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Experimental setup to research power quality parameters in systems with LED light sources

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The article describes the design, construction and research capabilities the experimental setup for measure the parameters of power quality of load which is mapping the lighting installation of LED sources. The standing has been build in order to study the disruption comes from the electroluminescent lighting mostly. The construction of standing also allows conducting the experimental research with the equipment which could improve the quality of electricity.

In the paper quoted the concept of the power quality according to suggestion of Advisory Committee on Electromagnetic Compatibility (ACEC). Also has been presented the causes and consequences of exceeding the permissible values of power quality parameters. In the publication has been described the procedure for preparing and setting up the experimental setup for measuring the higher harmonics of current flowing through the tested LED lighting.

KEYWORDS: electroluminescent diode, experimental setup, LED source, higher harmonics, lighting installation, power quality, THD ratio

1. Introduction

The history of electric power supply dates back to the second half of the 19th century. In 1866, Werner von Siemens invented a self–excited direct current generator and it has become possible to produce electric energy on a massive scale ever since. However, power networks allowing transfer of electric energy to numerous recipients at long distances were non–existent at that time. Only in 1882 in New York the world's first system being a prototype of the contemporary power network was put into use. It was Thomas Edison who first came up with this idea. He constructed an overhead line ca. 50 km long which powered to 59 households in Lower Manhattan. The line had a 110 V DC. Yet due to considerable voltage drops and losses, this sort of network did not prove itself.

A significant step forward in the development of power network was using the idea of alternating current. The first overhead line of alternating current was constructed in Frankfurt am Main for the purposes of the International Electro–technical Exhibition in 1891. The network was 175 km long and operated with

25 kV alternating voltage, whereas its efficiency was close to 75%. The network in Frankfurt was designed by Michal Doliwo–Dobrowolski from Poland [10].

In the 20th century power networks were growing rapidly. A number of electric power stations came into existence. Enterprises which required electric energy supply for proper operation of their equipment emerged. Urban and rural electrification process started back then. All these actions resulted in construction of new as well as development and modernization of the existing power networks. It was a challenge, as it was necessary to design a network which provided electric energy of similar parameters to all recipients, regardless of their location in relation to the power plant, and assured failure–free operation of electrical equipment [1].

2. Quality of electrical energy

2.1. Definition of energy quality

At the end of the 20th century when fast development of electrical engineering and electronics was observed and the number of equipment sensitive to power supply parameters considerably increased, the requirements of recipients of electrical energy changed as well. Uninterrupted supplies of electrical energy of relevant parameters were expected, which would allow correct and failure–free operation of electrical equipment. The operators of the power grid had to meet these requirements. However, it was difficult to find which energy parameters of the network influence power supply quality and have the biggest impact on the connected load. Hence, there were a lot of definitions of electrical energy and no clear and official definition has been given until today.

Today it is found that the most accurate definition of the quality of electrical energy is "a set of parameters describing properties of the process of electrical energy supply to the user under standard operating conditions, determining power supply continuity (long and short power failures) and characterizing the supply voltage (value, frequency, shape of the time function, unbalance)". The above–mentioned definition has been proposed by members of ACEC (Advisory Committee on Electromagnetic Compatibility), however, it is still not officially binding, as most of organizations all over the world do not agree with this formula in its full wording [3].

In spite of lack of the official definition, already in the year 1994 the parameters defining the electrical energy quality have been set. These include [4]:

- effective value of the supply voltage,
- supply signal frequency,
- sudden changes of voltage,
- transient overvoltages,
- short–time overvoltages,

- voltage sags,
- random and planned power stoppages,
- voltage unbalance,
- voltage harmonics,
- voltage interharmonics,
- voltage signals for transmitting the information.

2.2. Reasons and consequences of power quality deterioration

Deterioration of parameters in the power grid may come from many sources. Disruptions may be caused by [2, 5]:

a) receivers connected to the grid (which happens most frequently):
   - great number of non–linear receivers (computers, RTV equipment);
   - switched power supply, unswitched power supply and DC–DC units;
   - energy–saving lighting (LEDs, luminous tubes);
   - high–power non–linear receivers (e.g. pressure welding machines);
   - equipment which does not meet the EMC requirements;
b) equipment used for generation and distribution of electrical energy:
   - switching overvoltages;
   - atmospheric discharge overvoltages;
   - failures of power supply grid components;
   - lack of synchronization of generators in the electric power stations;
   - sudden changes in power grid load;
c) poor condition of the connection system in the buildings:
   - the system executed without conformity with legal regulations;
   - incorrectly selected section of circuits or partially burnt circuits;
   - use of defective switches or fuses;
   - breakdowns and current leaks resulting from incorrect insulation;
   - improperly executed joints, loose or overheated, etc.

