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Selected aspects of electrical equipment operation with respect to power quality and EMC

Streszczenie. *Skuteczność działań dotyczących poprawy jakości energii elektrycznej i kompatybilności elektromagnetycznej urządzeń elektrycznych jest związana z ograniczaniem zakłóceń wprowadzanych przez odbiorniki do sieci elektroenergetycznej oraz uzależniona od identyfikacji tych zakłóceń. W pracy przedstawiono wyniki badań w torze zasilania kilku popularnych odbiorników bazujących na energoelektronice. (**Wybrane zagadnienia pracy urządzeń elektrycznych w odniesieniu do jakości energii i EMC**).*

Abstract*. The effectiveness of measures to improve the quality of electricity and the electromagnetic compatibility of electrical equipment is linked to limiting the disturbances introduced by receivers to the power grid and depends on the identification of such interference. The paper presents the results of examining several popular receivers based on power electronics*

Słowa kluczowe: jakość energii, kompatybilność elektromagnetyczna.
Keywords: quality of energy, electromagnetic compatibility.

Introduction

In recent years we have seen a dynamic growth in the number of receivers in use, as well as in the changes occurring in their structure, which translates into troublesome effects of voltage distortion in the power grid. One reason is a significant increase in the number of receivers with power electronic input circuits that convert alternating current electricity into energy with other parameters than the mains. Such devices allow to reduce electricity consumption, but at the same time bring to the grid disturbances that distort the signal voltage (at deformed currents, higher harmonics are identified in the spectral distribution).

From the point of view of the user of electricity it is desirable to ensure continuity of supply and a voltage of constant frequency, effective value and perfectly sinusoidal waveform. Yet many phenomena depreciate the quality of energy. Thus waveform deformations are caused by consumers, and are associated with the working conditions of receivers, their operating principle or construction. With the increase in the number of devices causing disturbances, more and more equipment becomes sensitive to them. Work on improving the quality of electricity is basically related to the reduction of noise introduced by receivers to the power grid, and thus their electromagnetic compatibility.

The disruption in the voltage and current waveforms in electricity grids require research on electricity receivers. Such studies include the impact of noise on the correct operation of receivers and receiver impact on the power grid, i.e. emission of interference to the power grid. There is thus justification for the need for continuous research on receivers regarding both the basic parameters of power frequency (analysis of the shape of the momentary waveforms of voltage and current, harmonic content) and the frequency range of 9kHz-30MHz.

Requirements for power quality and electromagnetic compatibility

Monitoring of the quality level of electricity is still of interest to groups of scientists conducting research in the field of electricity generation and distribution, but more often is the practice of engineers in grid plants, with manufacturers, industrial and institutional customers, and even with individual customers. This is particularly important in the era of the development of distributed energy based on renewable energy sources. Electricity has become a commodity, and therefore must have its quality evaluated.

By definition (following the Advisory Committee on Electromagnetic Compatibility ACEC) power quality is a set of parameters describing the properties of the process of supplying energy to the user under normal operating conditions, determining continuity of supply (short and long power outage) and characterised by the supply voltage (value, asymmetry, frequency, waveform).

The quality of electricity is thus characterised by specific figures and ratios. The documents governing the basic issues related to power quality include Energy Law [1], Polish Standard PN-EN 61000-4-30 Electromagnetic compatibility (EMC) - Methods for testing and measurement - Methods for measuring the quality of energy, Polish Standard PN-EN 50160 [5], and the Regulation of the Minister of Economy and Labour of 20 December 2004 on detailed conditions for the operation of the power system setting out the quality standards of customer service and the technical parameters of power supply in the national power system. In relation to the MV and LV networks they are consistent with the values contained in the basic standard EN 50160. The legislative support in the area of power quality in the power system also includes other legal acts [3,4,5].

Supply voltage quality tests rely on the registration in good time of parameters determining the quality and after analysing the results, comparing them with the limit values contained in industry standards and regulations [8].

In accordance with current regulations in our country, all producers of electrical and electronic equipment must comply with the requirements defined in the EU directives including: the Machinery Directive, Low Voltage and EMC Directive [2]. According to the Electromagnetic Compatibility Directive a device should meet the requirements contained in the dedicated set of technical standards. There are two aspects of product evaluation. The first type of tests are measurements of emissions disorders. They give knowledge that the device does not cause interference with other equipment. The second type of research is the study of device resistance to disorders. Thus, by definition, electromagnetic compatibility means the ability of a device to satisfactorily operate in an electromagnetic environment without causing excessive electromagnetic disturbances to other equipment in that environment. This environment is also the supply system - thus disorders generated and propagated at high frequencies may affect the quality of energy.

