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Research of the impact of selected equipment used in laboratory at the Institute of Applied Biotechnology and Basic Science for the supply line

***Abstract**. The article presents selected results of measurements of the impact on the supply line for the equipment used in the laboratory at the Institute of Applied Biotechnology and Basic Science, University of Rzeszow. There are presented parameters of measuring instrument used to record voltage and current waveforms of input individual systems. Definitions of individual harmonic factor HD and total harmonic factor THD have been shown.*

Streszczenie.** W artykule zostały zaprezentowane wybrane wyniki pomiarów oddziaływania na linię zasilającą urządzeń laboratoryjnych stosowanych w Instytucie Biotechnologii Uniwersytetu Rzeszowskiego. Zaprezentowano parametry przyrządu pomiarowego, który posłużył do rejestracji przebiegów napięć i prądów wejściowych poszczególnych układów. Przedstawiono definicje indywidualnego współczynnika zawartości harmonicznych HD oraz współczynnika zawartości wszystkich harmonicznych THD.* ***(Badanie oddziaływania na linię zasilającą wybranych urządzeń laboratoryjnych stosowanych w Instytucie Biotechnologii Stosowanej i Nauk Podstawowych Uniwersytetu Rzeszowskiego)

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Słowa kluczowe: jakość energii, harmoniczne, odkształcenia napięć i prądów

Introduction

Most of laboratory equipment has advanced features that allow us to adjust the required parameters such as e.g. rotational speed, temperature setting and stabilization, software control of working time, etc. This is possible through the use of advanced electronics equipment and motor drives. These systems are equipped with power-electronic AC adapters. Unfortunately, despite the functionality which AC adapters offer, power supplies are a source of significant harmonic distortion of currents charged from the power supply line. It is associated with a strong non-linearity of semiconductor devices used there. Electricity is a product and as such should be of adequate quality. The distortion degree of currents charged from the power supply line, (as one of many factors) significantly affects the quality of electricity, which has become one of the most important issues of the modern economy. Harmonic currents can cause overloading of neutral conductors in single phase installations, as well as interfere with the security and other devices which directly affects the safety and reliability of use [1, 3 ,7, 9, 10, 11].

Harmonics in the supply line can be reduced through the use of appropriate solutions at the design stage installation, using devices with limited propagation of harmonic, or by filtration using passive or active filters.

Symbols and definitions of the measured values

The following values used for measuring certain parameters or indicators of distorted waveforms are defined as follows [3, 7, 8, 11]:

- RMS voltage

$$U_{RMS} = \sqrt{AVG(u[n])^2}\ , \tag{1}$$

- RMS current

$$I_{RMS} = \sqrt{AVG(i[n])^2}\ , \tag{2}$$

where, $u[n]$ and $i[n]$ - are instantaneous values of the voltage and the current, n - is a given sample period depending on the settings synchronization of the measuring instrument.

- The average value of a discrete periodic voltage waveform

$$AVG = \frac{1}{N_0}\sum_{n_0}^{n_0+(N_0-1)} u[n]\ , \tag{3}$$

- The average value of a discrete periodic current waveform

$$AVG = \frac{1}{N_0}\sum_{n_0}^{n_0+(N_0-1)} i[n]\ . \tag{4}$$

The various RMS values of voltage and currents harmonics are calculated according to the formula:

$$U_{RMS}(k) = \sqrt{(U_R(k)^2 + U_I(k)^2}\ , \tag{5}$$

$$I_{RMS}(k) = \sqrt{(I_R(k)^2 + I_I(k)^2}\ , \tag{6}$$

where, *k* - is the number of subsequent harmonic, *R*-represents the real part and *I*-an imaginary part.

The parameters which determine the impact of harmonics on the voltage and current waveforms are:

- individual voltage distortion factor HD_U and current HD_I defined as the ratio of the *k*-th harmonic to the fundamental harmonic

$$HD_U = \frac{U_{RMS(k)}}{U_{RMS(1)}}\ , \tag{7}$$

$$HD_I = \frac{I_{RMS(k)}}{I_{RMS(1)}}\ , \tag{8}$$

The coefficients of equations (7) and (8) allow for the most uniquely assessment of the impact of the *k*-th harmonic for voltage and current waveforms. Factor, which in turn takes into account the contents of all the harmonics in the distorted voltage and current waveforms, is a voltage and current total harmonics distortion THD_U and THD_I.

