Characteristics of the Flicker in Chosen Industrial Plants

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Abstract—**Peculiarities of different kinds of industrial loads in relation to produced flicker effects have been presented in this paper. The analysis bases on measurements performed in different industrial plants using conventional power quality instruments. Various types of industrial plants will be chosen from the group of largest power consumers in Poland in order to observe specific properties of the flicker. Some changes of the short term parameter of the flicker in relation to load type in those objects will be exposed and discussed. The two main purposes of the performed analysis are, description of observed specific features of flickers registered using instruments and calculation methods based on the standard EN-61000-4-15 and evaluation basing on the standard EN 50160, and, critical evaluation of obtained measuring results in relation to the physical sense of flicker effects. The problem of calculation procedure of the flicker, first of all its short term parameter, for chosen kinds of industrial plants will be discussed based on the performed analysis.**

Keywords: power quality, flicker, industrial plants

I. INTRODUCTION

The term flicker is one of the basic parameters used in evaluation of power quality. It refers to the subjective impression that is experienced by human beings when subjected to changes occurring in the illumination intensity of electrical light sources, caused by voltage changes and fluctuations. Measurements of this effect are defined and described in the standard [1]. There are many papers describing this phenomenon [2-8]. It is basically characterised by the short (P_{st}) and the long-term, (P_{lt}) flicker severity. The level of the flicker can be examined in two manners:

- First, applying the calculations for the given scenarios of perturbations using a simplified method [2-6] which enables to predict the flicker effect caused by a certain load. In this method each single perturbation with a serial number *i* is characterised by the deepness of voltage changes $\Delta U/U$ and its time-flow as well as the voltage level before and after the perturbation. For each of such perturbations the individual short-term flicker severity $P_{st,i}$ is calculated using a general formula [3]:

$$P_{st,i} = ar^{b}\frac{\Delta U}{U}, \tag{1}$$

where: r – number of identical perturbations in [min^{-1}] during observed time period T, (usually T = 10 min or T = 1 min) , ΔU – maximal voltage change during the perturbation, U – reference voltage, usually the voltage level before the perturbation or rated voltage of the network, a, b – factors corresponding to the standard curve [1] of the flicker severity P_{st} = 1.

The final value of short-term P_{st} can be calculated as a sum of the series of reciprocally independent n voltage perturbations [3]:

$$P_{st} = \sqrt[\alpha]{\sum_{i=1}^{n} P_{st,i}^{\alpha}}, \tag{2}$$

where: α – exponent dependent on the form of the voltage disturbance and other parameters, like duration of the observation period T (1 min or 10 min), number of independent voltage disturbances during this period.

The values of the exponent α vary from 1.4 to 3 and the proper choice of it has the significant influence on the final value of the P_{st} [3].

- Second, applying the direct measurements in the existing electrical installation using apparatuses equipped with the flickermeter, i.e. special calculation procedure according to the standard [1]. Measuring methods give the current value or registered flicker changes in the certain time interval.

This paper rises the problem of considerations related to flicker measurements in an industrial installations. The reported measurements were performed using a standard power quality recorder. The main purpose of these measurements was to observe some relations between the flicker characteristics and the type of load in industrial plants. These observations are reported in this paper.

II. DESCTRIPTION OF THE ANALYSED INDUSTRIAL OBJECTS AND MEASURING OBJECTIVES

The measurements were performed in two different industrial objects. First object was a coalmine with skip hoists and ventilating systems. Second, was a steel plant where the main loads are ladle and arc furnaces.

- Coalmine:

The coalmine was supplied from the electrical power system via the main supplying point equipped with two transformers 110/6 kV. The nominal voltage of the factory main distributing network was 6 kV. The measuring device was installed between 220/110 kV supply line and a 110/6kV transformer.

- Steel plant:

The factory was supplied from the electrical power system via the main supplying point equipped with transformers 110/30 kV. The nominal voltage of the factory main distributing network was 1.2 kV, 0,7 kV and 0,5 kV adequate for the main loads. Flickermeter was installed on the main supply line of the factory 110 kV.

