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# POWER QUALITY CONTROL IN THE POWER DISTRIBUTION NETWORKS

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**ABSTRACT**
*To establish a practical guide for the Power Quality (PQ) control represents the main aim of this paper. The reasons that impose the determination either of the main indicators or of the specific ones to a certain type of end-user or even of all PQ indicators are the following:*
*- responsibilities establishment of the end-users, the equipment producers and the electrical power delivery units, regarding to the PQ non-providing;*
*- emphasizing of the most adequate methods and resources, technically and economically justified, in order to provide and maintain the PQ in the analysed electrical network.*
*A general and critical analysis referring to the analytical basics of the PQ indicators determination is presented, with the purpose of giving an impulsion to their correct determination. The measures that have to be taken in order to realise a professional harmonics analysis are substantiate on the discrete Fourier analysis particularities. The presentation of a complete vision over the symmetrical components calculus represents as well an important original contribution of the authors. The recommended measurement points are indicated on a general power distribution scheme. Further on, the concrete manner of the transducers connecting in order to acquire the voltages and currents systems, is presented related to the voltages and currents levels. Finally, the Virtual Instrumentation utilization in the PQ monitoring and control is argued.*
**Keywords:** Power quality, Virtual instrumentation, Power quality monitoring, DAQ

## 1. PQ CONTROL NECESITY AND ORGANIZATION

The PQ assessment of either the main indicators or the specific ones of the end-users or of all PQ indicators is necessary owing the following considerations:

- PQ norms and standards accomplishment;
- establishing of the end-users, equipment producers and electrical energy providers responsibilities regarding the PQ disturbances;
- emphasizing the most adequate methods of the PQ maintaining, justified from the technical and economical points of view.

The PQ indicators determination methodology involves the following aspects:

- the adequate apparatus for the measurements and experimental data computing;
- analytical basis of the PQ indicators computing;
- the suitable measurements points in the power system;
- measuring schemes and errors;
- optimum, imposed or chosen measuring period;
- data statistical processing.

The computer aided data processing can be done according to the following three ways: in anticipated, real or quasi-real and posterior time. The anticipated time estimation can be necessary for the measurements preparation and for the responsibilities emphasizing. The real time processing is possible for almost all indicators, excluding the statistical ones; the quasi-real time situation is specific for the frequency and the RMS values. The posterior time determination is proper to the statistical processing.

## 2 PQ INDICATORS DETERMINATION BASIS

### 2.1. Apparatus

There is a covering offer of measuring equipment that includes general purpose apparatus, like the power-meters or dedicated ones, as the flicker-meters, frequency-meters, harmonics analyzers etc. Almost all this apparatus have to be connected to a computer in order to increase firstly the memory capacity and, secondly, the processing facilities.

Taking into account the necessity of some flexible processing methods, the high costs of the mentioned apparatus and the control method adaptability to the electric network specificity, the authors have developed and proposed the PQ monitoring using the Virtual Instrumentation (VI). In this case, the following configuration is required: voltage and current Hall transducers with voltage and current transformers if necessary, data acquisition card, a computer and a LabVIEW license.

### 2.2. Analytical considerations

The PQ indicators determination has to be done through calculus algorithms and relationships so that the results will be relevant for the analyzed disturbances. The following initial remarks can be done:

- the frequency and voltage deviations are simply and correctly determined in accordance with the known relationships [1,2];
- the voltage fluctuations should be better characterized by the following proposed relationship:

$$\delta V_j = \frac{\left|V_j - V_{j+1}\right|}{V_j} \cdot 100,\ \%, \tag{1}$$

where $V_j$ from the denominator is replacing the rated voltage $V_n$;

- the voltage impulses characterisation is insufficient and there are no imposed limits for their indicators.

