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Evaluation of the Impact of Specialized Biotechnological Laboratory Equipment in the Context of Higher Harmonics Generation

Abstract. *Specialized laboratory equipment, often uses power converters, which are the source of higer harmonics. These devices, depending on their functions, are composed of several additional elements (such as UV light, a heater).They also enable the speed adjustment .Mostly, these are low-power devices used in laboratories, scientific research units engaged in research and teaching.*

Streszczenie. *Specjalizowane urządzenia laboratoryjne, bardzo często wykorzystują przekształtniki energoelektroniczne, które są źródłem wyższych harmonicznych. Urządzenia te w zależności od swoich funkcji składają się z kilku dodatkowych elementów (np. lampa UV, grzałka), a także umożliwiają regulację prędkości. Najczęściej są to urządzenia małej mocy i stosowane są w laboratoriach badawczo-naukowych jednostek prowadzących badania naukowe i zajęcia dydaktyczne. (**Specjalizowane wyposażenie laboratorium biotechnologicznego z uwzględnieniem wyższych harmonicznych**)*

Słowa kluczowe: odkształcenia napięcia i prądu, wyższe harmoniczne, specjalizowane urządzenia laboratoryjne
Keywords: Voltage and Current Distortion, Higher Harmonics, specialized laboratory equipment

Introduction

Commonly used non-linear devices are the sources of higher harmonics, which increase the apparent power of devices and power losses in the power lines, but information about their impact on the supply network of specialized laboratory equipment can rarely be found in the literature. Higher harmonics also cause electromagnetic interference and sometimes strong resonance phenomena. In this way, they adversely affect the operation of security systems, automation and control systems, robot and communication, as well as other receivers of electricity. The results are economic losses caused by decrease in reliability and service life of these devices. Correct operation of electrical equipment is possible under the right conditions, in terms of the guarantee by the manufacturer of the device. They mainly concern the environment in which the device will operate, the quality of the supply line and the level of electromagnetic interference affecting the inverter. At the same time power electronic equipment should not be cumbersome to operate, and in particular it should not adversely affect the operation of other devices - in particular electrical equipment [2,3,4].

We can talk about the power quality standard, if in the place of observation (measurement) the voltage curve is exactly sinusoidal, the nominal frequency and its rms value is equal to the rated voltage. In practice, this ideal situation is not available and necessarily power quality is considered acceptable if the deviation from the standard of the quality is not adverse for the selected device (do not interfere with its operation). A growing number of different sets connected to the power system affects the intensity of the interaction between them, which in the end leads to a deterioration of their electrical conditions of operation. This interaction is mediated by mutual galvanic coupling from the supply network and the electromagnetic waves emitted by the receivers (electromagnetic interference – EMI) [5,6,7,8,9]. Converters adversely affect a supply line and are a source of electromagnetic interference. They are susceptible to interference reaching from the power supply and from electromagnetic fields generated in their main circuits, and generated by other adjacent equipment.

Electric operating conditions of power electronic devices are determined primarily by parameters of AC or DC supply line, the intensity of different types of electromagnetic interference and type of load. Hence the need to take into account the nature of the operation of specialized laboratory equipment, which is often found in the same room in a laboratory, and is supplied from the same power network. It should be noted that operating time of specialized equipment varies and depends on whether the measurement tests are done and how many instruments work at the same time. The target scientific functions are different, depending on the purpose of the study and the type of a device, but nevertheless all the devices are supplied from the same power network [10,11,12,13,14,15,16,20]. Therefore, knowledge of the characteristics of these devices is important.

The paper shows the results of measurement tests of the impact on a supply network of two devices - a laminar chamber and a thermal cycler. The structure and appropriate control of the device are important to reduce or minimize the negative effects of this type of equipment to power supply from the point of view of a power network.
The research was engaged in the laboratory of the Institute of Applied Biotechnology and Basic Sciences University of Rzeszow in Werynia.

Characteristics of the laboratory equipment

The thermal cycler is an electric device which controls the temperature. The samples placed in the device are alternately heated and cooled in accordance with the requirements of the methodology used in the PCR (Polymerase Chain Reaction) e.g. to reproductive DNA chains in the laboratory conditions. PCR has many applications - for example, in the study of genes (gene cloning, characterization of gene expression), in the identification of missing persons, in establishing paternity and paleontology. The thermal cycler, which is a basic device used in molecular biology laboratories, offers fast temperature control.

Two models of thermal cycler were tested – Mastercycler Personal and Mastercycler Gradient. The state of start-up and increase of the temperature as well as a condition of stable operation of equipment were measured.

A chamber with laminar air flow is electrical equipment used in molecular biology laboratories in order to protect the sample from contamination. Through the use of biosafety cabinets sterile working area in the laboratory is obtained.

