A VIRTUAL APPARATUS FOR ENERGY QUALITY MEASUREMENT

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Abstract. This paper presents a virtual measurement apparatus used for measuring the values of energy quality indicators, which characterize the slow voltage variations. The apparatus use, for the values of measured voltage sampling a data acquisition device such as PCI/LPM/16 made by National Instrument. LABVIEW is the programming environment used for the realization of the virtual apparatus.

Keyword: Virtual apparatus, quality standards, slow variations, data acquisition, energy

1.THEORETICAL CONSIDERATIONS

The electric energy quality (EEQ) represents a complex estimation concept for the quality level of the electric energy product, expressed by a system of indicators of which values, determined for certain part of the electric network, in a certain time spell, could be compared with the optimum or possible proper values.

EEQ together with the safe performance and the electromagnetic compatibility of the installations with the environment in which they work, define and determine the quality of electric energy provider service.

The indicators system of EEQ refer to the next concrete aspects:

- frequency deviations;
- voltage variations;
- voltage deviations from the ideal form;
- voltage and current system deviations from phase symmetry.

1.1. Indicators for slow voltage variations

For the estimation of the slow feeding voltage variations, generic called the voltage irregularity, there are used indicators, which expresses the voltage deviations toward its nominal or medium value.

a). The voltage variation represents the percentage expression of the difference between efficacy value, real U_s of the voltage in a certain point of network, called work voltage and the nominal voltage Un in the same point, divided to the nominal voltage.

$$\Delta u_{\%} = \frac{U_S - U_n}{U_n} 100, [\%] \tag{1}$$

The medium voltage variation it is determined, as in frequency case, with the relation:

$$\overline{\Delta u_{\%}} = \frac{1}{T_0} \int_0^{T_0} \Delta u_{\%}(t) dt, [\%] \tag{2}$$

Where $T_{o,}$, represents the observation time. Considering the fact that efficacy value. of the voltage Us can be determined and it's constant during a basic period, the medium variation can be practically calculated with the relation:

$$\overline{\Delta u\%} = \frac{1}{T_0} \sum_{k=1}^{N_T} \Delta u_{\%k} T_k \tag{3}$$

Where T_k is the period with the order number K from the observation line.

N_T – number of period of the basic voltage during the observation time

$\Delta u_{\%k}$ – the voltage variation during T_k

Because the usage of the relative magnitude is easy and expressive, the relative work voltage u, called voltage level, can be introduced by the relation:

$$u = \frac{U_s}{U_n} \tag{4}$$

so that for the voltages variation and medium variation can be written the expressions:

$$\Delta u\% = 100(u-1),[\%] \tag{5}$$

$$\overline{\Delta u\%} = 100(\overline{u}-1),[\%] \tag{6}$$

where u, the medium value for the voltage level is determined by the relation:

$$\overline{u} = \frac{1}{T_0} \sum_{k=1}^{N_T} u_k T_k \tag{7}$$

similarly to the relation (3)

b). The variation coefficient of the voltage.

The dispersion of the values of an aleatory variable toward it's medium value is characterized by dispersion, so in the case of the voltages level this relation can be written:

$$\sigma_u^2 = \frac{1}{T_0} \int_0^{T_0} \left[u(t) - \overline{u}\right]^2 dt \tag{8}$$

for which the next equivalent form can be deduced.

$$\sigma_u^2 = \frac{1}{T_0} \int_0^{T_0} u^2(t)dt - (\overline{u})^2 \tag{9}$$

The square medium deviation of an aleatory variable is defined as square root from that variables dispersion, so that for the voltage level there can be written the relation:

$$\sigma_u = \sqrt{\sigma^2} \tag{10}$$

Finally, the coefficient for the voltages variation is defined by the relation:

$$C_{vu} = \frac{\sigma_u}{\overline{u}} \tag{11}$$

similarly to relation 3.
c). The voltages irregularity rate.
The evaluation of the electric energy quality, considering the slow voltage variations can be done by the square medium deviation of the voltage with the relation:

$$\varepsilon_q^2 = \frac{1}{T_0}\int_0^{T_0}[\Delta u_{\%}(t)]^2\,dt,[\%]^2 \tag{12}$$

an indicator proposed by P. Albert also known as the irregularity voltage rate.
Considering the voltage level, this indicator is determined by the expression:

$$\varepsilon_q^2 = \frac{1}{T_0}\int_0^{T_0}[\Delta u_{\%}(t)]^2\,dt,[\%]^2 \tag{13}$$