The occurrence of the above–mentioned phenomena is connected with certain consequences which may be immediately noticeable or may be latent and invisible, while their unfavourable results may be observed after a longer time. The immediate consequences include, among other things: flickering of the light, damages or improper operation of equipment, mechanical vibrations and increased noise during operation, increased temperature of operation and more frequent operation of thermal safeguards as well as drop in power, efficiency and effectiveness of electrical equipment and machines [5].

The latent consequences will manifest themselves as the progressing degradation of power supply circuits and equipment along with their insulation as a result of a long–term overheating of these elements or increase in reactive power intake, which in the long–term results in economic loses connected with more frequent activation of electrical equipment, machines and systems. Additional costs of electrical energy fees are also incurred. Maintaining high efficiency of operation is connected with higher power intake. Penalties for exceeding the contractual reactive power intake may also occur [2].

2.3. Work on improving the power quality

Today the actions aiming at improving the energy quality are connected with a certain paradox – receivers requiring power supply of high quality are introduced, but, at the same time, these receivers have an unfavourable impact on the quality of electrical energy. Even certain simulations were conducted according to which it is estimated that merely in the European Union over EUR 50 billion per year is spent in connection with poor quality of electrical energy. As indicated by the authors of the report, these problems do not concern only industry. Even such businesses as banks, hospitals, hotels or telecommunication industry have a big impact on the quality of electrical energy [6].

In each of the above–mentioned activities, the same group of electrical equipment that deteriorates electrical energy quality can be found. The equipment includes lighting systems in which modern lamps containing semi–conductor sources of LED light are used. Their controllers very strongly distort the supply signal, introducing higher current and voltage harmonics.

In connection with such a great number of receivers disturbing the operation of the power grid many scientific and research centres all over the world constantly work on improving the energy quality. Research is conducted in two directions: on one hand, it is attempted to make the power grid resistant to disruption, on the other hand, the solutions allowing to compensate the disturbances caused by the recipients still at the level of internal power supply systems are sought [7].

3. Design and construction of the experimental setup for testing the operation states of LED light sources

The electric circuit diagram of the experimental setup (Fig. 2) allowing to measure the disruptions coming from the lighting systems based on the LED sources was designed in the AutoCad Electrical environment. Several blocks can be distinguished in the diagram [8]:

- power supply with the main switch,
- terminal board for connecting the measurement devices,
- control of the lighting system circuits with transmitters,
- control of switching on individual circuits of the system,
- connections of next circuits of the rooms lighting.

On the basis of the electrical circuit design, the station was executed and fixed to the mobile support frame. The exemplary plan of the building on which the elements of the lighting system, that is switches and symbolic sources of light were arranged, was placed on the front plate (Fig. 1a). In the bottom part of the front several clamps enabling connection of measurement devices and equipment for improving the quality of electrical energy were included (Fig. 1b). In the back part of the test station a socket was placed for connection of the power supply and terminals for connecting the load (LED light source) being the equivalent of lighting in individual rooms of the building (Fig. 1c).

Also five panels with LED lamps were executed. Two of them allow to test 30 sources of light on the GU10 handle, the other two have the space for 20 lamps with E27 handle, while 20 LEDs on E14 thread can be screwed into the last panel. Each panel has 10 switches allowing for stepwise regulation of the power of the installed lighting every 10%. There is one switch per each two (E14 and E27 thread) or three (GU10 handles) light sources. Diagrams of electric circuits of the panels were presented in Fig. 2a and Fig. 2b [8].

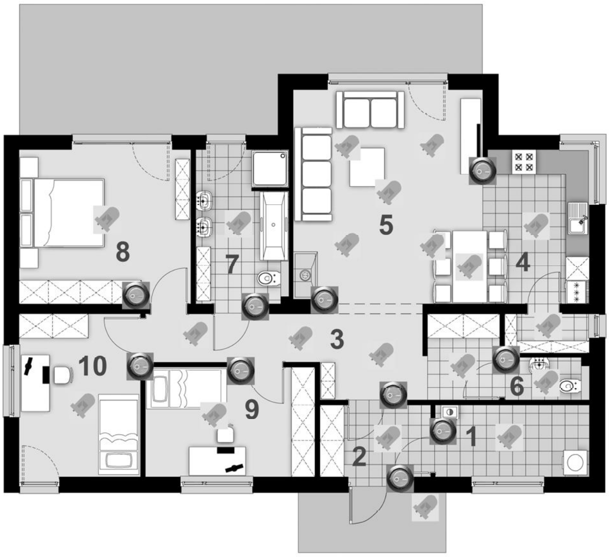
The test station enables simultaneous tests of even ten lighting circuits. The panels allow to select any number (power) of light sources, making it possible to create various configurations of connections. Also, the use of electric sockets of E types as load connections allows to connect to the station any LED lighting operating at alternating voltage of 230 V (50 Hz), with the plugs of CEE 7/7 (or 7/16, 7/17 type) used in Poland. Its offers even greater possibilities for tests [9].

