Abstract—In this paper are defined procedures for a flicker measurement according to standard IEC 61000-4-15 and the definition of a flicker is given. The software for measuring a flicker severity was developed and this software was implemented on concrete example. The developed software is based on digital signal processing. Input data is a certain file or data from the computer’s RAM memory and the result is a value of the flicker severity. This concept allows that the developed software can be used both for the flicker measurements and for a simulation of flickers in the power network. A hardware support for the software can be any acquisition card which satisfies minimum conditions concerning the flicker measurement and a range of input signal. The aim of this work was to develop a universal application that can be used both for the flicker measurement and also for the flicker analysis which can be made after simulations in the power network. In this paper is made a model of characteristic consumer which produces flickers in the power network. The conclusions in this paper relate to the procedures of development of a flickermeter and to the example that is analyzed in this work.

Index Terms—power quality, flicker, flickermeter, flicker definition, testing flickermeter, example of flicker measurements, flicker simulation example.

I. INTRODUCTION
A flicker is one of the main indicators of power quality (PQ) i.e. voltage quality. This term is determined by an experiment and it can be described as follows: if the flicker severity of \( P_{st} = 1 \) is applied to 100 people, 50 would perceive flicker and 50 wouldn’t.

Changes of light intensity in the working or living environment negatively affects human health, their working and other skills (Fig.01). This was a reason why there was a need for defining and measuring flickers. The flickers can cause headache, nervousness, depression, damage to eyesight, etc.

The flicker is the result of an amplitude modulation of a voltage signal. Its frequency range is from 0.005Hz to 33Hz (for 50Hz voltage) where the amplitude is directly proportional to the frequency of modulation.

The term flicker severity can be found in the context of defining the flicker as an indicator of PQ. There are defined two parameters (indicators) of the flicker severity according to UIE-IEC standard: the short-term flicker severity \( P_{st} \) and the long-term flicker severity \( P_{lt} \).

The device for measuring flicker severity in the power network is called flickermeter. It must measure the previously mentioned parameters according to certain standards. The procedure of flicker measurement is very complex and demanding in terms of mathematical model, processor, memory requirements and requirements for data acquisition.

II. PROCEDURES OF FLICKERMETER DEVELOPMENT ACCORDING TO IEC 61000-4-15 STANDARD
There is a procedure for measurement and evaluation of flickers. This procedure consists of the several steps that are specified by the standards. International standards IEC61000-4-15 and IEC61000-3-3 are commonly used for the measurement procedure.

Flicker measurements are carried out on phase voltages of three-phase system (each phase separately). Some specialized measurement systems have the ability to measure flicker severity also on line voltages. The real-time measurements of power quality, according to standard IEC61000-4-30, include also flicker measurements. Time needed for flicker measurement is approx. 30-40% of total measurement time [8]. This fact is one of the reasons why flickers are measured only on the phase voltages.

The two indicators of flicker severity of the measured voltage can be determined by measuring the voltage waveform with the precisely defined vertical resolution and sampling frequency. The first indicator is a short-term flicker severity \( P_{st} \). It is measured in intervals of 10 minutes. The second indicator is a long-term flicker severity \( P_{lt} \) which is measured in intervals of 120min (2 hours). Twelve consecutive measurements of the short-term flicker severity should be made in order to obtain
long-term flicker severity. Its value can be determined using the following expression:

\[
P_{lt} = \sqrt[3]{\frac{1}{12} \sum_{i=1}^{12} P_{st}(i)^3}
\]  

(1)

The limits of the flicker severity are defined using these two parameters \((P_{st} \text{ and } P_{lt})\) in accordance with the standard EN50160.

It is easy to conclude from the previous discussion that the procedure for measuring flicker severity comes down to the measuring severity of short-term flicker. The procedure of measuring the short-term flicker according to [5] will be treated further in this part of the paper. The procedure for evaluation of the short-term flicker severity of the measured voltage can be seen on the following block diagram (Fig.02).

The block structure which describes the procedure for flicker measurement can be realized using hardware components or software support. The block diagram shown in the (Fig.02) has hardware components up to the block 5, and A/D conversion and statistical analysis are performed in the block 5.