The link between the irregularity rate and the deviations dispersion of the voltage can be obtained by writing for the last magnitude a similarly expression to this one:

$$\sigma_{\Delta u}^2 = \frac{1}{T_0}\int_0^{T_0}[\Delta u_{\%}(t)]^2\,dt - (\overline{\Delta u_{\%}})^2 \tag{14}$$

so, we can find in the second member the irregularity grad and deduce the relation:

$$\varepsilon_q^2 = \sigma_{\Delta u}^2 + (\overline{\Delta u_{\%}})^2,[\%]^2 \tag{15}$$

If by establishing the observation line To we can obtain a negligible medium deviation then the irregularity rate becomes, according to the relation, equal to the deviations dispersion of the voltage.

$$\varepsilon_q^2 = \sigma_{\Delta u}^2 \tag{16}$$

A variant to the indicator e2q is represented by the irregularity rate energetically expressed, suggested by the Gausses according to the relation:

$$\varepsilon_{uP}^2 = \frac{\int_0^{T_0}[\Delta u_{\%}(t)]^2 P(t)\,dt}{\int_0^{T_0}P(t)\,dt},[\%]^2 \tag{17}$$

which represents a weight for the voltage deviations through the consuming of electric energy. The integrals from the relations denominator represent the active energy consumed during the time T_o

$$W_u = \int_0^{T_0}P(t)\,dt \tag{18}$$

according to the active charging curve P(t) in the consuming point considered.
The limit values for the characteristic indicators for the voltages long term variations are specified only for the voltage deviation, which for Romania are as it fallows:

$\Delta u_{\%}adm=\pm5\%$ for installations with over 220 kV
$\Delta u_{\%}adm=\pm10\%$ for installations less than 220 kV

1.2. Statistic values of the CCE indicators

The statistic estimation of CCE indicators can be done between the mean time recommended spells recommended:

Very short TVS of 3s
Short TSH of 10 min
Long LT of 1 h
One day long TD oh 24 h
A week(TWh)

As a statistic value of an indicator, on any interval enumerated, there is considered the square medium Xt of the indicators values from the considered interval, calculated with the relation:

$$X_T = \sqrt{\frac{1}{M}\sum_{j=1}^{M} X_j^2} \tag{19}$$

Where: Xi= represents the indicators value at j. determination
M=number of determination during the statistic interval.
For the 3 s interval, the minimum number of measurements is $M_{min} = 1$.
Regarding the estimation of the thermal effects of the harmonics on the electric equipments there are recommended short observation intervals TSH.

According to the statistics there are considered interpretable the next square medium value.

Xmax (TVS) representing the biggest value of the square mediums, determined on very short time spells / intervals.

Xmax TSH same, for short time spells / intervals.

X_{TD}(95%) representing the square medium value u of an indicator in the one day interval, accordingly to the cumulated probability of 95%.
In other words this value can be outrun only in 5% of 3 s intervals (M_{Min}=20)
X_{TD} (99%) is determined similar, for a cumulate probality for of 99%. This can be outrun only by 1% of the 3 s intervals (M_{Min} = 100).

2. THE DESCRIPTION OF THE VIRTUAL APPARATUS

The virtual measurements apparatus is accomplished in the programming environment LABview. As any other virtual instruments accomplished in this programming environment the apparatus has 2 components: Panel window and diagram window.

2.1 Panel Window

The panel window allows the programmer, both the visualization of the data introduced by him and the ones obtained after the programs run, namely the proper measurements as well as the modification of this magnitude. In fig. 1 it is presented the panel window of the “Virtual Apparatus for supervision of the electric energies quality ”.
The input elements of the apparatus are:

- acquisition board
- acquisition channels
- supervising time
- nominal voltage

the output elements are:

- “Voltage level” diagram
- the displayed values of the voltage level
- the displayed values of the voltage deviation
- Voltage medium deviation
- the medium value of the voltage level
- the variation coefficient of the voltage
- the voltage irregularity rate
- the voltage deviation description.

