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Analysis of electrical quantities for electricity supply systems. Case study

Analiza mărimilor electrice pentru sisteme de alimentare cu energie electrică. Studiu de caz

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Abstract: *The presence of harmonics in the electrical installations and in the electrical systems of power supply is due to the currents. Measuring the values of harmonic voltages and currents is very important, and the determined values must be explicitly specified as values of voltage and current. At present, the types of equipment that produce harmonics have increased so that careful consideration of the harmonics and their effects must be given. For this reason, the article presents an analysis of the electrical quantities related to the supply system for sterile speakers inside the Emergency Clinical Hospital for Children "Louis Țurcanu" in Timisoara. The measurements directly measured by the recording equipment are the currents and voltages, in instantaneous values, on the three phases of the input in the supply panel. The monitored sizes were transferred to the processing - evaluation - recording unit which provided information for evaluating the THD distortion factor.*

Keywords: *harmonics, electrical installations, voltage, distortion factor, electric power quality*

Rezumat: *Prezența armonicilor în instalațiile electrice și în sistemele electrice de alimentare se datorează curenților. Este foarte importantă măsurarea tensiunilor armonice şi ale curenţilor, iar valorile determinate trebuie specificate explicit ca valori ale tensiunii şi curentului. În prezent, tipurile de echipamente care produc armonici a crescut, astfel că trebuie acordată o atentă considerare armonicilor și efectelor pe care le generează. Din acest motiv, articolul prezintă o analiză a mărimilor electrice aferente sistemului de alimentare pentru boxele sterile din incinta Spitalului Clinic de Urgență pentru Copii, ”Louis Țurcanu”din Timișoara. Marimile masurate direct de aparatul de inregistrare sunt curentii si tensiunile, in valori instantanee, pe cele trei faze ale intrarii in tabloul de alimentare. Mărimile monitorizate au fost transferate unitatii de procesare - evaluare - inregistrare care a furnizat informații pentru evaluarea factorului de distorsiune THD.*

Cuvinte cheie: *armonici, instalații electrice, tensiune, factor de distorsiune, calitatea energiei electrice*

1. Introduction

The main form of energy for powering many types of equipment, at present, is electricity. Consumers' electrical installations refer to their electrical receivers and power networks, including the corresponding connection, protection and measuring devices. An important condition for the proper functioning of a receiver is the continuity of the electricity supply [1]. Depending on the category of consumers they fall into, their power supply can be achieved through two independent sources, each one being able to provide the necessary electricity, with an additional power source that is not obligatory to be independent (for short periods of time.) which can take over the entire required load or can only supply one. In buildings in the hospital category, the availability of a reliable electricity source is vital to ensure continuity of care.

Power outages voltage of any duration that can lead to critical situations, are unacceptable. [1].

Measuring the electrical parameters of electrical installations, periodically or in monitoring applications, is important for a better understanding of the behavior of the entire electricity supply system with effects on improving the availability and reliability of the system by detecting potential problems before it occurs [2, 3].

In ideal electrical systems, the voltage and current curves are perfectly sinusoidal. In practice, non-sinusoidal currents occur if the load is non-linear with respect to the applied voltage. In the case of simple circuits having only resistive, inductive or capacitive linear loads, the current flowing is proportional to the applied voltage (at a certain frequency) so that if the voltage applied is sinusoidal a sinusoidal current will flow. If there is a reactive element in the circuit there will be a phase difference between the voltage curve and the current one; the power factor is low, but the circuit may still be linear.

The presence of harmonics in the electrical installations and in the electrical systems of power supply is due to the currents. The harmonics (voltage or current) represent the voltage, respectively sinusoidal current, with the frequency equal to an integer multiple of the fundamental frequency of the supply voltage [2, 3].

Generally, in a three-phase system, only odd-numbered harmonics (3, 5, 7, 9) appear, but when they appear harmonic of rank, the existence of deficiencies in the system is suspected. Measuring the values of harmonic voltages and currents is very important, and the determined values must be explicitly specified as values of voltage and current.