4. Operation rules of the experimental setup for testing the operation states of LED light sources

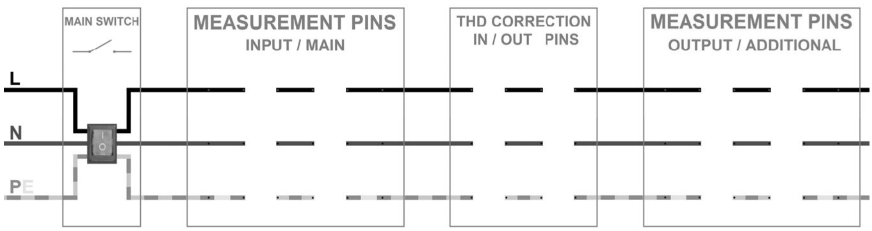
Before starting the measurements the stand shall be configured. At the beginning the power should be lead. Then the load consisting of the tested LED lamps shall be connected. If these sources have E14, E27 or GU10 bases they shall be installed in the panels constructed especially for this purpose. After selecting the circuit for simulation (e.g. the lighting system in the living room) the panel is connected to the relevant joint (No. “5”). Then the measurement devices shall be connected to the proper connection clamps located in the front–bottom part of the stand. The unused measurement pins shall be connected in such a way as to create the closed path for current flow to tested light sources. After that works the power supply can be switched on using the main switch.

The last step before conducting measurements is switching on the selected circuit of the lighting system using the appropriate switch located on the visualization of the housing premises found on the front plate of the test station (e.g. the switch at the entrance to the living room). This enables the current flow through the transmitter’s coil, which, in turn, allows to close two contacts of the transmitter.

a)



b)



c)

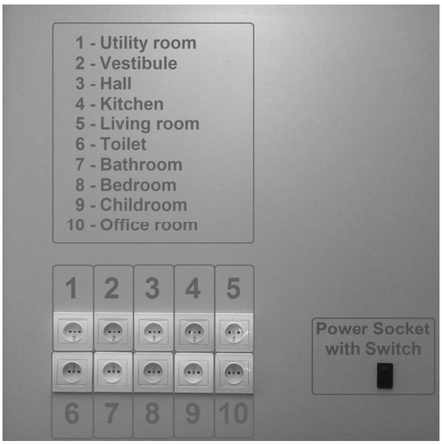
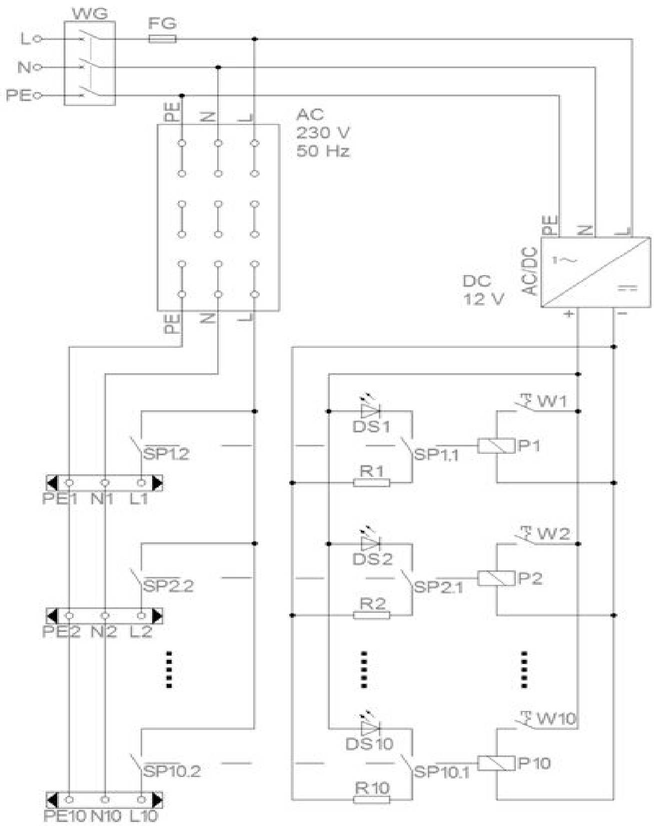


Fig. 1. Elements of experimental setup: a) projection of building with light sources and switches (front side), b) measure connectors (bottom of the front side), c) extension connectors to board with LED lamp and power socket (rear side)

a)



b)

