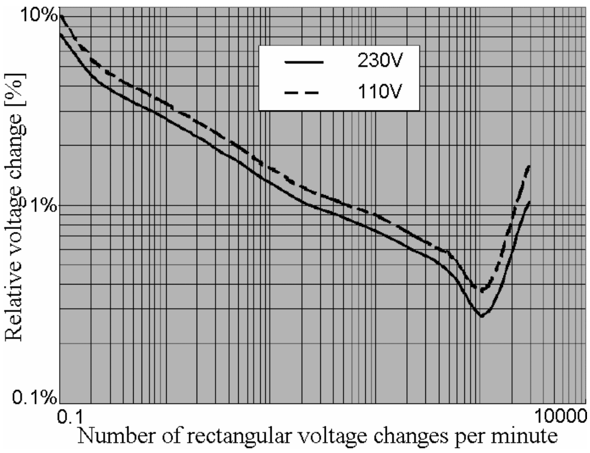

Fig.2 Curve of equal severity for rectangular voltage change

The testing system should be able to generate and measure three sets of wave shapes, one for the P_{st} response and two for the P response. This validation testing method requires measurement and setting of all combination of frequencies and voltage fluctuations for square or sinusoidal wave shapes. One set of test points for sinusoidal and square modulation signals is given in Table I for $P=1$ and Table II for $P_{st}=1$.

TABLE I
TEST POINTS FOR SINUSOIDAL AND SQUARE MODULATION (P=1)

Squarewave modulation		Sinewave modulation	
f[Hz]	ΔV/V[%]	f[Hz]	ΔV/V[%]
0.5	2.290	0.5	0.501
1.0	1.375	1.0	0.463
1.5	1.050	1.5	0.422
2.0	0.865	2.0	0.391
2.5	0.735	2.5	0.363
3.0	0.635	3.0	0.345
3.5	0.555	3.5	0.336
4.0	0.489	4.0	0.326
4.5	0.435	4.5	0.307
5.0	0.390	5.0	0.286
5.5	0.352	5.5	0.263
6.0	0.320	6.0	0.243
6.5	0.295	6.5	0.227
7.0	0.275	7.0	0.213
7.5	0.261	7.5	0.202
8.8	0.247	8.8	0.192
9.5	0.251	9.5	0.196
10.0	0.258	10.0	0.203
10.5	0.268	10.5	0.209
11.0	0.281	11.0	0.219
11.5	0.296	11.5	0.230
12.0	0.312	12.0	0.243
13.0	0.351	13.0	0.271
14.0	0.393	14.0	0.305
15.0	0.440	15.0	0.341
16.0	0.489	16.0	0.378
17.0	0.541	17.0	0.414
18.0	0.596	18.0	0.454
19.0	0.655	19.0	0.505
20.0	0.717	20.0	0.557
21.0	0.781	21.0	0.604
22.0	0.849	22.0	0.642
23.0	0.921	23.0	0.706
24.0	0.997	24.0	0.768
25.0	1.076	25.0	/

TABLE II
TEST POINTS FOR SQUARE MODULATION (P_{ST}=1)

Changes/min.	f[Hz]	ΔV/V[%]
1	0.00833	2.724
2	0.01667	2.211
7	0.05833	1.459
39	0.32500	0.906
110	0.91667	0.725
1620	13.5000	0.402

IV. Virtual Instrument Description

The proposed solution represents a virtual instrument for validation testing of LabVIEW based flickermeters. The simplified block diagram of the testing system is shown of Fig.3

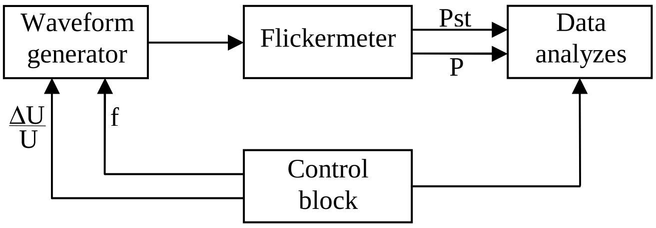

Fig.3 Simplified block diagram of the testing system

A software controlled virtual waveform generator is used for generation of the flickermeter input signals. The control block sets the input parameters for frequency and percentage of fluctuation of the modulation signal according to the test points specified in Tables I and II. The testing system generate and measure the results for all three sets of wave shapes, one for the P_{st} response and two for the P response. The data analyzes block is used for storing and processing of the measurement results and calculation of the measurement errors. The block diagram of the virtual instrument is shown on Fig.4.