Phot.1. The measurement tests of Mastercycler Gradient termal cycler

They are used during sterile work in microbiology and in vitro culture of plant and animal cells. They protect the environment from contamination during the work with the use of hazardous materials (eg, infectious bacteria and viruses, GMOs). The cells in the culture require providing an environment simulating the natural one. One of the factors is a sterile environment for growth. It should provide adequate temperature and humidity. The laminar chamber provides cells with the sterile environment while working with them. The air in the chamber is passed through a special filter, which provides the purification of bacterial or fungal spores which cause the infection arising [1].

The various states of a Thermo Scientific laminar chamber were studied. This is a chamber of class II safety designed to work with infectious material (tissue, blood, viruses, bacteria) and pure material requiring protection (cell culture), with a capacity of 0.8 kW. It has two filters - the main and in the air outlet. The efficiency of the filter is 99.999% for particles of 0,3μm. It has the microprocessor control which allows controlling both the flow of air in the working chamber and the use of filters.The laminar chamber is supplied from single-phase. At first the study included the start-up state - the preparation of chamber to work. Then the operating conditions when using the blower and the UV lamp were studied.

Results of laboratory tests

In order to analyze the work of selected biomedical laboratory equipment for selected indicators and power quality parameters, selected quantities were measured in the laboratory of the Centre of Applied Biotechnology and Basic Sciences, where the equipment is used for scientific research. As the measure of evaluation of harmonic distortion *HD* (Individual Harmonic Distortion) and Total Harmonic Distortion *THD* [17,18, 19] were assumed.

Total Harmonic Distortion factor *THD* (voltage or current) is defined as the ratio of the rms value calculated excluding the first harmonic (it is assumed that the constant is zero) to the value of the first harmonic effective:

$$THD = \frac{\sqrt{\sum_{k=2}^{\infty} X_{(k)}^2}}{X_{(1)}} \tag{1}$$

where *X(k)* was determined as the rms value of the *k*-th harmonic of the signal *x(t).*

The contribution of each harmonic in the final shape is defined as an individual signal distortion factor *HD* (current or voltage) and is calculated from the formula:

$$HD_k = \frac{X_{(k)}}{X_{(1)}} \cdot 100\ \% \tag{2}$$

where: $X_{(k)}$ – rms value of the harmonic of k order, $k = 2, 3, 4, \ldots, n$; n – number of harmonic taken into account in analysis, in accordance with PN-EN 50160 n=40; $X_{(1)}$ – rms value of fundamental harmonic.

The paper also contains the rms value of current waveforms under varying operating conditions, to characterize the changes in power consumption.

Figures 1-2 show the waveforms of rms values of current of thermal cycler in various stages of work, from preparation to work with the heater on and off, as well as start-up to a normal, stable operation.

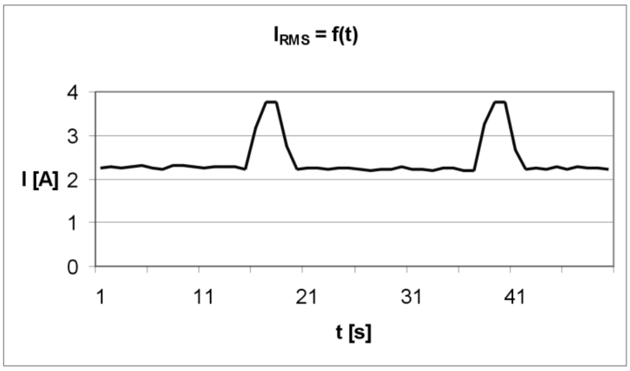

Fig.1. The course of thermocycler rms current value for 50 seconds, switching on and off the heater (Mastercykler Personal)

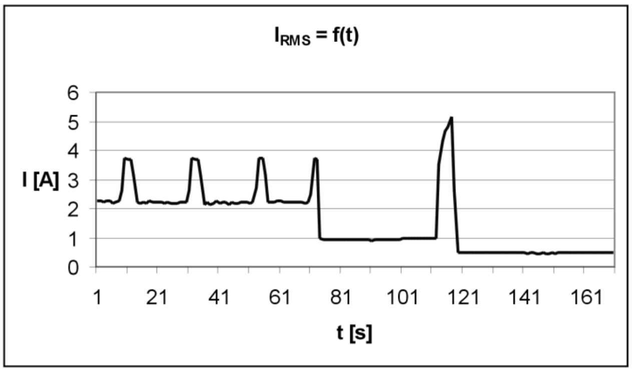

Fig.2. The course of thermocycler rms current value within 170 seconds, the preparatory work from the start to a stable job

Waveforms of rms current does not allow for an evaluation of the distortion, so in the following section there is provided the analysis of the components of distortion. Considerations concern a variety of operating conditions of biomedical laboratory devices.

