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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 Część 2: Badania czułości modelu miernika

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***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.

***Streszczenie*: Użytkownicy mierników uciążliwości migotania światła zauważyli, że pomimo pozytywnych wyników testów (wg normy[2]) wskazania ich mogą się znacznie różnić.**
Jednym z istotnych problemów konstrukcyjnych podczas budowy mierników uciążliwości migotania jest dopuszczalna tolerancja używanych komponentów. Trudne do przewidzenia są sumaryczne efekty spowodowane rozrzutem parametrów za stosowanych elementów. Dlatego ważne jest określenie możliwych do zaakceptowania odchyłek każdego z bloków które nie spowodują zlej pracy całego przyrządu.
Poniższy artykuł prezentuje wyniki bada wrażliwości miernika uciążliwości migotania światła na zmian wybranych parametrów filtrów, istotnych w odniesieniu do funkcji jaka dany filtr spełnia.
Przedstawione wyniki są wskazówka informująca o dopuszczalnych rozrzutach (odchyłkach) parametrów budowanych bloków funkcjonalnych.

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

1. 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 vale 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.

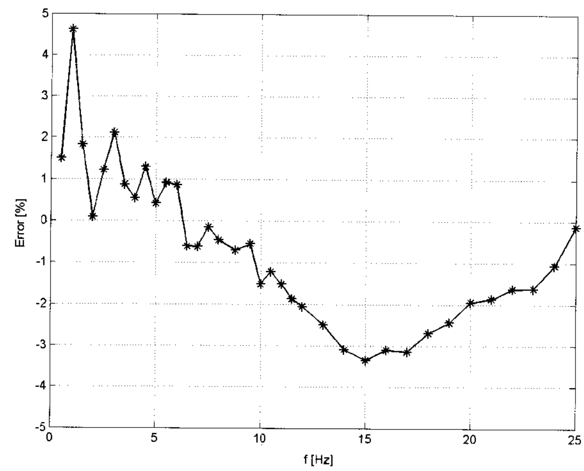

Fig. 1. Error of the model analogue part response to sinusoidal voltage fluctuations

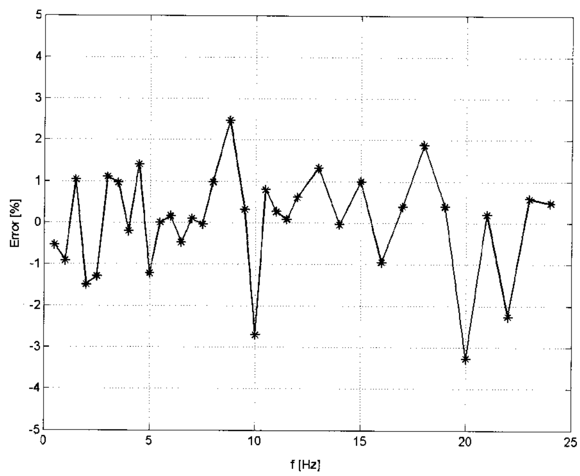

Fig. 2. Error of the model analogue part response to square-wave voltage fluctuations

Table 1. Parameters of modulating signal and obtained Pst values

Number of changes per minute	Voltage change [%]	Pst
1	2.72	1.0112
2	2.21	1.0067
7	1.46	1.0096
39	0.905	1.0107
110	0.725	1.0017
1620	0.402	0.9845

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 P_{st} values are listed in table 1.

The instrument can be found compliant with standard requirements, when the obtained short term flicker severity P_{st} for each test signal is $1 \pm 5\%$.

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 = 0.05Hz

This filter has been made in seven versions for cut-off frequency f_g equal: 0.02Hz; 0.04Hz; 0.05Hz; 0.08Hz; 0.lHz; 0.15Hz and 0.2Hz.

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

The P_{st} 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 P_{st} values were confined within the permissible range, according to standard [2] $P_{8t} = 1 \pm 5\%$.

It should be noted that the model tested with 1620 changes per minute is not sensitive to changes in the filter cut-off frequency.

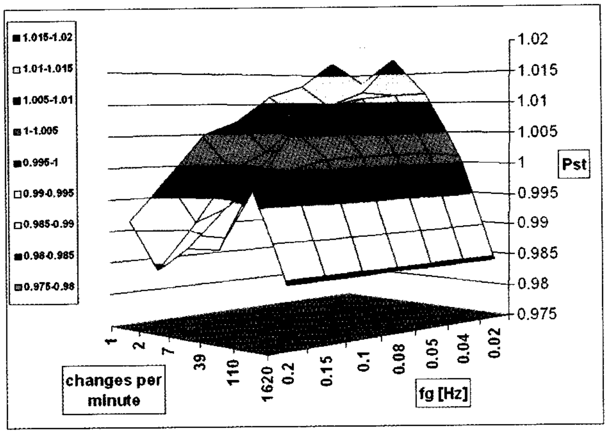

Fig. 3. Sensitivity of the model readings to the change in the high-pass filter cut-off frequency 0.05 Hz