At present, the types of equipment that produce harmonics have increased so that careful consideration must be given to the harmonics and their effects [2].

When the amplitudes and the rank of the harmonics are known, the reconstruction of the distorted origin curve is and is realized by summing point by point of the harmonic components. However, what is difficult to achieve and involves cumbersome calculations is the decomposition of the deformed curve into harmonic components. The solution of this problem is solved by using three- phase analyzers that are capable of digitally recording, in real time, a three-phase curve and performing analysis functions, including Fourier analysis, in order to determine the harmonics content. However, the functions of detecting and diagnosing problems generated by harmonics are still a challenge for these analysis equipment. For these reasons, the equipment manufacturers take measures to reduce the amplitude of the harmonic currents [2, 3].

2. Effects and solutions of problems caused by harmonics [2,3]

There are several general problems caused by harmonics that may occur at the distribution level, but also at the installation level, and the effects and solutions are very diverse.

2.1. Problems at the level of the installations determined by the harmonic currents:

- overheating of the transformers;
- inadvertent operation of the switches;
- overloading the capacitors for power factor correction;
- overloading the conductor from the non-working condition;
- film effect in conductors.

2.2. Problems at the level of the installations determined by the harmonic voltages:

- disturbances when crossing the curves;
- presence of harmonics.

The presence of current and voltage harmonics implies the appearance of increased thermal effects, determined by the occurrence of additional losses of active power.

2.3. Problems at the level of the installations determined by the harmonic voltages:

- losses in PCu conducting material;
- losses in PFe magnetic materials;
- losses in dielectric Pd.
- additional losses in the conductive material due to the increase of the effective value compared to the pure sinusoidal regime or to the increase of the electrical resistance of the conductors, taking into account its frequency dependence (the film and proximity effect);
- additional losses in magnetic materials that occur due to hysteresis and the existence of turbulent currents.

2.4. Overvoltages at network nodes or equipment terminals

- resonance on voltage harmonics;
- increasing the potential of the neutral point for star connections of transformers or other receivers;

2.5. Overcurrent in three phase electrical networks (RET)

- the current resonance in the circuits of the electricity consumers;
- overloading the null circuit of the three-phase networks. For example, if the harmonic phase current represents 60% of

the phase current, it will determine, at the neutral conductor level, a harmonic current of 180% of the phase current. Measurements made in commercial spaces indicate values of the order of 150 up to 210% of the phase current in neutral conductors, often with a half-section from the active conductor.

2.6. Effects of harmonics on equipment in electrical networks

The presence of harmonics has effects on:

- *three-phase transformers* due to the losses through Foucault currents that increase with the square of the harmonic rank and result in the increase of the temperature which leads to a drastic reduction in the life of the transformers. On the other hand, the harmonics with multiple ranks of 3 are effectively absorbed by the winding of the transformers not propagating for supply and generating effects such as: increase of the active power losses in the conductive material and the magnetic materials, the increase of the electrical demands of the insulations, additional mechanical demands and not lastly increases of the value of the distortion factor of the current.

All these effects generated by the presence of harmonics, can lead to the decrease of the efficiency of the transformation of the electrical energy having also a negative influence on the mode and the operating regimes.

- *the operation of the rotary machines* due to additional losses in the conductive material and in the magnetic materials, generating the increase of the temperature of the coils and the magnetic core, due to interactions between the magnetic flux determined by the fundamental and the one determined by the higher harmonics, due to the changes of the torque of the electric machine which leads to the reduction of the efficiency rotary machines
- *electronic equipment* that may constitute polluting sources for the network to which they are connected, due to the specific way of modifying the controlled quantities (adjustment, phase, duration adjustment, etc.). Applying a non-sinusoidal voltage to the terminals of these equipments leads to the modification of their technical characteristics, with negative effects on the controls and improper operation of the equipment due to the multiple zero crossings of the voltage curve due to the harmonic distortion, increasing or reducing the amplitude of the voltage curve (the effect for sharpening or flattening the curve).
- *the operation of the switches* and fuses due to the distortion of the electric current which leads to the increase of the losses of active power, the reduction of the efficiency of the devices of extinguishing of the electric arc, accidental trigger and noise due to the commutation, and regarding the operation of the fuses the additional fuses sensitive to the heating superior, there is a translation of the operating characteristic, and in very severe cases, an accidental operation.