(9) $$THD_U = \frac{\sqrt{\sum_{k=2}^{max} U_{RMS(k)}}}{U_{RMS(1)}},$$

(10) $$THD_I = \frac{\sqrt{\sum_{k=2}^{max} I_{RMS(k)}}}{I_{RMS(1)}},$$

The measuring system

The power meter Yokogawa WT500 allows monitoring of parameters needed to determine the quality of electric power. The meter has a 3-phase input (measurement channels) allowing for simultaneous recording of current and voltage three-phase supply line. Voltage range of measurement varies from 7,5 V to 1000 V, while the current range varies from 250 mA to 40 A. Measurement accuracy depends on the frequency of the measured waveform. For frequencies less than 1 kHz accuracy is not worse than 0,1% of reading value and 0,2% of the range. Presented accuracy is guaranteed in the selected range. Measurements can be made for the fundamental frequency of input waveform equal 100 kHz. The accuracy of calculation of the parameter based on the waveforms of measured values is 0,001% of reading. A standard feature of the meter WT500 is harmonic measurement function, which allows to measure waveforms with frequency of the fundamental wave in the range 10 Hz to 1,2 kHz. The results of the analysis can be presented starting from zero sequence and ending with the 100-th harmonic. Harmonics can be displayed in numerical or graphical form. All measured data can be stored in internal memory, USB disk or can be uploaded to computer. WT500 meter also allows to work in the oscilloscope mode, allowing the registration of voltage and current waveforms [11].

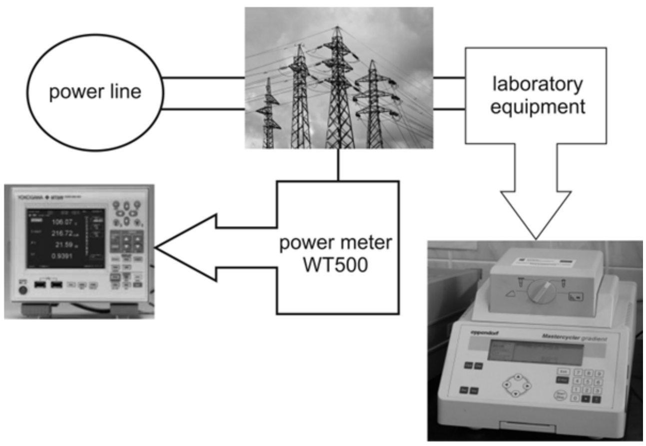


Fig. 1. A block diagram of the measuring system

The results of measurement and analysis

Measurements of voltages and currents were made using a Yokogawa WT500 power meter. The device can operate in two modes of measurements i.e.: measuring the value, among others RMS values in the fundamental mode and in harmonic measurement mode. Research were conducted by thermal cycler, laminar chamber, centrifuge, ultracentrifuge and electrophoresis system in the laboratory and Applied Biotechnology and Basic Science Centre of University of Rzeszow [2, 4, 5, 6,9, 10, 11]. All loads were powered from a single phase line. Power range of the appliances housed in with the range of tens of W - in the case of electrophoresis-set to almost 3,5 kW in the case of ultracentrifuge. Depending on the device type and the degree of its nominal power, currents charged from the supply line was characterized by varying degrees of deformation of sinusoidal waveforms. Thermocycler machine is equipped with a heating block with holes for tubes, that carry the reaction. The device provides block temperature changes in accordance with a predefined program. Heating blocks, by changing its temperature as quickly as possible, are provided with a Peltier module. It is a semiconductor element constructed of two thin plates, between which there are arranged in series bismuth telluride semiconductors doped with antimony and selenium. The use of semiconductor deforms supply current waveform of the device even though the input voltage is sinusoidal [2]. Recorded voltage and current waveforms at different operating conditions are presented in figures 2 and 3. Figure 2 shows the thermocycler current waveform without heating function switch on. Current total harmonic distortion factor in this state is THD_I = 48.6%.

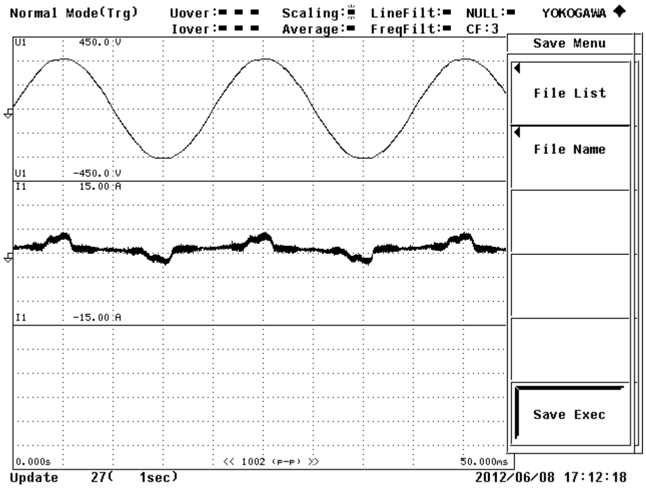


Fig. 2. Thermocycler working without heating, the voltage U1 and power line current I1 waveforms

