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CORRECTNESS OF FLICKERMETERS CALIBRATION

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Abstract: High power electric energy receivers are loading power network, with result of light flickering, for witch the IEC standard defines a quality, measured with instruments named as flickermeters. In this paper authors' opinion the method of flickermeters calibration misses actual network properties, so that vagueness of measurements results arises. The results of analysis and model investigations of this problem are presented.
Keywords: flickermeter, calibration

1 THE ALGORITHM OF CALIBRATION OF LIGHT FLICKERING PERSISTENCE MEASURE PERFORMED BY FLICKERMETERS

Power network realisation and nonstacionary high power electric energy receivers have significant influence upon the electrical energy quality. Loading the supply transformers with time-varying impedances and consequently time-varying heavy currents they cause network voltage amplitude fluctuations. This causes light-flickering phenomenon, in consequence of which negative physiological and technical effects occure. Therefore in succeeding IEC documents 868(1986), 61000 4-15(1998) and others the measure of light flickering persistence have been introduced as well as an algorithm of its determining, performed in devices termed flickermeters.

In the above mentioned documents this algorithm is strictly defined as a sequence of linear and non-linear operations upon the measured network voltage signal. These operations reflect one after the other static and dynamic properties of light sources, dynamic properties of human eyes as well as the static and dynamic properties of human brain. The measure of flickering persistence is a functional calculated upon the output signal? The authors have formed these operations sequence as compennd Wiener-Hammerstein operation.

$$y(t) = \int_0^\infty k_{br}(t-t)\left\{\int_0^\infty k_{ey}(t-x)\left[\int_0^\infty k_{ls}(t-z)u_{en}^2(z)dz\right]dx\right\}^2 dt \qquad (1)$$

$$P_{ST} = A_{ST}\{y(t)\} \qquad (2)$$

Where: P_{ST} - short-period measure of light-flickering persistence,
$y(t)$ - output signal after the operations,
u_{en} - network voltage signal,
$k_{br}(t)$, $k_{ey}(t)$, $k_{ls}(t)$ - pulse transition functions of dynamic model factors: human brain, human eye, light source respectively.
$A_{ST}\{\cdot\}$ - functional of the P_{ST} measure calculation.

Therefore algorithm can be effectively performed in discrete form by means of signal processor, previously converting the network voltage signal by means of A/D converter with suitable determined resolution power.

2 FLICKERMETER CALIBRATION PRINCIPLES

Flickermeters are calibrated similarly to other measuring devices, by use of input signals with known parameters, which are expected to imitate fluctuating network voltage. In the mentioned IEC documents they were assumed as sinusoidal signal with network frequency f_n and amplitude u_n, linearly amplitude-modulated with sinusoidal or rectangular (pulse train) signal with amplitude Δu_n and basic frequency f_m. In the case of sinusoidal modulation the celibrating signal is:

$$u_{cal}(t) = u_n(1 + \frac{\Delta\ u_m}{u_n} \sin 2p \quad f_m t) \sin 2p \quad f_n t \tag{3}$$

The variable parameters of calibrating signal are: relative value of amplitude fluctuation $\frac{\Delta u_m}{u_n}$ within the range from 0.234 to 0.25 and the basic frequency f_m within the range from 0.5 th to 25 th (addition of frequency 33 th is also planned). The calibration principle assumed in the mentioned documents consists in fixing of such relationship of these parameters, that for every pair $\left\{\frac{\Delta u_m}{u_n}, f_m\right\}$ the measure value obtained as a result of flickermeter action, would be $P_{ST} = 1$. The spectrum of three stripes: the main one for the frequency f_n and two sick stripes for frequencies $(f_n - f_m)$ and $(f_n + f_m)$. An exemplary form of the spectrum for the frequencies values $f_n = 50 Hz$ and $f_m = 4 Hz$ and for $\frac{\Delta u_m}{u_n} = 0.13$ is represented in the figure 2.a.

3 THE MODEL OF NETWORK VOLTAGE FLUCTUATION IN REAL SYSTEMS

In this paper we will prove, that the accepted linear model of amplitude modulation for calibrating signal (3) does not give a proper imitation of power network voltage fluctuations for real systems, in which flickermeters work. So the result of above presented method of calibration may by ambiguity of interpretation of the P_{ST} measure value, obtained as a result of measurements. The analysis - which we have performed - of the way of network voltage fluctuation origin shows, that the effect of voltage modulation is not linear in respect of modulating factor. As an example we will consider a simplified, but sufficient for proving of above submitted proposition, case of parallel loading of one-phase network with a variable impedance of high-power receiver and light sources, shown in the figure 1.