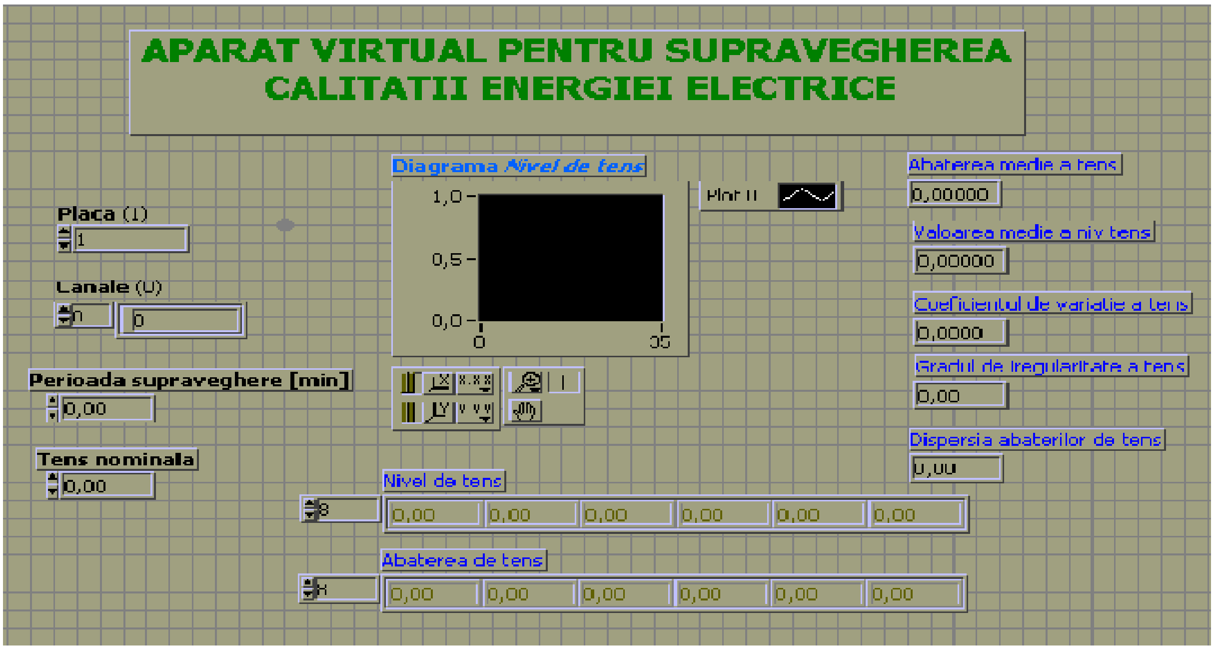

Fig. 1 Panel window

2.2 Diagram window

The diagram window allows the description of the operation performed since the input data acquisition until the obtainance of the values of the indicators required to the supervision of the electric energies quality.
This aspect is presented in the figure 2
2.3 The virtual apparatus performance.
The virtual apparatus for the supervision of the electric energies quality accomplished to calculate the slow voltage variation indicators, sow that there deviations can be traced.
The data acquisition is done on one channel thought the acquisition board PC – LPM – 16. The constant input elements: “nominal voltage” and “supervising time” are being introduce by the user though the panel window. The voltages E. V. obtained are transformed through a “while loop” cycle, cycle which end is conditioned by the purchase of the supervising time (introduced by the user in minutes).
During the “While loop ” cycle there is calculated the voltage deviation for each acquired value according to the relation.
The value for the voltage level, according to the relation (1) such as the square voltage deviation according relation (2) and the square subtractions (u-l)
At the output of the “while loop ” cycle, the values for the previous calculated magnitudes are stocked in vectors suggestively labeled:
u_K(voltage level vector)
$(u_{K-1})^2$(square subtraction (u-l) vector)
du % (voltage deviation vector)
du $\%^2$ (square voltage deviation vector)
and the proper values for the voltage level are graphically as well as numerically displayed through the indicators:

“the voltage level diagram” (graphic output element) and
“the voltage level” (output elements as numerical string)

The $(u_{K-1})^2$ vectors elements are processed in such way that in the end to obtain the value of the voltages irregularly rate , according to the relation :

$$\varepsilon_q^2 = \frac{1}{T_0}\int_0^{T_0}[\Delta u_{\%}(t)]^2\,dt,[\%]^2 \qquad (20)$$

this so obtained value is posted trough the numeric output element labeled “voltages irregularly rate ”
The du % vectors elements are processed so that the value for the voltages medium deviation can be obtained according to the relation :

$$\overline{\Delta u_{\%}} = \frac{1}{T_0}\sum_{k=1}^{N_T}\Delta u_{\%k}T_k \qquad (21)$$

The value will be posted through a numerical output element labeled as “voltage medium deviation ”.