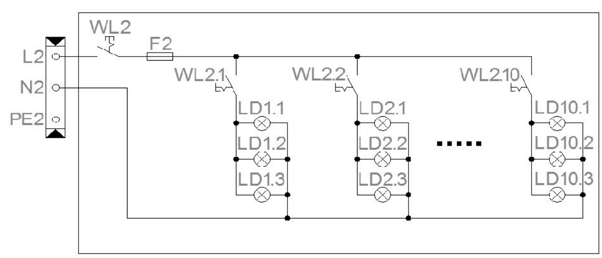


Fig. 2. Electrical circuit diagram of the experimental setup: a) main unit, b) board with LED lamps

The first one closes the circuit which signals switching on of the lighting in a given room. At the same time, the second contact of the transmitter closes the main circuit resulting in power supply of the panel with the tested LED lamps. Then it is possible to start measuring quality parameters of electrical energy of the lighting system with the LED sources.

It is possible to adjust the load (number of lamps) using the switches located on the panels. At the same time, you can connect next circuits with the LED sources to the station and test the correlation between them as well as the parameters of energy quality in total for a few source types. Fig. 3 presents the experimental setup with the connected measurement devices during tests. The exemplary global measurements of power, current intensity and higher harmonics of the current for two circuits with LED lamps – living room and bathroom – were conducted. The light sources were installed in the panels located behind the test station. On Fig. 4 are present 3 from the 5 constructed panels [8, 9].

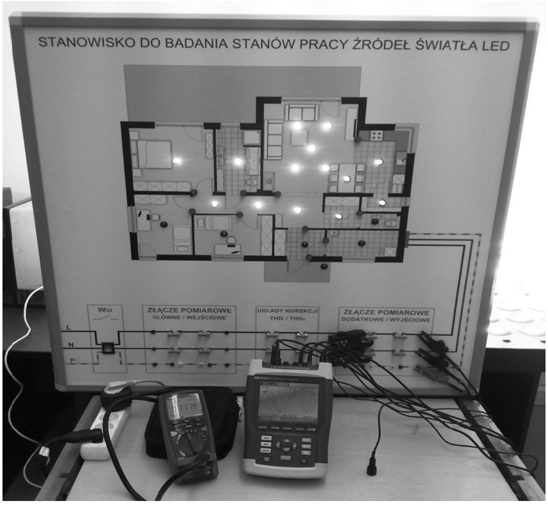


Fig. 3. The experimental setup with connected measuring devices ready to perform the measurements

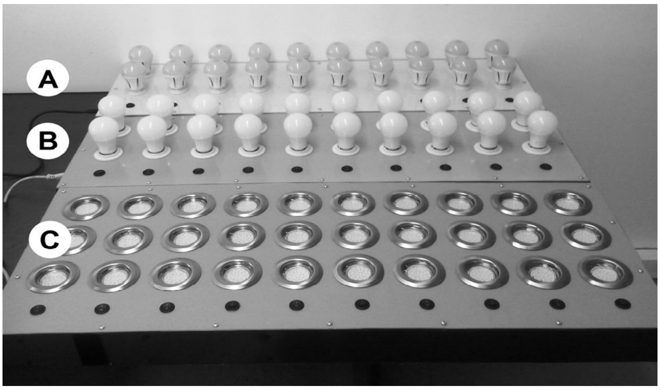


Fig. 4. The three additional panels (boards) with mounted LED lamps: A) E14 base, B) E27 base, C) GU10 base

5. Research possibilities of the experimental setup for testing the operation states of LED light sources

The experimental setup for testing of operation states of the LED light sources was constructed in such a way as to enable measuring all electric parameters including parameters of the quality of electrical energy. The limitations only result from availability of the relevant measurement devices. With two digital multimeters, e.g. UNI–T UT71E and energy quality analyser e.g. FLUKE 434/PWR, you can measure up to 13 parameters: effective voltage, effective current, frequency, active power, reactive power, apparent power, power factor, total harmonic distortion of voltage and current, higher harmonics of voltage and current, interharmonics of voltage and current. Also, connection of measuring instruments to the PC allows for online registration and archiving of many measurements in a short time.It is possible to conduct a many measurement series to confirm the results and eliminate measurement errors.

The properly distributed measuring junctions at the experimental setup enable to introduce additional equipment for improvement of energy quality parameters to the circuit of the lighting system. Duplication of the measuring junctions give the possibility to conduct measurements at the same time on input and output of the higher harmonics correction device (Fig. 1b) [9].

6. Summary

The current technological progress, especially in the field of electrical equipment, has definitely a negative impact on keeping high level of energy quality in the power grids. Tests in this scope are conducted in many scientific centres. This is demonstrated by a great number of published studies, expert opinions or reports discussing energy quality [3, 4, 6, 7]. One can notice that the subject is still relevant. The solutions improving operation of the power grids shall still be sought. Tests conducted at the constructed station will contribute to that to a certain degree.

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