The individual factor of supply current distortion of a thermocycler (Mastercykler Gradient type) shown in Figure 3 for the standby operating status, clearly shows the large distortion of the supply current, and the value of the *THD* of current is 75.6% (the value of the voltage *THD* was 1.74%)

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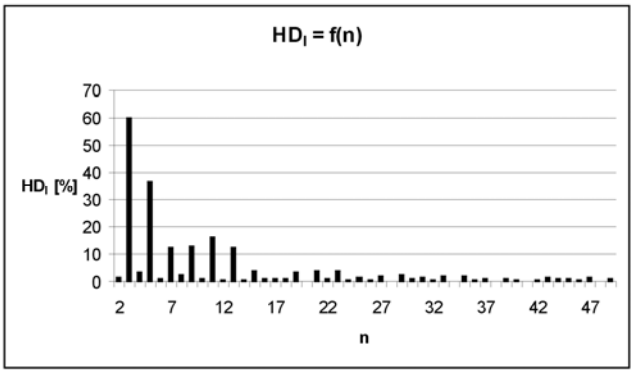

Fig.3. Individual Harmonic Distortion of supply current of Mastercykler Gradient (standby status)

Large values of *THD* factor indicate high amplitudes of higher harmonics (mainly harmonic: the third, fifth, eleventh, thirteenth, etc.).

Figures 4-5 contain an individual supply current distortion factor for the thermal cycler at 58 °C (operation with heater turned on) and steady state ("Second" heat cycle (high time constant)).

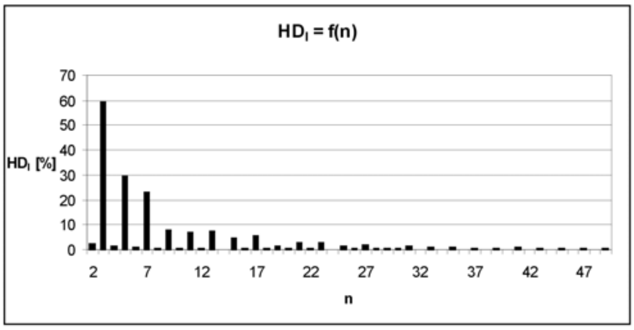

Fig.4. Individual Harmonic Distortion of supply current of Mastercykler Gradient (standby status) (operation with the heater turned on - the temperature 58 °C)

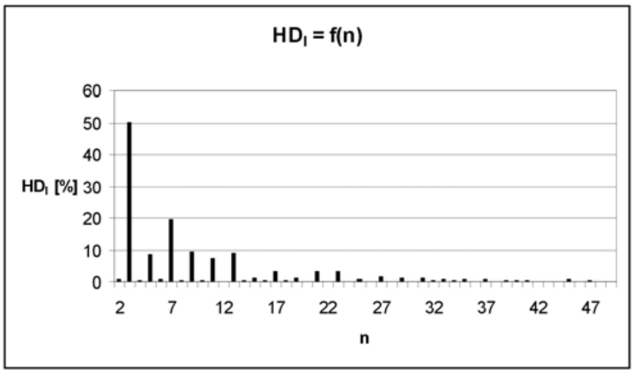

Fig.5. Individual Harmonic Distortion of supply current of Mastercykler Gradient ("Second" heat cycle)

Visible differences on the graph of *HD* factor in fig. 4 and fig. 5 show different ways of control dependent on a thermocycler mode of operation, in particular, the setting and a way of temperature control inside the thermal cycler.*THD* current factor for the case of a heater turn on is 71,9% (*THD* of voltage is 1,88%), and for the case with second cycle of heating is 57,1%. It is related to the long duration of the temperature increase inside the thermal cycler (voltage *THD* 1.81%).

Figures 4-5 show high values of *HD* factor for individual harmonics, which demonstrate the diverse nature of the work, depending on the selected mode of operation.

For the laminar chamber, measurements for different states of work were performed - from the state of preparation to work, the inclusion of fan until the UV lamp is turned on.

Figures 6-8 show graphs of individual factor distortion *HD* for the laminar chamber. In Figure 6 for the standby status, current *THD* value in this case was 30.5% (*THD* for a supply voltage was 1.7%), for the case of Figure 7 *THD* current value was 18.9% (a value of voltage *THD* was 1.79%). It was the case with the fan turned on inside the laminar flow. In fig. 8 a change of *HD* factor value for individual harmonics is shown, for the UV lamp turn on inside the laminar chamber, and at the time of measurement value of current *THD* was equal to 24.8% (a value of voltage *THD* was 1.71%).