It should be noted that modern measurement systems use software support for measuring flicker severity i.e. the A/D conversion is performed at the entrance to the block 1 and other blocks are made using software. This approach has several advantages. Some of them are: developed software tool can be used multiple times, upgrade of the measurement procedure is simple, reliability of the measurement procedure is independent of the hardware. One of the major disadvantages is that A/D conversion must be much better (vertical resolution and sampling frequency) than in the case of the combination hardware-software.

The above block structure can be divided into three parts. This classification is made on the basis of what is done in certain blocks:
- retrieve data about measured signal (voltage) and calibration of the measurement system (input transformer and block 1);
- a simulation of human perception of flickers i.e. link eye-brain (block 2, block 3, block 4);
- statistical analysis of data and calculation of flicker severity (block 5).

III. FLICKERMETER

The software for flicker analysis was developed in the programming language Visual Basic 6.0 as a part of this work. The application was created according to standard IEC 61000-4-15 for flicker measurement and flickermeter development. This application, together with hardware support of developed measurement system (PQs), represents a flickermeter [1]. A measurement is implemented through development of the function for measurement of short-term flicker severity.

The measurement of flicker severity is performed on phases (A, B, C). The short-term flicker severity \(P_{st}\) is calculated on all phases in intervals of 10 minutes. The long-term flicker severity \(P_{lt}\) can be calculated after twelve consecutive measurements and calculations of \(P_{st}\) (2 hours).

Duration of measurement is unlimited i.e. it depends on the capacity of computer’s RAM memory. The measurement data are stored in the computer’s RAM memory and they can be displayed graphically during the measurement. The appearance of application for flicker measurement and accompanying diagrams are shown on the following figure (Fig.03).

When the button “start” is clicked, flicker measurement begins. It is possible to observe trends of \(P_{st}\) and \(P_{lt}\) on all phases (A, B, C) during the measurement. When the measurements have been completed (by clicking the "Stop" button), data are recorded in an Excel file by clicking the button "Excel". The recorded data are divided in two sheets, a sheet for the short-term flicker severity and a sheet for the long-term flicker severity.

This application, besides the flicker measurement, can be used for analyzing certain problems concerning flicker severity calculations. A file which contains 10 minutes of measurement could be created. This file can be used later for simulation purposes.

IV. TESTING THE FLICKERMETER ACCORDING TO IEC STANDARD

Standard IEC 61000-4-15 defines the test procedures of flickermeter. The testing should be implemented for six
values of the short–term flicker which are given in table Tb.01.

<table>
<thead>
<tr>
<th>Pst</th>
<th>0.1</th>
<th>0.5</th>
<th>1.0</th>
<th>2.0</th>
<th>3.0</th>
<th>5.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tb.01 Table of the short-term flicker severity used for testing the flickermeter [4, 5]</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

The testing was conducted for the voltage of 230V and the frequency of 50Hz. The six values of flicker severity for different modulations were calculated for all previously given values of flicker severity (Tb.01).

The application was developed in Visual Basic 6.0 for the needs of these tests. The testing procedure lasted approx. 35 minutes on the PC with following characteristics: processor 1,6GHz Intel Centrino, RAM 756MB and operating system Windows XP SP3.

Fig.04. Results of testing the flickermeter

The figure (Fig.04) presents the appearance of the application and the results of testing the procedure for flicker measurement. According to [5], flickermeter measurements should have a range accuracy of ± 5% for all tested values. The maximum error in testing was 3.4832% what is within given boundaries.

V. EXAMPLE AND SIMULATION

Mathematical models from [2] describe very well certain consumers in flicker analysis. The problem appears when it is necessary to model consumer for other analysis (harmonic analysis, response on transient voltage values etc.).

A model of the flow boiler (24kW) is made in this example. This consumer makes significant voltage dips (fig. 05) and thus affects the flickers in the network. A building where the hot water is obtained using such boilers can be used as an example. A stochastic nature of the use of hot water (uncontrolled switching on and off the boiler) can be directly connected with the flicker injection into the network.

Fig.05. Phase Voltage waveform of the phase A when the flow boiler whose power is 24kW is attached [1]

The figure above (Fig.05) shows the voltage measurement in the interval of 30s. The considered household appliance was in operation four times in that period. The voltage is measured at one of the sockets in the apartment. On the diagram can be seen the voltage dips due to flow boiler inclusions and jumps during voltage dips. These jumps are caused by two modes of water heating. This device produced voltage dips of order 5.05% during inclusion.