Essential requirements of the emission of electromagnetic disturbances and immunity to electromagnetic interference are contained in Directive 2004/108/EC relating to electromagnetic compatibility (EMC) [2], as implemented into Polish law by the Act of 13 April 2007 on Electromagnetic Compatibility (Dz. U. [Journal of Laws of the Republic of Poland] 2007, No. 82, item. 556).

Specific requirements, or acceptable limits for electromagnetic emissions or evaluation criteria of the tests for electromagnetic immunity can be found among norms harmonised with the EMC directive [6,7]. Equipment complying with the EMC directive for conducted interference must generate electromagnetic emissions set inside the respective ranges. Permissible limits depend on the purpose of the device and are dedicated to the home, office or lightly industrialised (Class B) user or for use in industrial environments (Class A).

Measurements

The quality of electricity in the power system depends on the characteristics of the connected and used electricity receivers. A particular impact on the degree of degradation of the quality of electricity are non-linear receivers, on the one hand high-power appliances (mining and metallurgical), on the other thousands of low-power mass use devices, e.g. energy-efficient lighting, computers, impulse chargers). Non-linear receivers are complex technological devices generating a continuous spectrum of current harmonics causing distortion, voltage fluctuations and generating disturbances in the band of conducted radio interference. On the other hand, recent advances in power electronics introduce broadly understood improvement in the quality of electricity.

Energy quality refers to the standard supply voltage parameters that characterise the level of a specific disorder which causes a change in the ideal voltage waveform. Acceptable values of quality parameters are specified in PN-EN 50160 [5]. The study was conducted in the laboratory of the Institute of Electrical Engineering and Electrotechnology and completed in two stages. In the first part, tests were made using a power quality analyser, the second part focused on measuring interference. The study involved 3 laptops (Dell Vostro 3360, Dell Vostro 3560, HP Pavilion dv6899ew with the original power supply), energy saving lamps (N3PY15 15W, N3PY11 11W, CE3UT4 18W, Econ Twister 8W), ULTRAGLISS FV4350 iron and two CPU Desktops (with power adapters ATX-230P and FEEL LC-8300ATN). Such an inspection list of receivers is a good representation of a typical range of devices in a typical household.

Most of the parameters to be evaluated are recorded as samples averaged during certain periods of time. Legislation [5] contains the maximum permissible deviations of specified parameters from the nominal values of each parameter on a weekly basis.

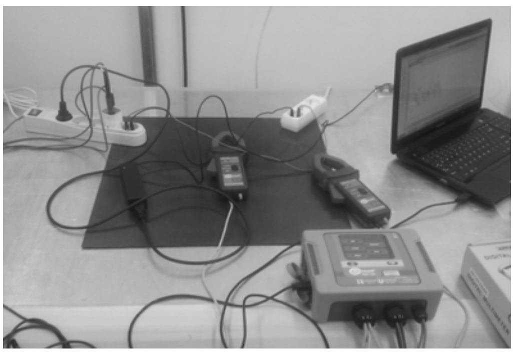

Fig.1. Photos from the study of power quality, a view of the PQM700 meter

For the measurement, recording and analysis of the supply power parameters the PQM-700 Sonel meter was used. The analyser fully complies with the requirements of the class S PN-EN 61000-4-30:2011. The meter is equipped with wires attached directly to the power supplying the voltage measurement point. For measuring currents a measurement clamp is used (in the tests it was type F5 current clamp). The analyser used allows to measure and record the parameters of supply voltage, effective current, current and voltage peak coefficients, mains frequency, power and energy, current and voltage component harmonics (up to the 40th), the current and voltage *THD* harmonic distortion coefficient, power factor, cos*φ*, tg*φ*. The full capabilities of the device are achieved with the "SONEL Analysis" dedicated software. The stand was assembled according to the scheme set out in Figure 2.

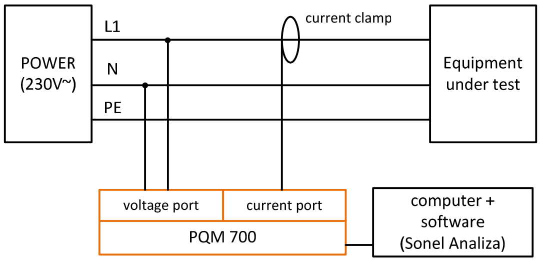

Fig.2. Block diagram for the measurement of power parameters

The following figures present screenshots of the Sonel Analysis program (Fig. 3, 4, 5) with values for selected receivers tested.

