IEC FLICKERMETER USED IN THE POWER SYSTEM MONITORING
Part 2: Investigation of the flickermeter model sensitivity

Miernik wahań napięcia IEC do pomiarów w systemie elektroenergetycznym
Cześć 2: Badania czułości modelu miernika

Marek ROGOŻ¹  Andrzej BIEN²  Zbigniew HANZELKA²  Marek HARTMAN³
¹ Power Distribution Company – Cracow, POLAND
² University of Science and Technology, Cracow, POLAND; ³ Gdynia Maritime University, Gdynia, POLAND

Summary: Flickermeters users have noticed that despite of positive test results (acc. to standard [2]) the instruments’ readings can still disagree significantly. One of the crucial problems in the flickermeter design is permissible tolerance of the components used. It is difficult to predict cumulative effects of the components parameters dispersion. Therefore it is essential to determine acceptable deviations for each signal-processing block, which do not result in a faulty operation of the whole instrument. This paper presents results of investigation on the flickermeter sensitivity to changes in the filters selected parameters, relevant to the function of a given filter. The results provide information on permissible dispersion of parameters of functional blocks.


Keywords: electrical power quality, flicker, flickermeter, sensitivity, model
Słowa kluczowe: jakość energii elektrycznej, migotanie światła, miernik migotania światła, wrażliwość, model

I. THE FLICKERMETER MODEL

The flickermeter model has been built in order to investigate the sensitivity of flickermeter.
The model has been developed according to recommendations of standard IEC 61000-4-15, which specifies the principles of flickermeter structure, provides its block diagram and specification for each block.

A detailed description of the tests results have been described in publication [3]. The described flickermeter model was developed and simulated in MATLAB environment using SIMULINK package.
The model has been tested for its adequate operation and compliance with standard [2], which verify its correct operation [4], [3]. The results of obligatory tests are presented below.
2. FLICKERMETER MODEL TESTS ACCORDING TO STANDARD IEC 61000-4-15

Each flickermeter, to be approved for use, must be tested according to standard IEC 61000-4-15 to verify its adequate and correct operation.

2.1. Test 1 — Analogue response

Correctness of the analogue part operation was confirmed by means of checking the model response to sinusoidal and square voltage-wave voltage modulation with values conforming to Table 1 and 2 in standard [2].

The correctness of operation is assessed using the maximum recorded value of the short term flicker severity at the instrument standard output 5. This value shall not exceed 5% deviation from 1 for each measuring point.

Figures 1 and 2 show the error values recorded for sinusoidal and square-wave voltage fluctuations respectively.

Fluctuation of results, visible in figures 1 and 2, particularly in response to the square-wave voltage modulation is mostly caused by numerical errors in calculation.

The test results confirm correct operation of the model analogue part because error characteristics are contained within the assumed 5% tolerance.

<table>
<thead>
<tr>
<th>Number of changes per minute</th>
<th>Voltage change [%]</th>
<th>Pst</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.72</td>
<td>1.0112</td>
</tr>
<tr>
<td>2</td>
<td>2.21</td>
<td>1.0067</td>
</tr>
<tr>
<td>7</td>
<td>1.46</td>
<td>1.0096</td>
</tr>
<tr>
<td>39</td>
<td>0.905</td>
<td>1.0107</td>
</tr>
<tr>
<td>110</td>
<td>0.725</td>
<td>1.0017</td>
</tr>
<tr>
<td>1620</td>
<td>0.402</td>
<td>0.9845</td>
</tr>
</tbody>
</table>

2.2. Test 2 — The overall instrument test

The overall instrument check consists in applying square-wave modulated signal to the instrument input. The modulating signal parameters and obtained Pst values are listed in Table 1.

The instrument can be found compliant with standard requirements, when the obtained short term flicker severity Pst for each test signal is 1 ± 5%.

It is therefore clear that the model easily meets the standard [2] requirements regarding this test.

3. THE MODEL SENSITIVITY TO CHANGES IN THE FILTERS' SELECTED PARAMETERS

Analysis of the model sensitivity to changes of filters selected parameters has been performed. Such investigation enables to check the model overall reaction to changes in parameters of a chosen filter. It enables to realize how stringent are the requirements of standard [2] concerning filters parameters.