All measurements here presented were performed on the high-voltage side of the transformers. Results presented here are limited to the two kinds of the industrial plants:

- Coalmine
- Steel plant

The following parameters were registered:

- the RMS values of the phase voltages and currents, averaged in T = 10 min time periods, according to the power quality evaluation rules given in the standard [9],
- the P_{st} measured in T = 10 min time periods and P_{lt} measured in T = 2 hours time periods, according to the standards [1, 9].

The evaluation of the results consisted in comparison of voltage and current flows and indicating of reciprocal correlations and influences on the flickers.

III. MEASURING RESULTS

A. Coalmine

The measuring apparatus was installed between 220/110 kV supply line and 110/6 kV transformer.

The analysed group of loads for this object was skip hoists and ventilating system. A typical RMS voltage and current flows are shown in Fig. 1.

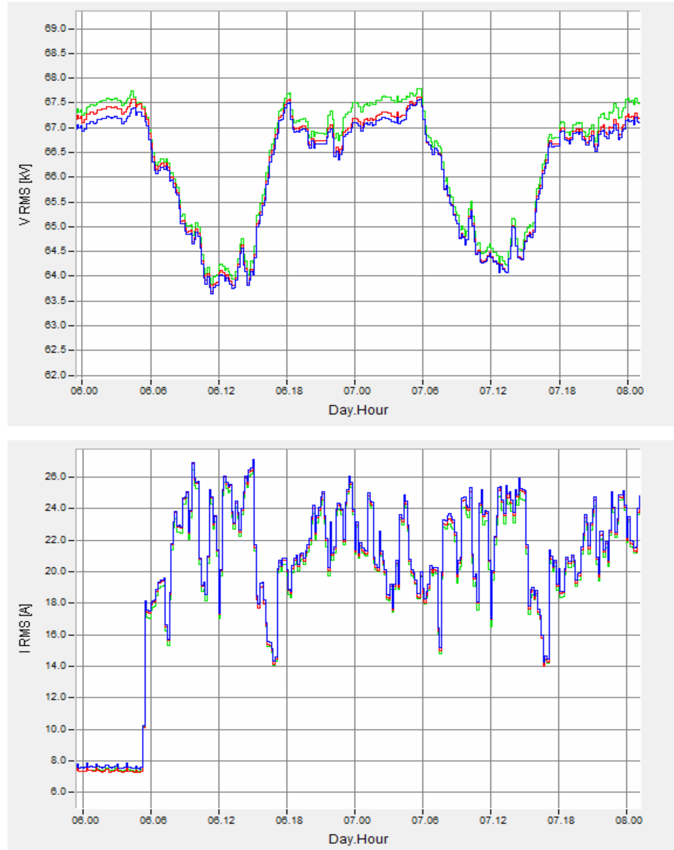


Fig. 1. The exemplary 2-day flows of the voltage (upper picture) and current (lower picture), as 10-minutes averaging RMS values, in the coalmine

The load current of coalmine machines is characterised by the rapid changes (Fig. 1) which have also a significant influence on the supplying voltage. The short-term flicker severity P_{st} (Fig. 2) for the same time is characterised by several peak values.

The initial value of the current RMS (Fig 1.) is at very low level. The reason for this effect is that the beginning of measurement was at the end of the weekend.

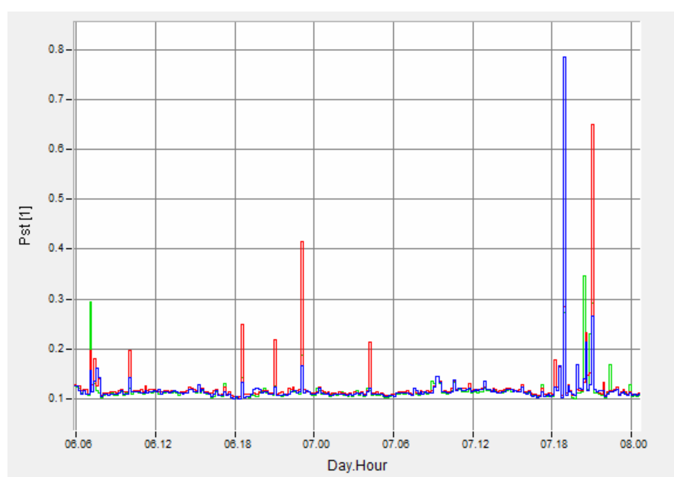


Fig. 2. The 2-day short-term flicker severity P_{st} in the coalmine circuits, corresponding to flows from Fig. 1