In addition to the above, periodic non-sinusoidal regimen may also have effects of the following type:

- electromagnetic disturbances in the TN-C distribution schemes (where the earth and neutral have combined - PEN) causing significant voltage drops that cause corrosion of the metal parts, the abnormal charge of an electromagnetic bond and radiation;
- influences on the protection relays depending on the amplitude and phase of the harmonics;
- influences on measuring devices resulting in relatively large errors (positive and negative), depending on the type of the device;
- disturbances at the zero crossing of the curves that lead to malfunctions when there are harmonics or transient phenomena at the power level, so the number of zero crossings increases.

3. Analysis of the electrical quantities related to the electricity supply of the sterile speakers at the "Louis Țurcanu" Emergency Hospital in Timișoara

As a result of the rehabilitation of the spaces related to the sterile speakers inside the Emergency Clinic Hospital for Children "Louis Turcanu" in Timisoara, in order to improve the availability and reliability of the electricity supply system, by detecting the potential problems before it appears, it was considered necessary to analyze the electrical parameters of the network and the distribution of powers on the three phases by carrying out direct measurements. The measured and monitored quantities (currents and voltages) using the FLUKE 435 network analyzer were measured in instantaneous values, on the three phases of the input in the power supply panel, after which they were transferred to the processing - evaluation - recording unit that provided information for the evaluation of the THD distortion factor [4, 5].

The monitoring of the electrical measurements was carried out between 10.10.2016 (10:28:41 am) - 12.10.2016 (10:20:11 am) [5].

Based on the recorded values, analyzes of the voltages were performed on the three phases and on the null, as (Figure 1) and on the harmonic spectrum of the currents on the three phases and on the null (Figure 2).

Figure 1. Variation of voltages on the three phases and on the null

In figure 1, the values of the voltages are represented on the abscissa, and the ordinate indicates the date and time of the measurements (eg: 10-10, 12 o'clock).

The values shown in figure 1 indicate the measurements made in the terval 10.10.-12.10 from 6 in 6 hours. A measurement interval was set at 30 s and the curves were drawn: Normal period Min (Green), Normal period Max (Red) and Normal period Avg (black) which represents the average between Min and Max [5].

The main characteristics of the voltage at the point of supply of electricity to the users of the public electricity networks for the distribution of alternative voltage, low voltage, medium voltage and high voltage, under normal operating conditions are specified by national and international standards [6, 7]. The characteristics are established for normal operating conditions, excluding periods with interruptions, the variations of the supply voltage should not exceed ± 10% of the declared voltage Uc. By convention, the threshold for starting the voltage gap is equal to 90% of the nominal voltage. For low voltage public networks, the standard rated voltage between phase conductor and neutral conductor is Un=230V or Un=400V between phase conductors.