Each time the parameter of only one filter has been changed and the test 2, i.e. checking the response to square-wave signal modulation, was performed. Parameters of the modulating signal were the same as in Table 1.

All Pst values were estimated classifying the flicker signal in 400 classes.

3.1. High-pass filter — $f_g = 0.05$Hz

This filter has been made in seven versions for cut-off frequency $f_g$ equal: 0.02Hz; 0.04Hz; 0.05Hz; 0.08Hz; 0.1Hz; 0.15Hz and 0.2Hz.

The instrument model was tested for each version of the filter.

The Pst values obtained in test 2 for given values of the filter cut-off frequency ($f_g$) are presented in Figure 3.

As follows from the test, in the investigated range of the filter parameters changes, the obtained Pst values were confined within the permissible range, according to standard [2] $P_{st} = 1 ± 5%$.

It should be noted that the model tested with 1620 changes per minute is not sensitive to changes in the filter cut-off frequency.
3.2. Low-pass filter — $f_g = 35\text{Hz}$

In order to investigate the influence of changes in the filter cut-off frequency on the obtained $P_{st}$ values, 11 versions of this filter have been modelled. The filter cut-off frequency ranged from 32.5Hz to 37.5Hz with a 0.5Hz step. Only the cut-off frequency was changed, the filter order remained unchanged throughout the test.

The $P_{st}$ values, obtained (according to test 2) for the considered range of the filter parameters are shown in Figure 4.

It follows from the test that changes in the Butterworth filter cut-off frequency over the range from 32.5Hz to 37.5Hz did not result in loss of $P_{st}$ accuracy. It also should be noted that changes in the obtained $P_{st}$ values show minimal variation with changes in the filter cut-off frequency and are of the same nature for all test signals from table 1.

3.3. Averaging filter — $\tau = 0.3\text{s}$

The filter time constant have been changed in the range from 0.1s to 0.6s with 0.1s step. $P_{st}$ values were estimated according to test 2, for the instrument model with the above filter parameters. The graph in Figure 5 illustrates the influence of changes in the filter parameters on $P_{st}$ values.

As seen from presented data, the model is highly sensitive to change in the filter time constant. The model meets the requirements of standard [2] concerning accuracy $P_{st} = 1 \pm 5\%$ only for the filter time constant $\tau = 0.3\text{s}$. It should also be noticed that, for a fast changing input signals (number of changes per minute = 1620), the change in the filter time constant did not result in exceeding the permissible 5% deviation of evaluated $P_{st}$ values.

3.4. Weighting filter

In order to investigate the influence of changes in the weighting filter parameters on the obtained $P_{st}$ values, seven versions of the filter were developed. The filter resonant frequency was varied from 7.3 to 10.3Hz with a 0.5Hz step. Figure 6 shows amplitude-frequency characteristics of investigated filters. The instrument model with the above filters' parameters was subjected to test 2 (test of the whole measuring channel).

Figure 7 shows the influence of changes in the weighting filter resonant frequency on obtained $P_{st}$ values.

As seen from the characteristic the model exhibits considerable sensitivity to changes in parameters of this filter. The investigation has demonstrated that only the model with filter of 8.8Hz resonance frequency yields results within the error limit compliant with standard [2].
Fig. 7. Sensitivity of the model readings to change in the weighting filter resonant frequency

It also should be noted that the trend of changes in \( P_{st} \) values obtained from the 1620 changes/min test is opposite to the trend of changes in the other tests characteristics. This suggests that correct results of tests can be obtained by means of mutual compensation of respective portions of sensitivity characteristic of the weighting filter. Actually such compensation does not solve the problem of variation of sensitivity to waveforms with various rates of changes of voltage fluctuation. Obtained results were corrected only for a given combination of fluctuation variation.

4. CONCLUSIONS

The investigated flickermeter model has very good metrological properties. It fully complies with the requirements of standard [2] concerning the accuracy of measurement.

Results of all additional tests were in accordance to expectations (see publication [3]).

