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An Analysis of Transient States in the Power Supply System of a Selected Industrial Robot

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Abstract

Industrial robots are controlled by dedicated controllers powered by a single-phase or three-phase power supply system. The main power parameters characterizing the power supply system of these robots are: nominal supply voltage (1-phase: 100–120 V, 200–240 V or 3-phase 200–575 V AC), frequency of the supply voltage (50 Hz or 60 Hz), the nominal power consumed by industrial robot. The dynamics of power consumption in the power supply system of the controlled robot can be studied by recording instantaneous values of voltages and currents in each phase of the power grid. In this article, results are presented for the measurements of mentioned instantaneous values for a chosen single-phase powered robot, taken by specialized recorder. The measurements obtained from the recorder allows the calculation of numerically various energetic values in the power supply system of the robot: peak-peak values, RMS values, coefficients of deformation and values of harmonic amplitudes (FFT), values of active, reactive and apparent power and the power coefficient (tgϕ). The analysis of the waveforms of the instantaneous values of voltage and current allows the determination of the occurrence of transient states during the work of robot axes and characterizing its duration and the range of value changes. The analyses conducted can be used to properly design the protection systems of the power supply system, the eventual selection of filters for higher harmonics, and to determine the effective power consumption of the studied robot. The analyses of the transient states which occurred during the work of the studied robot in this publication significantly expand the knowledge about the dynamics of power consumption and its possible impact on the quality of electricity in the power supply grid.

Keywords:
industrial robot, power supply system, RMS values, instantaneous values, transient states

1. INTRODUCTION

Industrial robots are commonly using in many branches of industry, including increasingly in foundries. Opportunities to optimize the performance of various operations in technological processes are primarily an effect of robot parameters such as: number of axes, motion range or maximum payload at wrist. In this article results are shown of voltage and current transients analysis in a single-phase power supply system for the selected 6-axis industrial robot realizing a previously programmed work cycle. The discussion of the results obtained is also carried out.

2. METHODS AND MATERIALS

Electric devices such as industrial robots are characterized by power consumption dynamics in their power supply system, what also means the presence of transient states in the voltage and current waveforms. In this article results of measurements are shown, together with the analysis of these waveforms in the FANUC [1] LR Mate 200iD/4S industrial robot's power supply system [1]. The main operating parameters of this industrial robot are shown in Table 1.

Table 1
Main operating parameters of Fanuc LR Mate 200iD/4S industrial robot [2]

Parameter	Value	Unit
Controlled axes	6	–
Power supply voltage	230	V
Nominal power	500	W
Maximum payload at wrist	4	kg
Reach	550	mm
Repeatability	±0.01	mm
Mechanical weight	20	kg
Ambient temperature	0–45	°C
Motion range/ maximum speed for axis 1	340 / 460	° / $°\cdot s^{-1}$
Motion range/ maximum speed for axis 2	230 / 460	° / $°\cdot s^{-1}$
Motion range/ maximum speed for axis 3	402 / 520	° / $°\cdot s^{-1}$
Motion range/ maximum speed for axis 4	380 / 560	° / $°\cdot s^{-1}$
Motion range/ maximum speed for axis 5	240 / 560	° / $°\cdot s^{-1}$
Motion range/ maximum speed for axis 6	720 / 900	° / $°\cdot s^{-1}$

The work of the industrial robot under study is controlled by a Fanuc R30iB Mate Plus Controller, of which the most important parameters are listed in Table 2.

Table 2
Technical specification of the Fanuc R-30iB Mate Plus Controller [3]

Parameter	Value	Unit
Power supply voltage	200–230 ±10–15%	V
Frequency of voltage	50/60 ±1	Hz
Mechanical weight	40	kg
External memory	USB	
Fieldbus	PROFIBUS, PROFINET, CC-Link, EtherCAT, FL-net, EtherNet/IP	

The analysis of transient state is carried out in a measuring system according to the scheme shown in Figure 1.

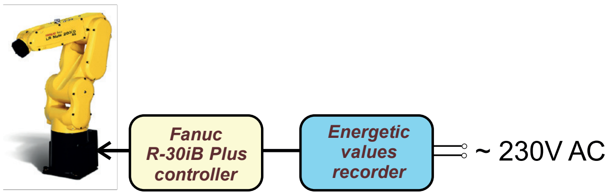

Fig. 1. Scheme of the recording of instantaneous voltage and current values in the power supply system for the selected robot

The measurements were made using recorders which realizes the measurements of instantaneous values of currents and voltages in three-phase systems via a microprocessor system with voltage transducers LV 25-600 [4] and current transducers LA 25-NP [5] from LEM Company [6]. These transducers allows up to 4000 instantaneous values of voltage and 4000 instantaneous values of current to be registered in every phase of the power supply system. The microprocessor system of the recorder realizes the transfer of results to the computer with the usage of a USB port. The view of the recorder is shown in Figure 2.

Fig. 2. View of instantaneous values recorder [7]

The industrial robot is powered by a single-phase power grid, thus the recorder recorded values in the single-phase system. The recorded values of instantaneous voltage and current in computer storage allows users to:

a) generate graphs with changes of instantaneous voltage and current values in the robot's power supply system in order to observe the dynamics of these changes,
b) calculate RMS voltage and current values through usage of chosen numerical methods,
c) calculate values of active, reactive and apparent power consumed during every cycle of work of the industrial robot,
d) calculate of tgϕ power coefficient,
e) determine the primal frequency values of voltage and current,
f) carry out analysis of voltage and current harmonics with application of Fast Fourier Analysis (FFT).