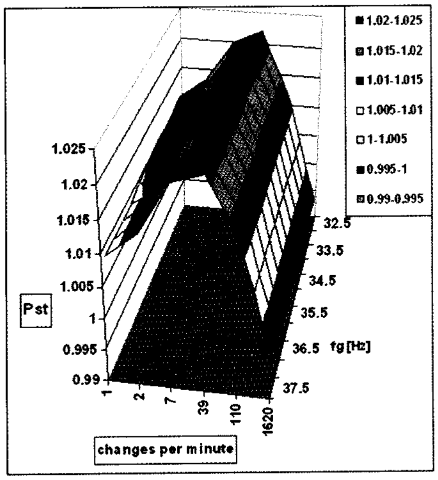

Fig. 4. Sensitivity of the model readings to the change in the low-pass filter cut-off frequency35 Hz

3.2. Low-pass filter — $f_g = 35$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 Pst 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 – $t = 0.3$s

The filter time constant have been changed in the range from 0.1s to 0.6s with 0.1s step. Pst 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

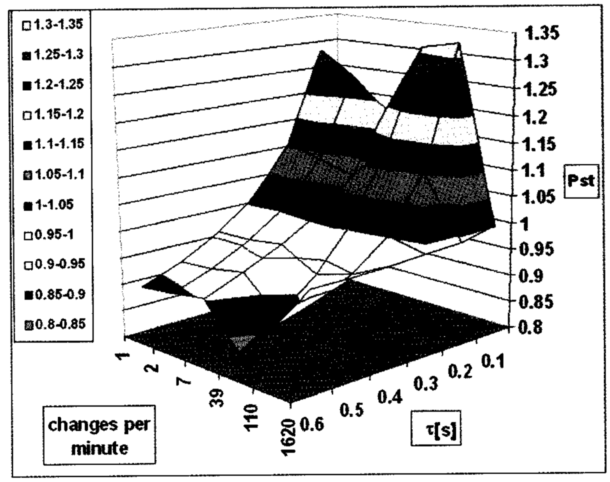

Fig. 5. Sensitivity of the model readings to change in the time constant τ = 0.3s of the sliding mean filter

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 $t = 0.3$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 Pst values, seven versions of the filter were developed. The filter resonant frequency was varied from 7.3 to10.3 Hz with a 0.5 Hz 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 8.8 Hz resonance frequency yields results within the error limit compliant with standard [2].

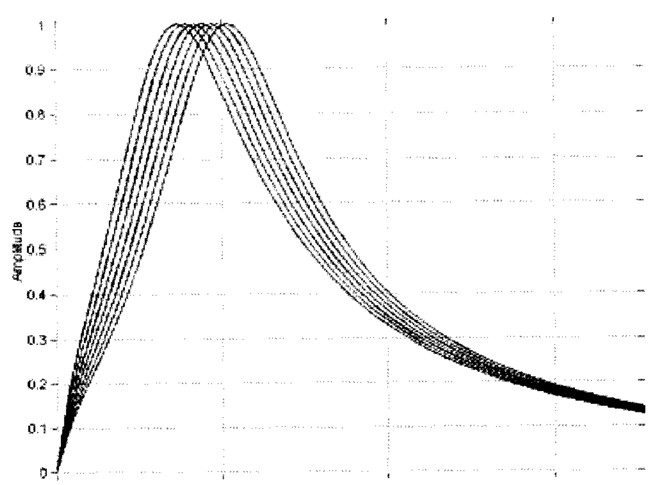

Fig. 6. Amplitude-frequency characteristics of investigated weighting filters

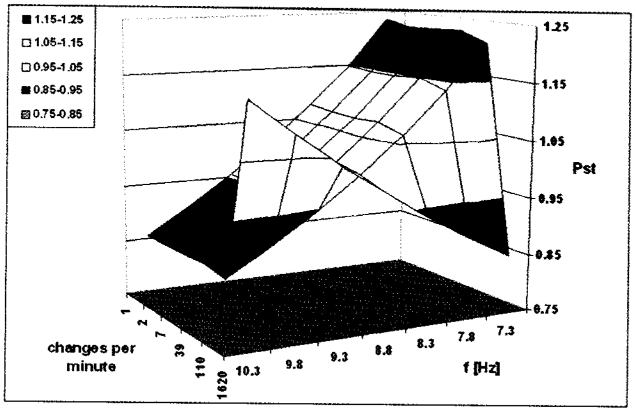

Fig. 7. Sensitivity of the model readings to change in the weighting filter resonant frequency

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 $\tau = 300$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.

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 will result in discrepancy of measurements.

5. REFERENCES

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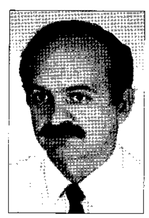

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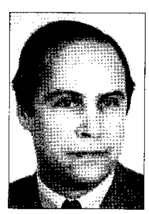

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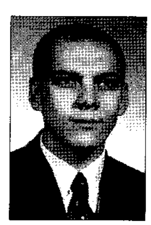

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