Fig.06. Voltage rms value of a phase calculated on the interval of 10ms [1]
According to the recommendation for this type of appliances, it should be provided a separate supply from a measurement point. According to the official information from the manufacturers and distributors of these devices, their sale is increasing. These consumers have a significant impact on the low-voltage power network and can significantly affect PQ what can be seen from the previous diagram.

By analyzing voltage and current waveform, it is determined that this consumer belongs to the group of the active consumers (heat consumers). The parallel connection of two active resistances (which represents a heater) forms an equivalent scheme of this consumer. The values of resistances are calculated taking into account the heater's nominal power and the network voltage. The measurements and simulations were made in order to develop the model of mentioned consumer and to verify it:

- The measurement of the voltage was made in the interval of 30s when the flow boiler was turned off. The flicker severity was evaluated in the network for this period (Tb.02, column \( P_{st1} \)).
- The measurement of the voltage was made in the interval of 30s when the flow boiler was turned on. The flicker severity was evaluated in the network for this period (Tb.02, column \( P_{st2} \)).
- The simulation in the interval of 30s was made for the considered consumer when its voltage waveform is the same as of the network waveform. The flicker severity was calculated in the network for this period (Tb.02, column \( P_{st3} \), Fig.07).
- The simulation in the interval of 30s was made for the considered consumer for the case of the sine voltage waveform. The flicker severity was calculated in the network for this period (Tb.02, column \( P_{st4} \), Fig.08).

The aim of the calculations of flicker severity in the previous four cases was to show that consumers, which are significant sources of flickers, have a dominant impact on the level of flickers in the network. This can be concluded by comparing the values of \( P_{st3} \) and \( P_{st4} \) (Tb.02). As it is said, this conclusion relates only on consumers which are significant sources of flickers in the network.

<table>
<thead>
<tr>
<th>( P_{st1} )</th>
<th>( P_{st2} )</th>
<th>( P_{st3} )</th>
<th>( P_{st4} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1799</td>
<td>3.0383</td>
<td>3.1224</td>
<td>3.1258</td>
</tr>
</tbody>
</table>

Tb.02 Values of the short term flicker severity for different measurements and simulations

The main difference of the models given on the Fig.07 and Fig.08 is in the used voltage source. On the basis of the flicker measurement procedure, it is known that it is not the amplitude of the voltage which has impact on the flicker severity, but its change. This fact was used in comparison of the obtained results.

![Fig.07. Model of the flow boiler (24kW) and the network voltage](image)

The results obtained by the simulation imply that there is a possibility of finding correlation parameters which would show what increase of flicker severity would happen in the network after a new production or consumer element is added.

![Fig.08. Model of the flow boiler (24kW) and ideal voltage sine waveform](image)

The analysis of the new production or consumer element on the flickers in the network requires measurements and calculations. The flicker limits in the analyzed network should be determined on the basis of the measurement results. After that the new flicker limits can be calculated using simulation of the network and the new element. This is a very complex and demanding simulation problem.

VI. CONCLUSION

The flicker measurement is realized through digital signal processing and statistical analysis of signals. The procedures of measuring flicker severity and testing the flickermeter are defined with the standard IEC 61000-4-15. The measurement system that was developed in this work was tested according to this standard.

The application for flicker evaluation may be very useful in planning, designing or reconstructing a power network in combination with some of simulation packages for analyzing power systems (EMTP-RV, MatLab, ATP, etc.). It can also be very helpful in the cases when it is required to make a selection of equipment which should be or shouldn’t be installed in the system (certain consumers) because of possible exceeding permitted flicker severity.
The developed applications with hardware support of the PQs system represent a flickermeter or a measuring instrument for flicker measurement. A practical application of this system can be shown on the next example. Suppose that there is a requirement for connecting a new consumer (which can affect flicker severity) to an existing power network. This system can be used to measure flicker severity before the new customer is connected. Firstly, the flicker severity is measured in the analyzed power network. The power network can be simulated and after that it can be checked whether the simulation shows the same or similar values of flicker severity. The final step is a simulation of the new consumer in the power network and evaluation of flicker severity. After this, it would be possible to conclude what should be improved in the given power network so the limit values of flicker severity wouldn’t be exceeded.

Future research will be concerned in developing a mathematical model of individual consumers for the flicker analysis and a verification of these models.

VII. REFERENCES