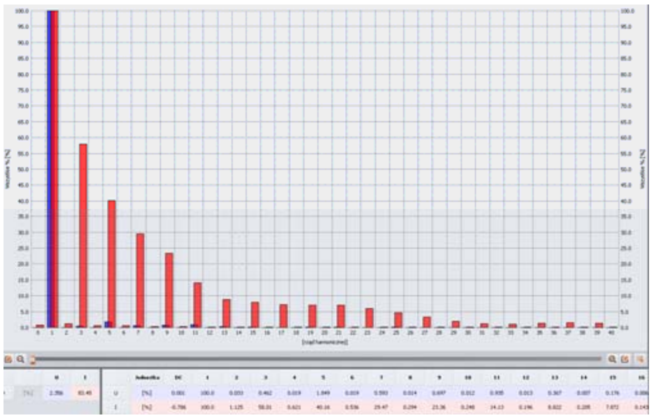

Fig.3. List of the power parameters of the PQM-700 analyser – the spectrum of current harmonics of 6 energy saving lamps working together

Fig.4. Voltage (blue/sinusoidal) and current (red/distorted signal) waveforms of 6 energy-saving bulbs studied together

Fig.5. Voltage (blue/ sinusoidal) and current (red/ distorted signal) waveforms of two desktops working together

Deformations of the voltage and current curve (higher harmonics) are among the adverse events occurring in electricity grids. They can cause disturbances in the network, usually involving the increase of power losses in the individual components, such as transformers or lines powering the recipients. Additional power losses directly affect the temperature rise in line wires, particularly the neutral line, which is important in the case of cable lines, resulting in faster aging of the insulation. Additional power dissipation in the windings of the transformers can in some cases lead to their overload or even damage. Receivers particularly sensitive to the presence of higher harmonics in voltage are also engines and capacitors. Higher harmonics give rise to parasitic moments in the motor windings, which may hinder its start-up and proper operation. Deformation of currents and voltages also interfere with the work of gauging instruments or security measures [10].

According to the Regulation of the Minister of Economy of 4 May 2007 on detailed conditions for the operation of the power system [3] (Dz. U. [Journal of Laws of the Republic of Poland] of 29 May 2007.), entities included in the connection group I-II are granted acceptable relative voltage values expressed as a percentage of the fundamental harmonic. The total harmonic distortion as a percentage ($THDU_{\%}$) calculated for harmonics up to the order of 40 cannot be greater than 8%. Because the cause of supply voltage distortions are deformed currents, in order to prevent the passage of current higher harmonics to the power system and reduce the risk of fire active higher harmonic filters are used.

Currents consumed by devices containing electronic converters are heavily distorted (have a significant THD ratio and strongly deformed course), depend on the type of rectifier used at the input, the way they are controlled and the type of converter load (its power, character, load variability in time). The current massive use of power converters in IT, electronic, industrial and lighting devices is causing distortion of the current drawn by such equipment, thus being a source of higher harmonics [8,10]. The results obtained indicate that the greatest deformation of the course is to be found in the circuit powering energy-saving light bulbs and desktop computers, and the lowest – an iron and laptop adapters.

The second stage of research were tests conducted to define the value of the conducted emission generated by consumer devices. This also requires appropriate methods and measuring devices.

The test stand is based on the Rohde&Schwarz ESCI3 measuring receiver and the NNB 41C Line Impedance Stabilisation Network. The system was powered by a dedicated circuit grid, according to the diagram in Figure 6. The disorder measurement boiled down to determining the UE voltage present at the input of the interference meter. Measurement stands for analysis of conducted interference do not require location in a shielded room, but in order to stabilise the measurement conditions a reference plane is used which is a 2x2 m grounded metal plate. In the measurements an interference meter was used (also known as a measuring receiver complying with the requirements) and an additional device, an artificial network, which represents a defined load impedance for the disturbance value. The artificial network stabilises the conditions of voltage disruption measurements in the power supply circuit of the object tested.

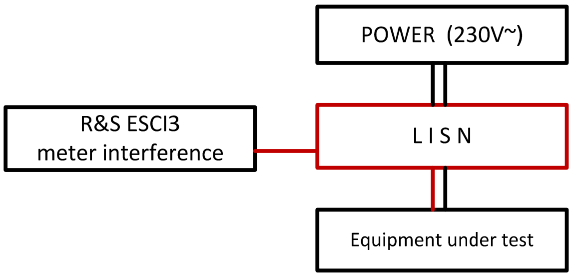

Fig.6. The block system for measuring disorders with line impedance stabilization network

The whole test was managed automatically by the EMC32 program. The sweeping settings were automatic, in accordance with CISPR16, sampling time was 7 ms, the measurement was carried out in the 150 kHz – 30 MHz band and included disorder detection at L1 and N. The analysis involved the same equipment as in the case studies of power quality: iron, laptops, CPUs of desktop computers and a set of energy-saving bulbs. According to the procedure for determining the compatibility of electrical devices/installations the disturbance values measured are compared with respective limits.