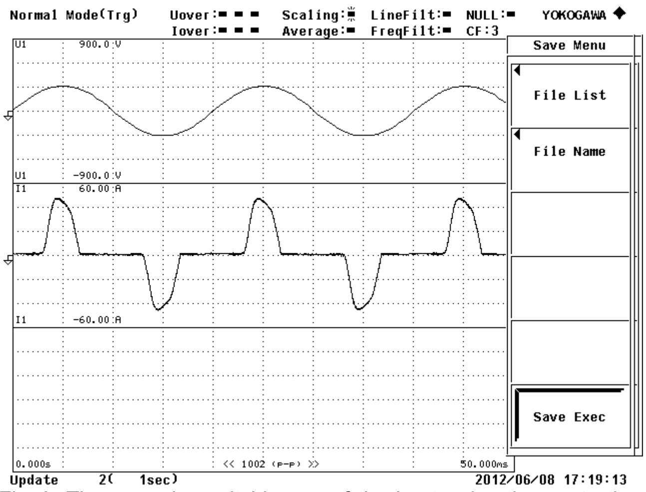


Fig. 3. Thermocycler switching on of the heater, heating up to the set temperature 46°C, the voltage U1 and power line current I1 waveforms

The current waveform in Figure 3 were recorded for the case of operation of the heater turned on after temperature of 46°C was set. In this operation mode the harmonic content is equal THD_I=61.2%.

Laminar chamber is a device in which there is a sterile laminar air flow. The chamber is also equipped with a UV lamp, which is incorporated prior to operation, to further sterilize the chamber operating space. Sterile air escaping from the chamber creates a barrier to the penetration into the spores of bacteria or fungal spores that are constantly floating in the air outside the chamber. This allows the maintenance of sterile conditions required for operation [4].

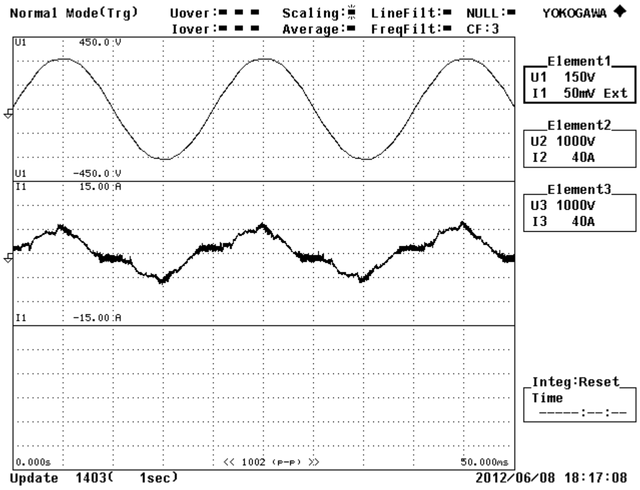


Fig. 4. The laminar chamber standby mode, the voltage U1 and power line current I1 waveforms

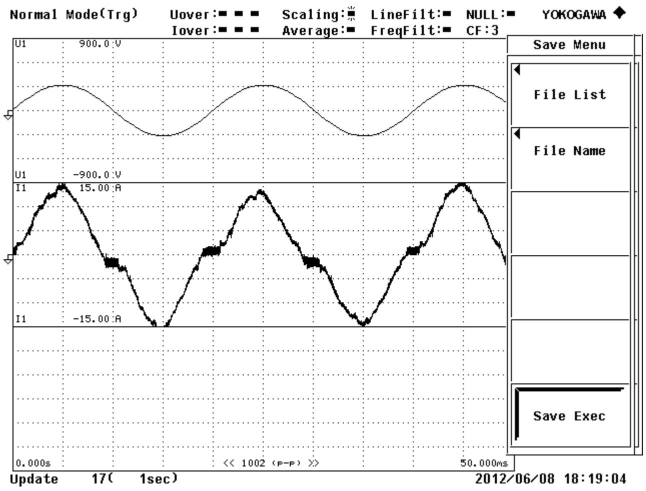


Fig. 5. The laminar chamber operating mode with active blower, the voltage U1 and power line current I1 waveforms