This type of load in coalmine has a rather moderate influence on the flicker effect, like in the reported case (Fig. 3) when the P_{st} value does not exceed 1 which is in conformity with standard [9].

However, in the Fig. 3 one can see the significant difference between P_{st} values in different phases, just in the time interval corresponding to flows shown in Fig. 1. In Fig. 4 the relative voltage changes $\Delta U/U$ in the analysed 10 minute time interval from 18:50 to 19:00 hours in Fig. 1 and 3 are presented. In spite of the mentioned differences in P_{st} values, the differences of $\Delta U/U$ are not such significant between three phases.

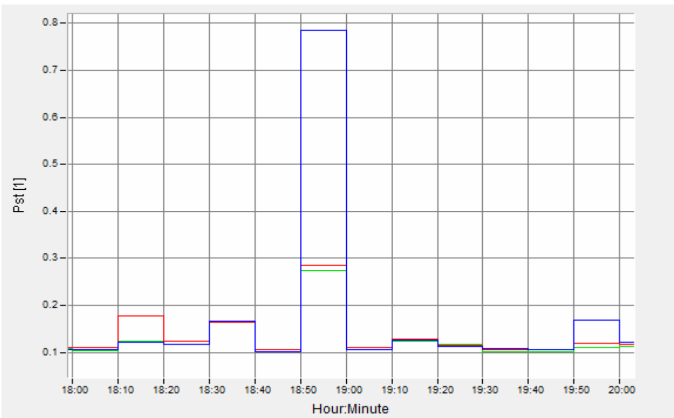
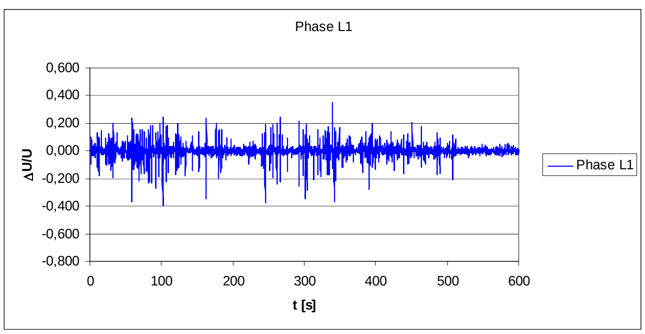
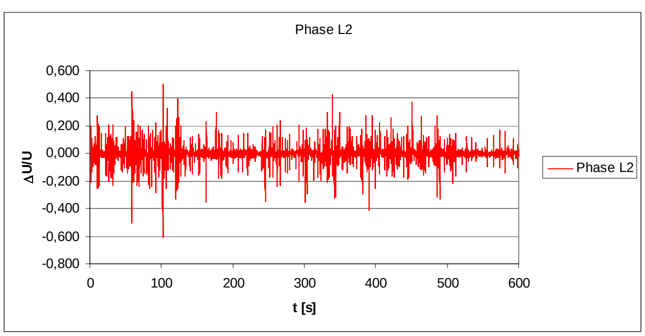