Analysis of the model sensitivity shows interesting results concerning the influence of parameters of three filters on the obtained \( P_{st} \) values. The parameters of the low-pass filter (0.05 Hz) and high-pass filter (35Hz) – difficult in technical realization – have no significant influence on the accuracy of flicker measurement. Selection of the sliding mean filter time constant \( \tau = 300 \text{ms} \) is of crucial importance. Even a small deviation from this value causes the loss of accuracy.

The weighting filter resonant frequency 8.8Hz is also critical for the correctness of results obtained. The model exhibits considerable sensitivity to changes in this parameter. In order to obtain adequate operation of the model this frequency has to be maintained with accuracy better than 0.5 Hz.

From the obtained characteristics it follows that compensation of frequency characteristics of incorrectly made function blocks is possible. Such compensation allows obtaining correct results of analogue tests [2], however for waveforms with a wider spectrum it will result in discrepancy of measurements.

Obtained results supply a valuable information on the necessity to comply with the standard [2] requirements concerning parameters of the three filters in practical realization of the flickermeter.

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5. REFERENCES

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Marek Rogóź, MSc, eng
Born 16 May 1976 in Olkusz, Poland. He completed his studies on electrical power engineering and graduated with distinction in 2001 at the faculty of Electrical Engineering, Automatics, Computer Science and Electronics, at the University of Science and Technology (AGH-UST) in Krakow. Presently employed in Power Distribution Company – Cracow. At the same time he continues his studies as a doctorate student at the faculty of Electrical Engineering, Automatics, Computer Science and Electronics at the AGH-UST. In his research work he focuses on the quality of electric power in power systems.

e-mail: marek@agh.edu.pl

Andrzej Bień
born in 1954 in Warsaw, Poland. He received M.Sc. and Ph.D. degrees from the University of Science and Technology – AGH in Cracow. At present he is researcher in this university, Department of measurement and Instrumentation. His field of interest is digital instrumentation based on DSP for electricity property measurement (especially power quality).

Mailing address: University of Science and Technology – AGH, Department of Measurement and Instrumentation, Al. Mickiewicza 30., 30-059 Kraków, POLAND, phone:(+48) 12 6172873, fax:(+48) 12 633856, e-mail: abien@ucr.agh.edu.pl

Prof. Zbigniew Hanzelka
professor in the Institute of Electrical Drive and Industrial Equipment Control of University of Science and Technology – AGH. His area of interest includes electrical power quality, particularly methods of reducing the influence of power converters on supply network. He is the member of several national and international committees, among other IEC, UIE, CIGRE.

Mailing address: University of Science and Technology – AGH, 30-059 Cracow, Al. Mickiewicza 30, POLAND, phone: +48 12 617 28 78, fax: +48 12 633 22 84; e-mail: hanzel@ucr.agh.edu.pl

Marcin Szlosek, MSc, eng
born 23-10-1976. He received MSc, eng in the faculty of Electrical Engineering, Automatics, Computer Science and Electronics, University of Science and Technology – AGH, Cracow. His choice is in power electronics, in particular its applications to the power quality improvement systems. Presently he continues his studies as a doctorate student at the faculty of Electrical Engineering, Automatics, Computer Science and Electronics at the AGH-UST.

e-mail: mszlosek@agh.edu.pl
Prof. Marek T. Hartman
received the M.Sc.Eng. and Ph.D. degrees in electronic engineering from The Technical University of Gdansk, Poland in 1970 and 1977, respectively. He received the habilitation degree from Warsaw University of Technology in 1988. In 1987/1988 he was on The British Council fellowship at Loughborough University of Technology, England. In the years 1989–2000 he worked at the Gdansk Branch of The Electrotechnical Institute as a Branch Director. Since 2000 he is a Professor at Maritime University at Gdynia and science consultant at the Electrotechnical Institute. Currently he is also the External Professor of Glamorgan University, Walsh. He is a Member of Power Electronics and Electric Drives Committee in the Polish Academy of Science and Corresponding Member and Fellow of IEE. He has published over 80 scientific papers in the field of power semiconductors, power converters, digital signal processing and electromagnetic compatibility. He is the Member of Scientific Committee of the Polish national technical magazine “Electrotechnical Review.”