The test results obtained were compared with the limits. Selected values are collected on charts compiled in Figures 7 and 8. All the values presented were measured with an average value detector and were referred to the limiting average value. In the case of the desktop computer graph a linear axis was used in order to better illustrate the overrun.

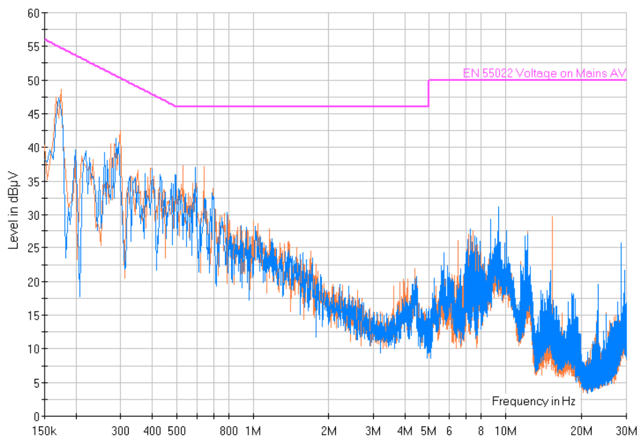

Fig.7. The measured values of conducted disturbances in the power supply circuit of 6 energy-saving lamps, range 150kHz-30MHz, AV detector, the orange line marks measurement in phase L1, the blue line – measurement in N, limit according to EN55022

The measurements clearly identified the levels of conducted disturbances. Qualitatively disturbances in the phase and neutral wires are similar.

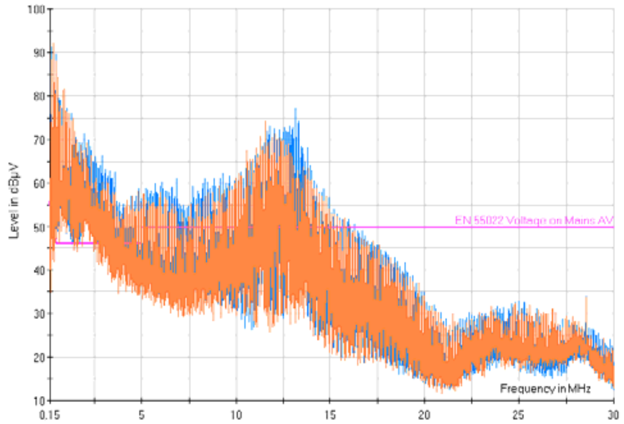

Fig.8. The measured values conducted disturbances in the power supply circuit of two desktop computers, 150kHz-30MHz, AV detector, the orange line marks measurement in phase L1, the blue line – measurement in N

In all devices manufactured today, emission levels have a good supply compatibility (iron, laptops, energy-saving light bulbs – Figure 7). Only desktop PCs over several years old have exceed acceptable levels – Figure 8.

Conclusions

In recent years there has been a continuous increase in the number of devices and systems susceptible to various types of electromagnetic disturbances, among which are the supply voltage distortion. This makes the issue of power quality and the installation of receivers the subject of active measures of a legislative and technical nature. In addition, the development of distributed systems using renewable energy sources with variable capacity, leads to a situation where both the energy source and the receivers are treated as nonlinear objects.

The presence of harmonics and disorders of higher frequencies is a potential problem for the operation of a supply network, as well as the correct operation of devices connected to the network – lack of electromagnetic compatibility may result in the danger of exploitation of other objects or systems.

It is thus important to work on the development of methods for location of sources of harmonic currents and voltages in the power system as well as methods of selecting the optimal compensation and filtration. Issues of power quality and reliability of power supply are addressed in a lot of scientific and technical publications [8,9,10,11], and a summary of the current state of knowledge in this field is a number of issued legal acts, defining, among others, permissible deviations from the nominal values describing electricity.

The measurements carried out by the author in an actual power network with attached to it selected devices permit to specify the parameters that characterise power quality, taking into account the EMC requirements.

On the energy market conducted disturbances as well as harmonics are bi-directional in nature. At the connection point for power reception the liability for distortions or disturbances may lie both with the energy supplier and the recipient. It is therefore particularly important that the equipment or installations put on the market were fully adapted to the applicable requirements defined by the directive on electromagnetic compatibility, and hence safe for the natural and working environment.

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