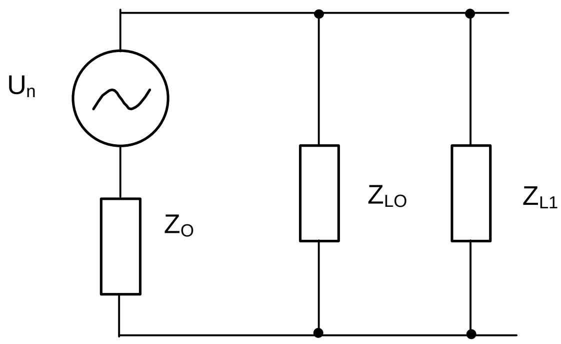

Figure 1. Replacement diagram of a network loaded with variable impedance.

The designations in the Fig. 1 and Fig. 2 are:

$u_n(t)$ - unloaded network voltage signal,

$u_{en}(t)$ -loaded network voltage signal,

Z_{L0} - time steady impedance of light sources,

$Z_{L1}(t)$ - time-varying loading impedance of high-power receivers,

Z_0 internal impedance of voltage source (feeding transformer).

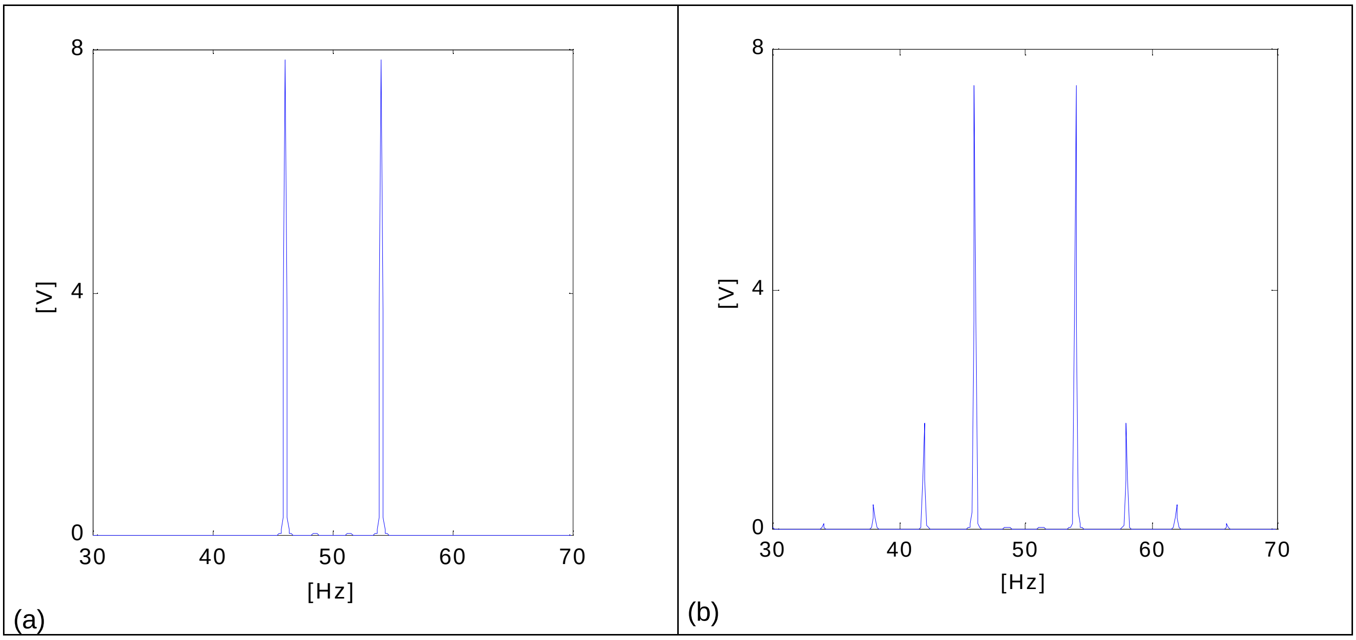

Figure 2. The spectrum of calibrating signal $u_{cal}(t)$ yielded from formula (3) (a) and the spectrum of the signal $u_{en}(t)$ yielded from formula (4) (b). The $50\,Hz$ stripe is omitted.

The fluctuations of network voltage signal, which feeds the load, may be described with formula:

$$u_{en}(t) = u_n \frac{1 + \Delta z_L(t)}{(1 + z_{00})[1 + \Delta z_L(t)] + z_{01}} \sin 2pf_n t \qquad (4)$$

Where: $\Delta z_{L1}(t) = \dfrac{\Delta Z_{L1}(t)}{Z_{L1}}$ - relative change of the load impedance value: $Z_{L1}(t) = Z_{L1} + \Delta Z_{L1}(t)$ and $z_{00} = \dfrac{Z_0}{Z_{L0}}$, $z_{01} = \dfrac{Z_0}{Z_{L1}}$.

To simplify the further analysis of formula (4) the phase angles of impedances quotients were neglected and only the modula were considered.