Regarding harmonics, all the conditions for a relevant analysis have been exposed in [3]. The authors have realised a virtual instrument for the harmonics analysis, based on the above mentioned conditions and tested by using functions with known harmonics composition. The main conclusions obtained with this virtual instrument are:

- the maximum order of the detectable harmonic, using Discrete Fourier Transform, is

$$N_{max} = p - 1, \tag{2}$$

considering that 2p scans have been acquired during the fundamental period;

- if the following relationships

$$A_N = \frac{1}{p} \cdot \sum_{k=1}^{2p} Y_k \cdot \sin\left(Nk\frac{\pi}{p}\right)\ ;\ B_N = \frac{1}{p} \cdot \sum_{k=1}^{2p} Y_k \cdot \cos\left(Nk\frac{\pi}{p}\right),\ N \geq 1 \tag{3}$$

are used for the Fourier coefficients determination, so $k \in \{1,\dots, 2p\}$, the phase error will be

$$\Delta\varphi_N = \frac{N\pi}{p}, \tag{4}$$

so that the real phase $\varphi'_N$ of each N order harmonic must be calculated as follows:

$$\varphi'_N = \varphi_N - \Delta\varphi_N; \tag{5}$$

- if the sums from the Fourier coefficients (3) are calculated for $k \in \{0,\dots, 2p-1\}$, there will be no phase error;
- the "alias" phenomenon, when a M order harmonic, M>p, appears as a N order harmonic, N<p, is analytically expressed with the relationship

$$(2p) \mid (M \pm N), \tag{6}$$

thus (2p) is dividing the integer number (M ± N). Consequently, the "alias" phenomenon avoidance imposes either an input signal filtering or the use of special analysis algorithms.

Concerning the voltage and current unbalances, there is a great number of relationships [2], more or less closed to the Stokvis-Fortesque theorem. In order to avoid the calculus in the complex form, we propose the next scalar expressions, where the iterative calculus is implemented:

$$Y_+ = \frac{1}{3} \cdot \left\{ \left[ \sum_{k=1}^{3} Y_k \cdot \cos\left( \varphi_k + \frac{2\pi}{3} \cdot (k-1) \right) \right]^2 + \left[ \sum_{k=1}^{3} Y_k \cdot \sin\left( \varphi_k + \frac{2\pi}{3} \cdot (k-1) \right) \right]^2 \right\}^{\frac{1}{2}} ; \qquad (7)$$

$$Y_- = \frac{1}{3} \cdot \left\{ \left[ \sum_{k=1}^{3} Y_k \cdot \cos\left( \varphi_k + \frac{2\pi}{3} \cdot (4-k) \right) \right]^2 + \left[ \sum_{k=1}^{3} Y_k \cdot \sin\left( \varphi_k + \frac{2\pi}{3} \cdot (4-k) \right) \right]^2 \right\}^{\frac{1}{2}} ; \qquad (8)$$

$$Y_0 = \frac{1}{3} \cdot \left[ \left( \sum_{k=1}^{3} Y_k \cdot \cos\varphi_k \right)^2 + \left( \sum_{k=1}^{3} Y_k \cdot \sin\varphi_k \right)^2 \right]^{\frac{1}{2}} , \qquad (9)$$

$(Y_k, \varphi_k)$, $k \in \{1, 2, 3\}$, being the RMS and the phase of the analysed system phasors.
The trend of some producers to implement simple relationships in order to characterise the unbalance, like

$$k_{unb} = \frac{Y_{max} - Y_{min}}{Y_{med}}, \qquad (10)$$

is not technically justified, because it is not in accordance with any unbalance indicator.

### 2.3. Measuring points

The main measuring points for the PQ experimental determination are presented in figure 1 in an hierarchical form according to the distribution network structure. It can be noticed that the points 1