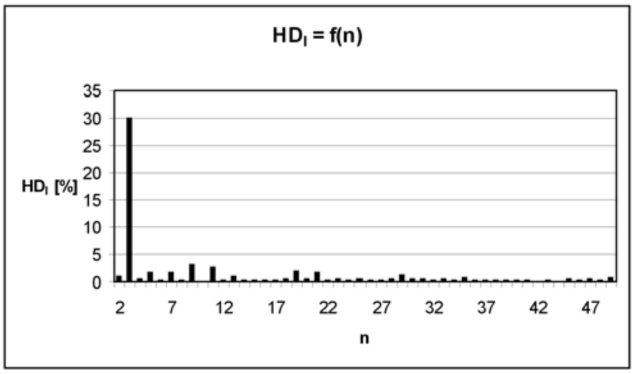

Fig.6. Individual Harmonic Distortion of supply current of laminar chamber (standby status)

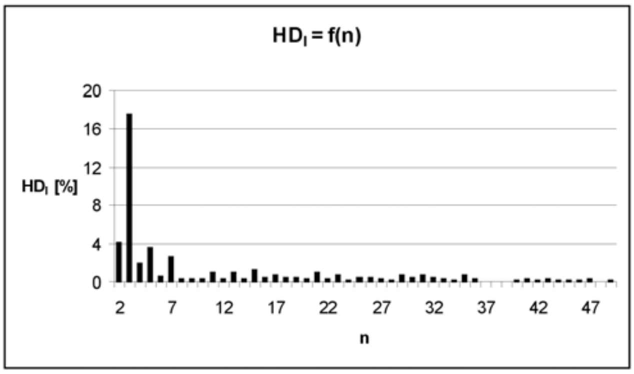

Fig.7. Individual Harmonic Distortion of supply current of laminar chamber (operation with the fun turn on)

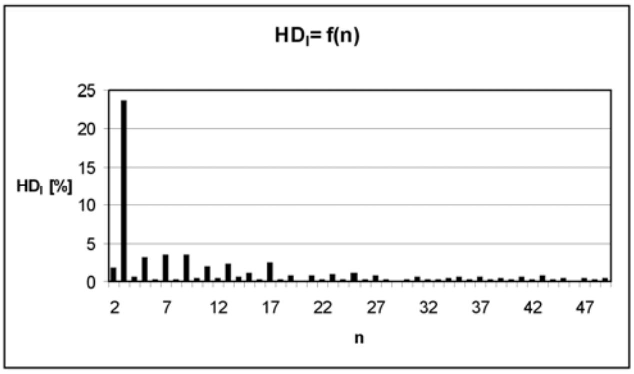

Fig.8. Individual Harmonic Distortion of supply current of laminar chamber (operation with the UV lamp turn on)

Figure 9 shows a course of rms current value of laminar chamber during 170 seconds of work.

The first seconds are a start-up, pumping the air out of the chamber, and in the 148 second the UV lamp was turned on.

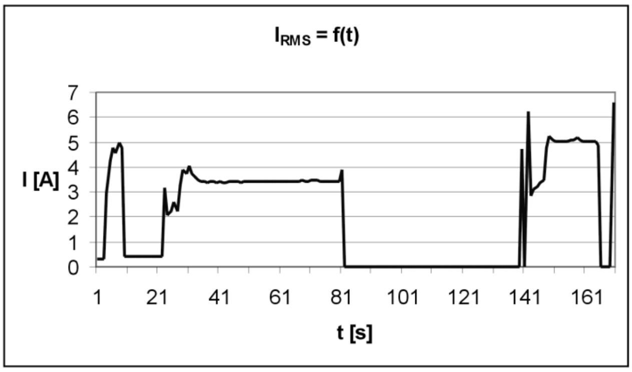

Fig.9. The course of rms current of laminar chamber within 170 seconds, the first seconds are the cycle of preparatory work, in the 148 second, the inclusion of a UV lamp

Summary

Based on experimental studies using a Yokogawa WT 500 power meter (which allows the simultaneous measurement of voltage, current, power, and total harmonic distortion), the evaluation of harmonics generated to the power supply by two selected specialized laboratory items of equipment can be carried out.

The first analyzed device – the thermocycler - depending on the nature of the work (as start-up, the status of temperature control (switching on and off the heater) is an example of the so-called. "restless" receiver. The next analyzed device - a laminar chamber is the same type of a device (the change of current distortion is visible in changes of the operating mode (turn on or off the fan, turn on or off the UV lamp, keeping a constant temperature level. Both devices placed in laboratories of Centre of Applied Biotechnology and Basic Sciences are used every day for about 10 hours.

Therefore, they are a source of harmonics generated to the supply network. At the same time, the same network supplies highly specialized unique devices for molecular analysis, for example Real Time PCR, sequencer, spectrophotometers and chromatographs.

Research related to the evaluation of specialized biomedical laboratory influence on supply network continues. The results of these studies will be presented in subsequent papers. This work aims to assess the level of current distortion generated in the whole research biotechnology laboratory and development of the manner of their limitations.

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