Fig. 3. The P_{st} flow of the analysed mining machines





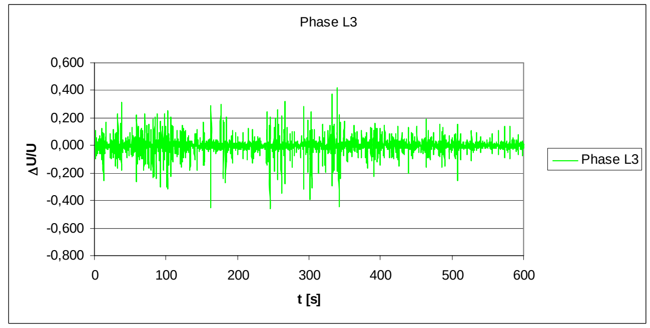


Fig. 4. Relative voltage changes $\Delta U/U$ in three phases L1, L2 and L3 in time interval from 18:50 to 19:00 in Fig 3 (0 s in the time scale corresponds to 18:50 and 600 s to 19:00 respectively in Fig. 3)

The proportion of P_{st} between phase L1 (blue line, Fig. 3) and two others, in approximate estimation, is in range of 3. However, the relative values $\Delta U/U$ in phase L1 are not in the same range in comparison to phases L2 and L3 (Fig. 4), like it could be expected from (1). As a conclusion of this observation, specific kinds of the industrial plants, with characteristic loads, such as: hoists, ventilations and furnaces, the measuring of flicker severity according to procedure described in [1] could be rectified in order to obtain results corresponding closer to the sense of flicker effect.

B. Steel plant

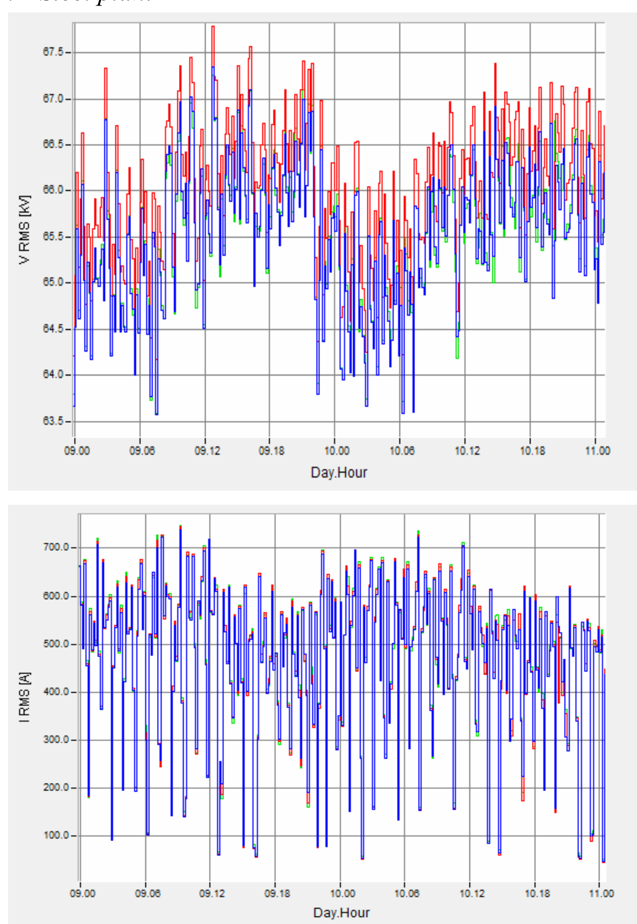


Fig. 5. The exemplary 2-day flows of the voltage (upper picture) and current (lower picture), as 10-minutes averaging RMS values, in the steel plant

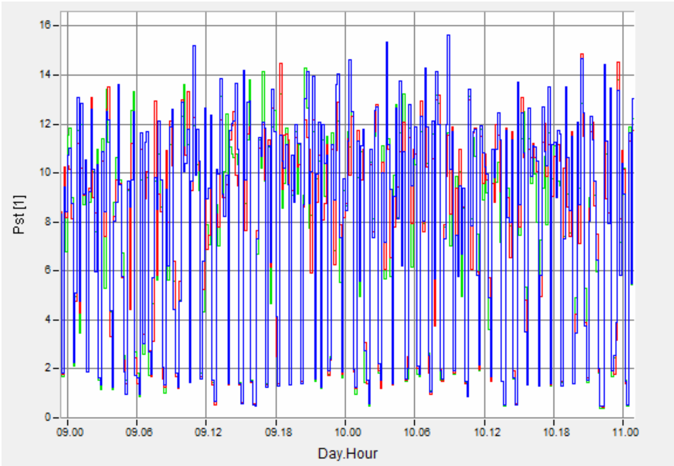


Fig. 6. The 2-day short-term flicker severity P_{st} in the steel plant circuits, corresponding to flows from Fig. 5