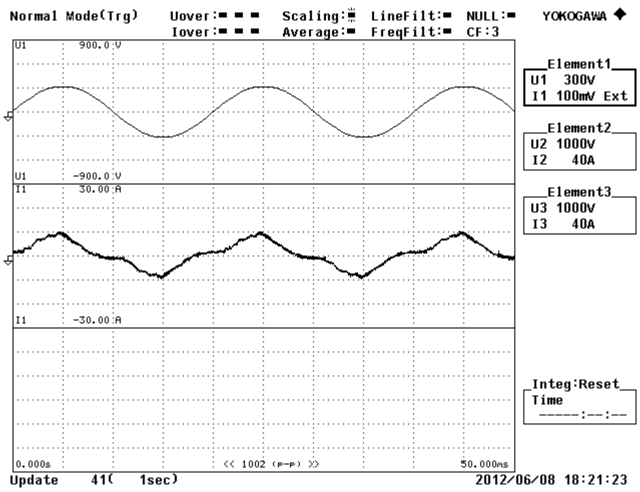
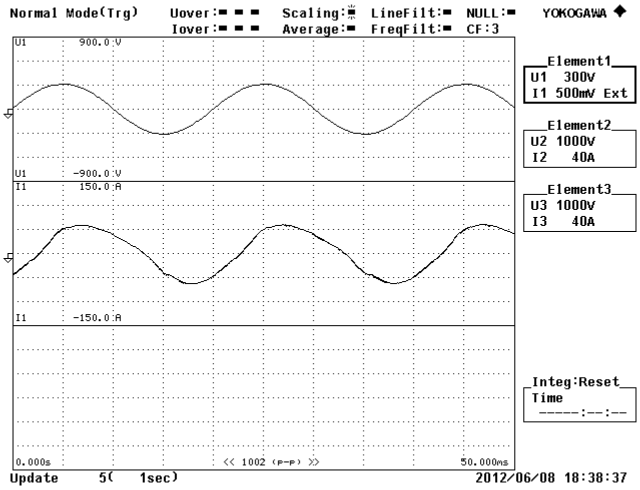


Fig. 6. The laminar chamber operating mode with active UV lamp, the voltage U1 and power line current I1 waveforms



Rys. 7. The centrifuge standby mode, cooling temperature 4°C, the voltage U1 and power line current I1 waveforms

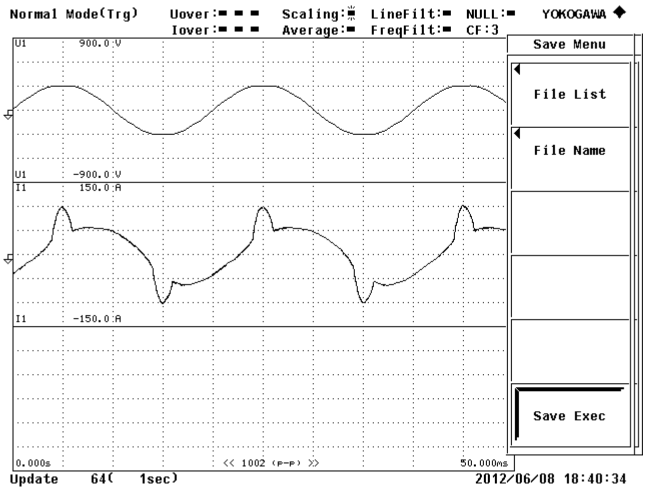


Fig. 8. The centrifuge standby mode, cooling temperature 4^0C, operation with rate 12000 rpm, the voltage U1 and power line current I1 waveforms

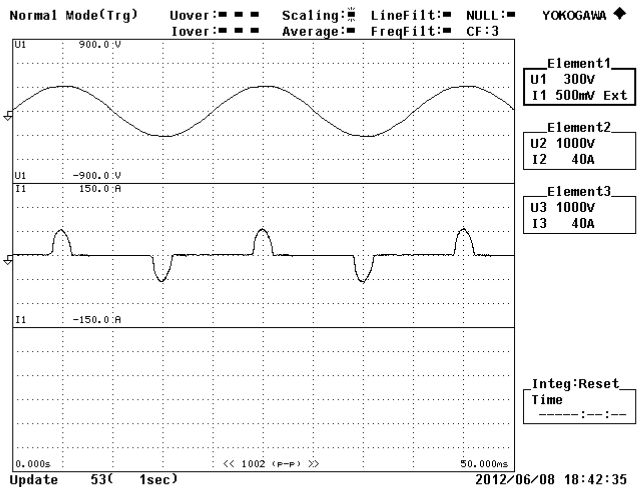


Fig. 9. The centrifuge temperature set at 4^0C, operation with rate 12000 rpm, the voltage U1 and power line current I1 waveforms

The tested laminar chamber is equipped with a brushless motor blower with an electronic commutator, which is responsible for the deformation of the power line current (Fig. 5). The electronics which control of laminar chamber operation and also UV lamp is require power electronics converter, which is a source of distortion (Fig. 4, Fig.6). The THD_I distortion level for each current waveforms shown in figures 4-6 is successively: THD_I= 29,1%, THD_I= 19,6%, THD_I= 26,1%.