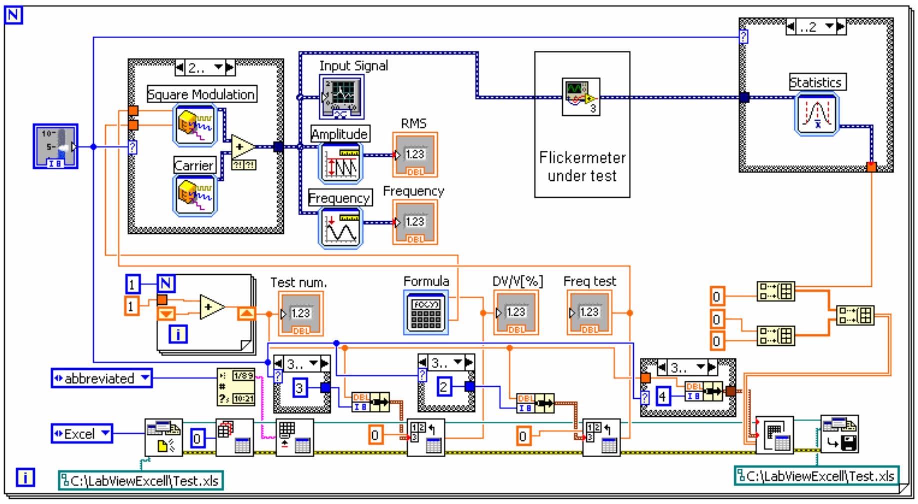

Fig.4 Block diagram of the virtual instrument

The flickermeter under test is inserted in to the testing system in a form of sub-virtual instrument with one input for the testing signals and two outputs for instantaneous flicker sensation P and short-term flicker Pst. The testing system reads the values of the testing points from a data file in excel format. This data are used for setting the parameters of the signal generation block which consist of two function generators, one for simulation of the supply voltage (carrier) and the second for simulation of the voltage fluctuations (modulation signal). The two waveform generators are operated by clock which is synchronized by the computer. During the tests the virtual instrument measures and displays the parameters of the input signal on appropriate graph.. Each test is executed continually for a fixed testing period of 1 minute and the measurement results are stored in a table in the same excel file. This procedure is repeated for all combinations of amplitude and frequency changes of square wave or sinusoidal modulations. The testing system calculates the measurement error and presents the results in a graphical form; this error should not exceed the maximum allowed value of ±5% defined by the standard.

Examples of typical results for measurement of P_{st} and P for one virtual flickermeter solution [3] are given in Tables III, IV and V and Figs. 5,6 and 7.

Table II
Results for measurement of P_{ST}

Changes/min.	P_{st}	Error [%]
1	1.041	4.1
2	1.046	4.6
7	1.020	2.0
39	1.047	4.7
110	1.031	3.1
1620	0.964	-3.6

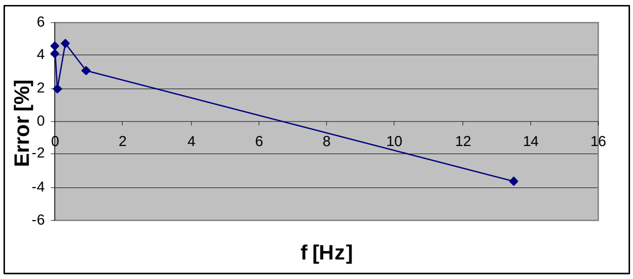

Fig. 5 Error for P_{st} measurement

TABLE IV
RESULTS FOR MEASUREMENT OF P (SINUSIUDAL CHANGES)

f[Hz]	P	Error [%]
1	0.96	-4
5	1.01	1
10	0.97	-3
15	0.99	-1
20	1.011	1.1
25	1.024	2.4