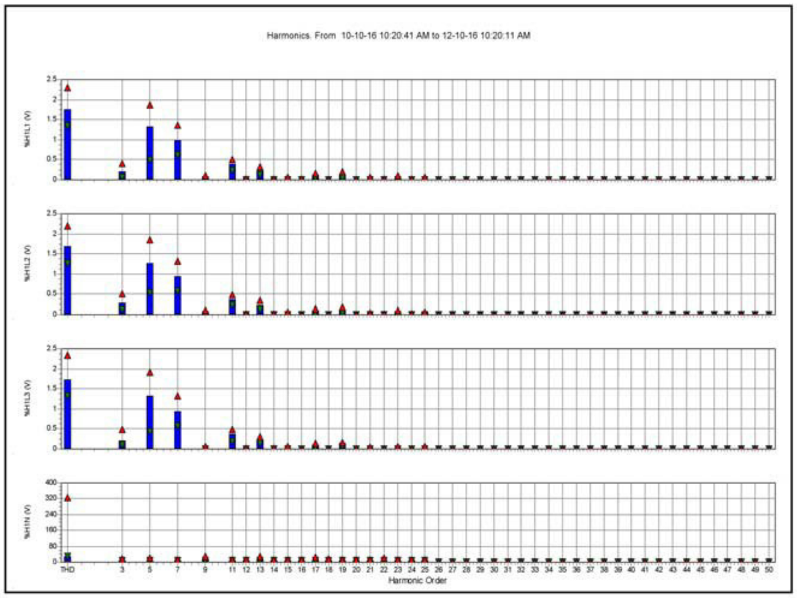

Figure 2. Harmonic spectrum of currents on the three phases and zero

In figure 2, on the abscissa are represented the harmonics, and the values of the distortion factor (THD) up to the rank 50, on the ordinate. Distortion factor represents the ratio between the actual value of all harmonics and the actual value of the fundamental of an alternative size.

The THD value of the supply voltage (including all harmonics up to range 40) must be less than or equal to 8% [6, 7]. From the analysis of the THD values in Figure 2, it is observed that the total harmonic distortion THDU $\leq$ 8% which means that the harmonics fall within the allowable values.

For a correct analysis, the events of occurrence of voltage gaps were also recorded, events that can be seen in figure 2, but for a clearer visualization, the graph of these events was presented, presented in Figure 3, in which the occurrences of the type of voltage drops or voltage gaps were also recorded, events that can be seen in figure 2, but for a clearer visualization, the graph of these events was presented, presented in figure 3, in which the occurrences of the type of voltage drops or voltage gaps.

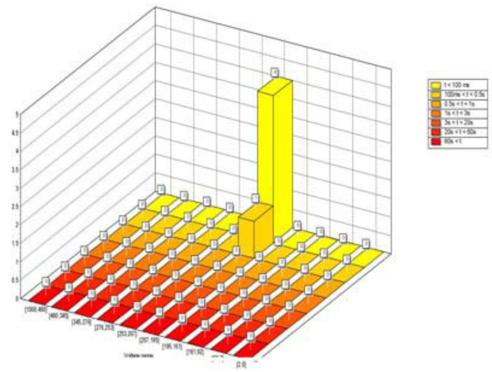

Figure 3. Occurrence of events during the measurements

In figure 3, on the abscissa the number of goals was represented, and on the ordinate, the voltage interval on which the voltage drops occurred. It can be observed that during the measurements there were 5 voltage drops: 2 on the L2 phase and 3 on the L3 phase, the drops which are also visible in figure 1. Four of them are with duration below 100ms and one with a duration between 0, 1s and 0.5s (Figure 3).

Voltage values recorded: 206.5V; 199.6 V; 195.1 V; 201.7 V; 198.1V were analyzed against the standardized value Un = 230.

Given that voltage gaps represent temporary reductions of the actual voltage at one point of the power supply network below a specified threshold value, which coincides with the initiation of the voltage gap [6, 7], it can be concluded that the values of the voltage gaps registered do not exceed the permissible threshold.

Thus, the normed and measured values for the network parameters (voltage & voltage harmonics) are presented in Table 1.

Table 1.

Measurement results for network parameters

Parameter	Standard values	Measured values
Voltage level	230 V ± 5%	falls within the limit of 230 V ± 5%
Total Harmonic Distortion	$THD_U \leq 8\%$	falls below the allowable limit

4. Concluzii

Following the measurements made it can be concluded that the measured network parameters are within the normal limits, the distribution of powers is relatively balanced on the three phases and that the depths reached by the voltage gaps being between 195.1V and 206.5V do not represent a danger to reliability electricity supply plant.

Also, for the THD value of the supply voltage (including all harmonics up to the rank of 50) it is concluded that it is below 2%, falling below the allowable value (≤ 8%).

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