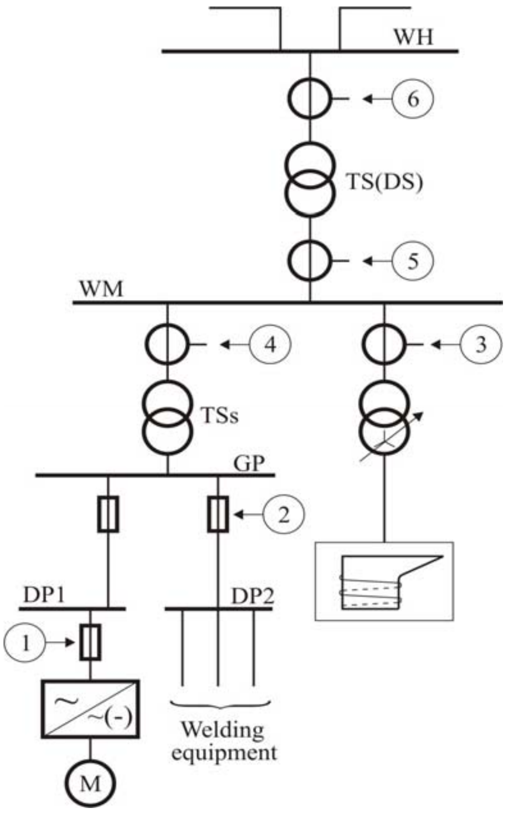


*Figure 1. Hierarchical levels of a distribution system for the PQ experimental determination: 1 – LV disturbant receiver; 2 – Distribution Panel (DP) with disturbant receivers; 3 – MV disturbant receiver; 4 – Transforming Substation (TSs) with disturbant receivers; 5 – MV station; 6 – MV connection; GP – General Panel; TS(DS) – Transforming (Distribution) Station.*

and 2 are on the low voltage (LV) side, 3, 4 and 5 are corresponding to the medium voltage (MV) network and 6 is situated on the high voltage (HV) side.

### 2.4. Measuring schema

The phasorial determination of the voltages and currents systems requires a more complex apparatus and a simultaneous storage of the data. So, in order to characterize the PQ level, only modern power-meters or data acquisition systems, connected to a computer, can be used.

The electrical schema for connecting the voltage and current Hall transducers in order to acquire the phase voltages and the line currents, is presented in figure 2 for the LV circuit. For MV and HV, the use of the measuring transformers becomes necessary.

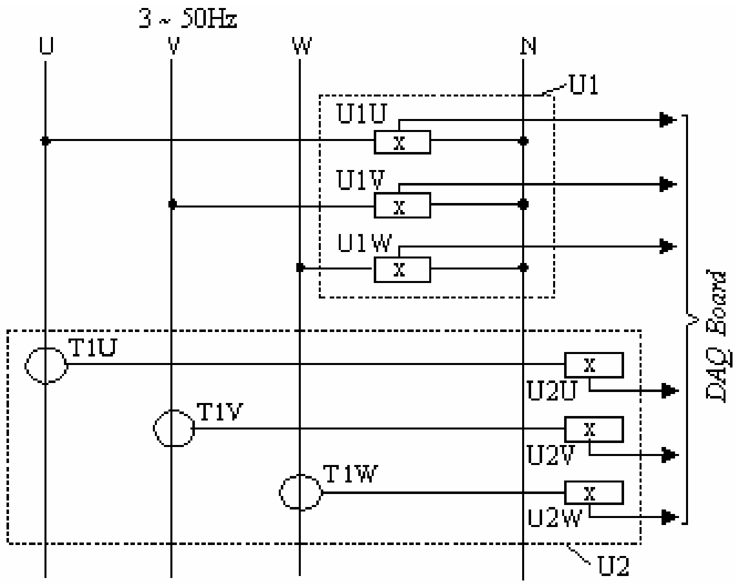


*Figure 2. The voltage and current Hall transducers connecting for the phase voltages and line currents acquisition: U1 – voltage transducer; U2 – current transducer.*

## 3. CONCLUSIONS

Regarding the observation periods, these ones are in accordance with the technological intervals, the shifts number and the concrete PQ measuring point from the system. Even the observation period is established as minutes, hours or days, the measurements extension, on an interval that represents a multiple for the observation time, to store the data in order to provide an adequate statistical processing becomes very useful.

Taking into account that the majority of the PQ indicators allow statistical definitions, their processing can begin after the required data storage, in order to determine the characteristic variables: the average values, the deviations and the dispersion. Owing to the software flexibility, the most appropriate method to realise a power-meter is using the VI. Moreover, this solution provides the required memory capacity, high working speed, lower cost, verification possibility of the analytical basis through simulation and extension availabilities.

The verification of the implemented analytical basis before starting the real data acquisition and processing is very useful, because not all the used calculus methods are relevant for the PQ disturbance type.

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