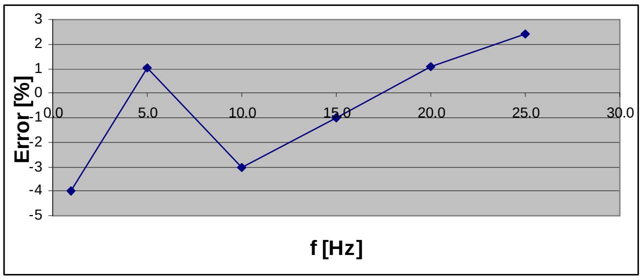

Fig. 6 Error for P measurement (sinusoidal changes)

TABLE V
RESULTS FOR MEASUREMENT OF P (RECTANGULAR CHANGES)

f [Hz]	P	Error [%]
1	1.019	1.9
5	1.012	1.2
10	1.031	3.1
15	1.028	2.8
20	1.041	4.1
25	1.055	5.5

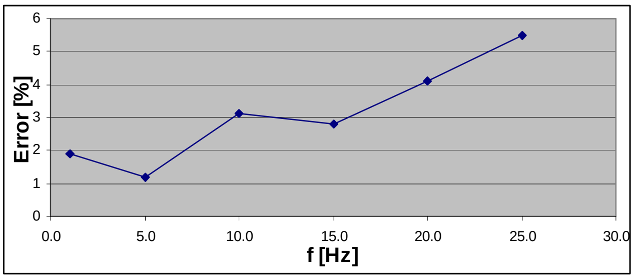

Fig. 6 Error for P measurement (rectangular changes)

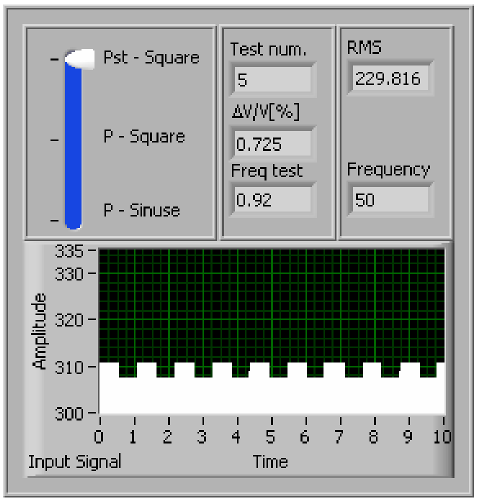

Fig.5 Front panel of the virtual instrument

From the results shown on Fig 5,6 and 7 can be seen that the flickermeter under test fulfills the verification tests except for P measurements (rectangular changes) for frequency of 25Hz where the flickermeter makes an error of 5.5%.

The front panel (Fig.5) consists of several groups of controls and displays. The type of the test for measurement of Pst or P with appropriate wave shape is selected with a sliding switch. According the type of measurement the virtual instrument chooses the right set of test points for the input signal. The second group of instruments indicates the parameters of the modulation signal, and the third group indicates the measurements for the frequency and the RMS voltage of the input signal. The generated waveform is shown on a graphic display.

V. CONCLUSION

This paper describes a virtual instrument used for verification testing of LabVIEW based virtual instruments for flicker measurement according to the standard IEC 61000-4-15. The standard defines procedure for determination of the flickermeter response which should be within the defined accuracy. The virtual instrument is used for generation of a set of amplitudes and frequencies for sinusoidal and rectangular modulation signals for 230V /50 Hz systems. These signals are the input data for the virtual flickermeter under test where the measured results for the maximum instantaneous flicker and the short-term perceptibility index should be equal to 1 within ±5% accuracy. The flickermeter under test is inserted in to testing system in a form of sub-virtual instrument. The tests are repeated for all combinations of amplitude and frequency changes for square wave or sinusoidal modulations. All measurement data are recorded in excel data file. The testing system calculates the measurement error and presents the results in a graphical form.

The system is designed in a way so it can be easily rearranged for verification of stand-alone flickermeters [4] or power quality analyzers. For this purpose a high accuracy data acquisition cards and power amplifiers are needed.

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