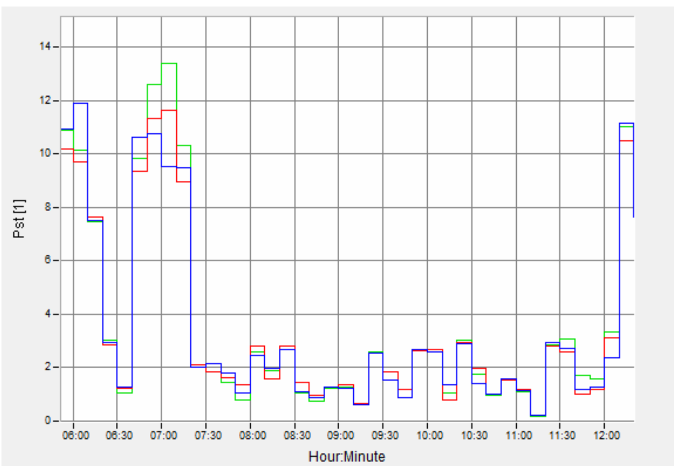


Fig. 7. The P_{st} flow of the analysed steel plant in the time range from 6:00 to 12:00

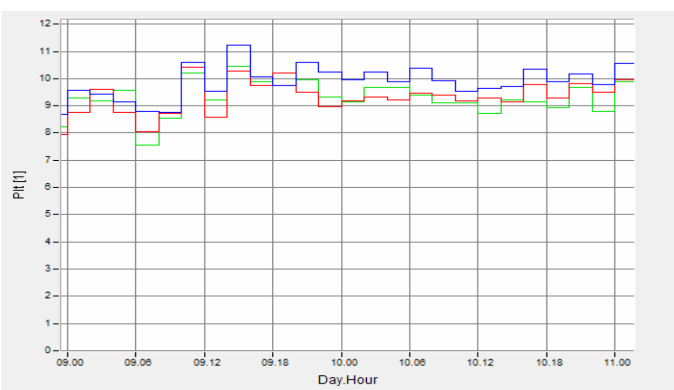


Fig. 8. The 2-day long-term flicker severity P_{lt} in the steel plant circuits, corresponding to flows from Fig. 5

The load current of steel plant installations is characterised by the rapid and significant changes (Fig. 5) which also has a meaningful influence on the supplying voltage. The short-term flicker severity P_{st} (Fig. 6) for the same time is characterised by several peak values.

Work of the furnaces in the steel plant causes rapid changes of load current in the wide range from 100 A to 700 A. An exemplary flow of the voltage and current is shown in Fig. 5 and corresponding P_{st} values are presented in Fig. 6. Furthermore, the frequency and the peak values of current are much higher than in the case of hoists and ventilation systems in coalmine. This has its consequence in the flicker severity value. According to standard [9], long-term flicker severity P_{lt} should be less than 1 for 95% of the measuring period. In the Fig. 8 one can see that long-term P_{lt} value is greater than 1 for the almost all the time. As a conclusion of this observation, during the measurements of objects with loads such as: Electric Arc Furnace and Ladle Furnace, the measuring of flicker severity according to procedure described in [1] must be updated in order to obtain results compatible with standard [9].

IV. Summary

The flicker severity depends on the type of the load characteristic for the types of industrial plants. It can be characterised particularly for certain kinds of the industrial load of large power. The presented work illustrates some effects only, which can be analysed in detail in order to obtain the calculation procedures specified for the typical kinds of the industrial plants. Such procedures could be helpful in the future to identification of the sources of voltage perturbations in the network.

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