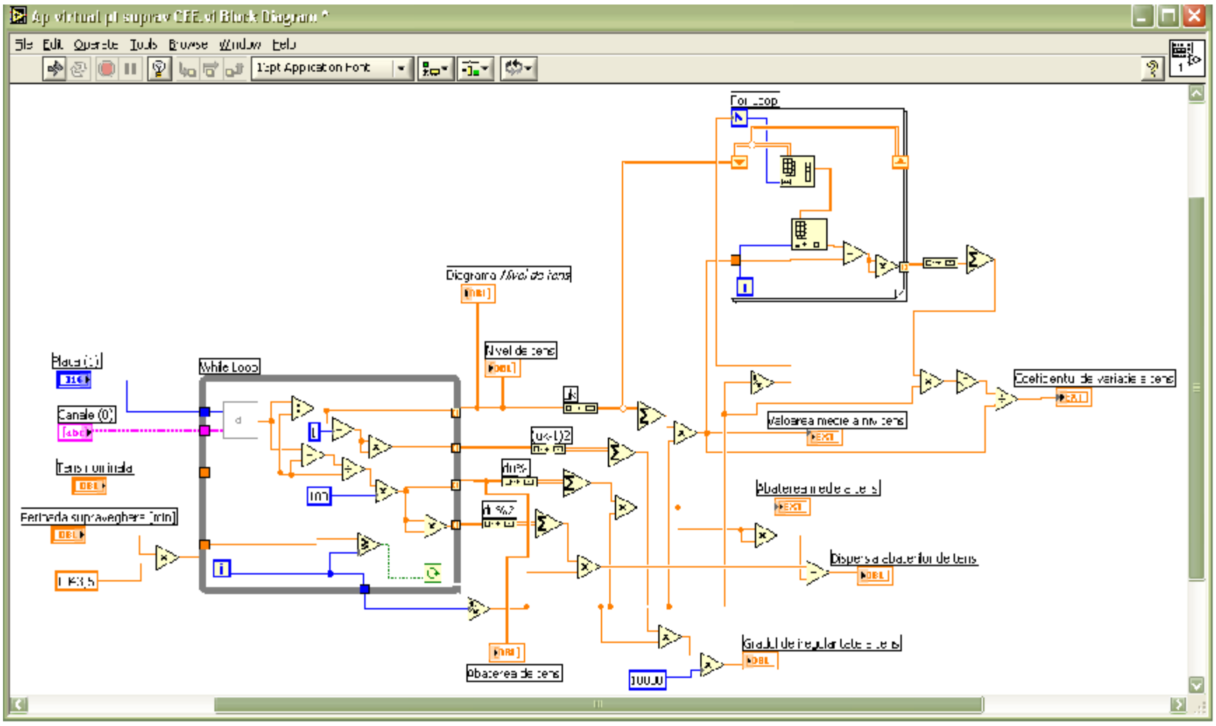

Fig. 2 Window diagram

The $du_{\%}^2$ vectors elements are processed together with the du % vectors elements in order to obtain the value of the voltage deviation dispersion according to the relation (14), value that will be posted through a numerical output element labeled as “voltage deviations dispersion ”.
The u_K vectors elements are processed in order to obtain the medium value for the voltage level according to the relation (7), the value will be posted through a numeric output element labeled “the medium value of the voltage level ” to obtain the value for the coefficient for the voltage variation , the u_K vectors elements are introduced through a “for loop ” cycle , in which they are processed so that in the end , to obtain a new vector , with elements such as $(U_I\,(t)\text{-}u)^2$.
The new vectors elements are processed forward in order to obtain the value for the coefficient for the voltage variation , according to the relation :

$$C_{vu} = \frac{\sqrt{\frac{1}{T_0}\int_0^{T_0}\left[u(t)-\left(\bar{u}\right)\right]^2 dt}}{\bar{u}} \tag{22}$$

This value that will be posted through a numeric element labeled “coefficient for the voltage variation”

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