Another device for which there were recorded voltage and current waveforms were centrifuge fractionation, which has the task of separating suspensions and emulsions by imparting them in rapid rotation, which significantly increases the rate of sedimentation.

Centrifuges - used mainly in laboratories, do not exceed a speed of 20000 rpm. To drive the centrifuge, like the laminar chamber blower is used brushless electronic commutator motor [4]. THD_I of current in figures 6-8 are as follows: THD_I= 9,92%, THD_I= 33,71%, THD_I= 82,10%.

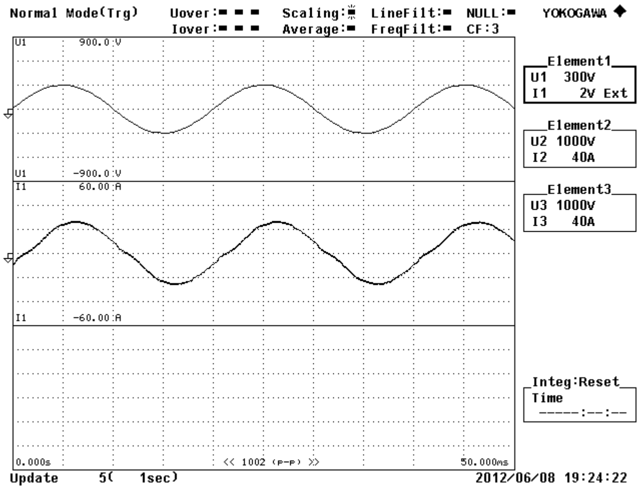


Fig. 10. Ultracentrifuge, steady state operation, power set at level of 3.5 kW, operation with rate 40000 rpm, the voltage U1 and power line current I1 waveforms

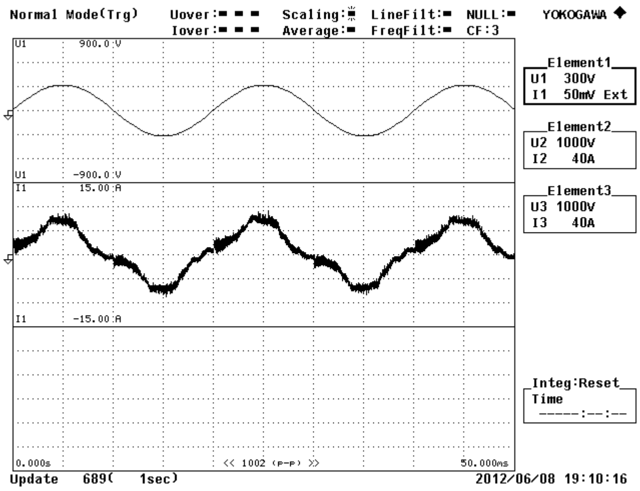


Fig. 11. Device for electrophoresis, work with the maximum power (200V, 300mA), the voltage U1 and power line current I1 waveforms

Analyzing the waveforms of the figures 7-9 it can be concluded that the most unfavorable *THD* obtained for operation with the determined temperature and constant rotational speed. This is due to the fact that in this state only brushless motor driving the centrifuge is working. The tested device has been working with a maximum speed of 40,000 rpm and the input power of 3,5 kW. The current waveform for the ultracentrifuge only marginally differs from the sine wave and the current total harmonic distortion is THD_I=4,74%.

The final testing of equipment was electrophoresis system. Electrophoresis is the electrokinetic phenomena, where under the influence of an applied electric field macromolecules move endowed with an unbalanced electrical charge. The device worked with the power of 60 W. Total harmonic distortion THD_I=23,18%.

Summary

There was tested laboratory equipment working in the laboratories of Center of Applied Biotechnology and Basic Science University of Rzeszow. Selected systems has been studied for different variants of the load. From the analysis of the presented results it can be concluded that the devices that have the most negative impact on the operation the power line are thermocycler (fig. 3.) and centrifuge (Fig. 9.), which is confirmed by registered current waveforms and values of *THD* factor. A significant increase in *THD* appears to be the work of these devices in terms of nominal fan of thermocycler and centrifuge speed. The largest in terms of power equipment in the examined group systems, may adversely affect the operation of other systems.

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