From the formula (4) the inference arises that the way of modulation of network voltage amplitude is nonlinear in respect of $\Delta z_{L1}(t)$. Therefore for both: the calibrating signal $u_{cal}(t)$ and loaded network voltage signal $u_{en}(t)$, with the same pairs of values $\left\{ \dfrac{\Delta u_m}{u_n}, f_m \right\}$ different P_{ST} values may correspond. The nonlinearity of formula (4) is also the cause of origin of complicated spectrum of network voltage signal $u_{en}(t)$, different from the spectrum of calibrating signal $u_{cal}(t)$.

4 MODEL INVESTIGATIONS

As a proof of the proposition submitted in the article **3** we are presenting the results of model investigations for the algorithm of calculation of the P_{ST} measure for the signal $u_{en}(t)$ according to formulae (1) and (2) and their comparison with the calibration characteristic defined by the standard.

In this purpose we assume, that the $Z_{L1}(t)$ impedance is sinusoidal variable, i.e. $\Delta z_{L1}(t) = \Delta z_{L1} \sin 2pf_m t$. Let's also assume, that one-phase network with replacement diagram presented in the Figure. 1 is supplied by a transformer with transmission 110 kV / 30 kV, apparent power 10 MVA and short-circuit voltage $u_z = 0.07u_n$ for frequency $f_n = 50\,Hz$. On the grounds of above data, the relative impedance values occurring in formula (4) are estimated as: $z_{00} = 0.13$, $z_{01} = 0.13$. We assume, that the relative value of the impedance Δz_L will vary in the range from 0.1 to

0.5, which corresponds the variability of $\frac{\Delta u_m}{u_n}$ value in the range from 0.02 to 0.1. For these values the short-period measure of fickering persistence $P_{ST}*$ of the signal $u_{en}(t)$ is calculated and in the Figure. 3 it is compared with the characteristic defined by the standard. Significant differences between them are evident, which confirms previously submitted proposition. Significant differences also occure between calculated spectrum of $u_{en}(t)$ signal, shown in the Fig. 2b, and spectrum of calibrating signal $u_{cal}(t)$, shown in the Fig. 2a, because the nonlinearity of the formula (4) is the source of additional components of the signal $u_{en}(t)$ spectrum.

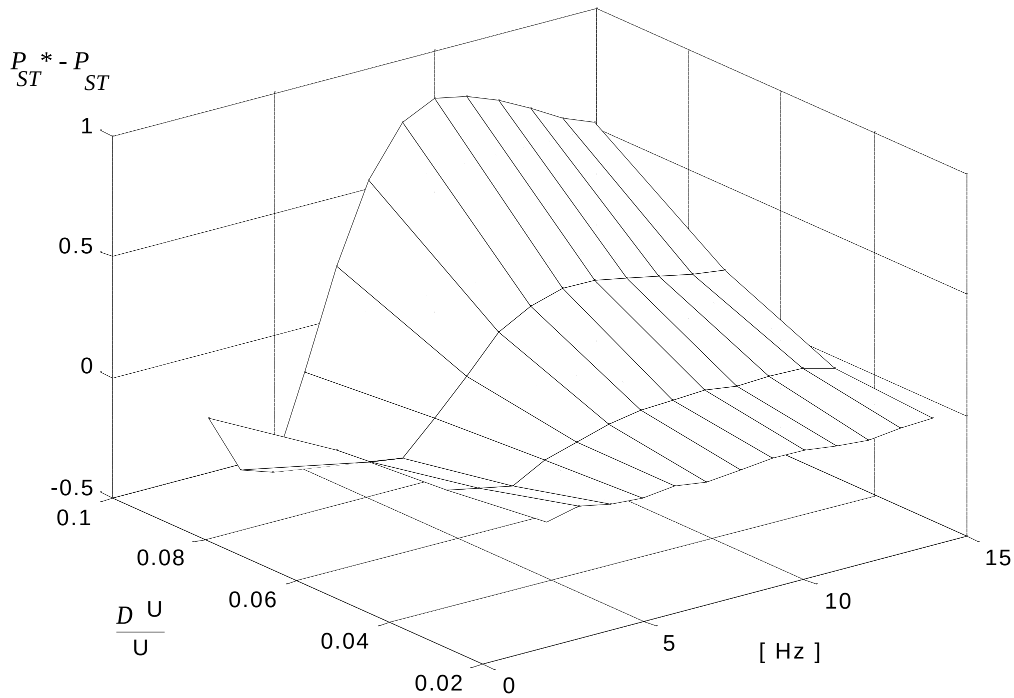

Figure 2. The difference of measures of flickering persistence $P_{ST}*$ and P_{ST} for the pairs of values $\left\{\frac{\Delta u_m}{u_n}, f_m\right\}$.

5 CONCLUSIONS

The authors of this papers are convicted, that for measurements of flickering persistence with flickermeters there may arise. Well-founded doubts towards the interpretation of P_{ST} values in respect to actual parameters of network voltage signal fluctuations. The source of these doubts is improper imitation of the fluctuation phenomenon by the calibrating signal.

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