All of the above mentioned calculations can be performed by a special computer program, developed by Eugeniusz Ziółkowski.

In the further part of article, analysis of transient states occurring in the robot power supply system during its work will be presented based on points (a) and (b).

The research methodology was conducted as follows:

1. Writing a program which imitates the motion of different robot's axes, including the simultaneous motion of all axes during the preset work cycle.
2. Carrying out a series of simulations in the dedicated ROBOGUIDE environment and verification of these simulations according to the objective of a program working.
3. Implementation of the program created to the R-30iB Mate Plus real controller via external memory (USB) in a readable format and verification of the program correctness for real robot movements.
4. Connecting elements of the measurement system in accordance with the scheme from Figure 1.
5. Carrying out measurements of instantaneous values of voltage and current along with the save of measurement data in the computer storage. Real execution of the program was also recorded by a video camera.
6. Generating graphs of instantaneous voltage and current changes and carrying out analysis in terms of the presence of transient values.
7. Performing calculations of RMS values of voltage and current in order to conduct their further analysis.
8. Formulating conclusions, which are based on operations from points 1–7.

The program executing the work cycle of a robot was created with the consideration of the following assumptions:

a) a load of a total weight 3000 g was attached to the face plate on the wrist of the industrial robot;
b) the robot starts and ends its cycle of work in the main resting position named the HOME position, the coordinates of which are defined as axial (angular) position data in the memory of the robot controller; it was assumed that at the end of execution program, the robot returns to the HOME position with a set 50% maximum rotational speed for each working axis;
c) the robot in the main part of program which occurs when it is in the position after it has left the HOME position, performs a simultaneous rotation of all six robot axes from one saved axial position data to the second and performs it three times with a set 20% maximum rotational speed for every axis, as described in the technical specification of the current robot [2].

After carrying out computer simulations, programming of the robot, verification of the robot working correctness and its work compliance with primal assumptions proceeded with the realization of points 4–8 from the methodology described above.

3. RESULTS

While recording, the recorder captured about 48 seconds of work performed by an industrial robot, which means recording 192,000 instantaneous current values and 192,000 instantaneous voltage values. The programmed effective work on the robot arm lasted approximately 20 seconds but the measurements were realized in the earlier assumed time interval to save values of voltage and current in the robot power supply system before the start of its effective work and after finishing it when the robot achieved the HOME position and went into standby mode.

In the order to determine whether in waveform of voltage and current occurred the transient states (in the time intervals equal 100 ms) calculations of RMS voltage and current values were carried out (Fig. 3). From the analysis of these waveforms it can be deduced that the value of RMS voltage is characterized by a good stability in all examined time intervals (the value of this voltage is within the range 230.8–232.4 V). A high degree of dynamics in the changes in current values of RMS when performing individual movements of the robot arm can be observed. In the background of the graph with changes in RMS current values (Fig. 4) chosen moments of the robot working are shown and which are related to views of the robot's positions (Fig. 5) during the execution of the program.

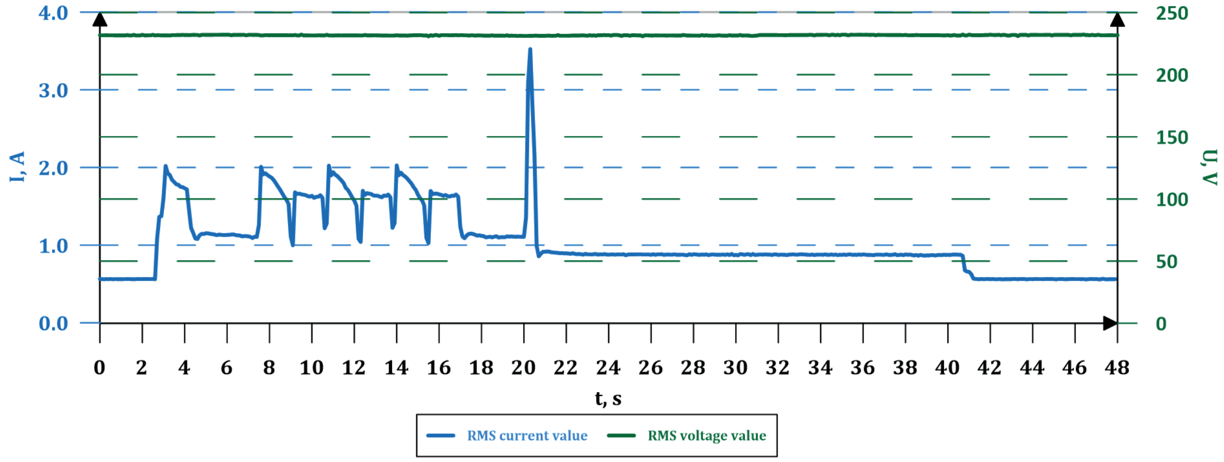

Fig. 3. Graph of changes in RMS voltage and current value in the power supply system of the examined robot

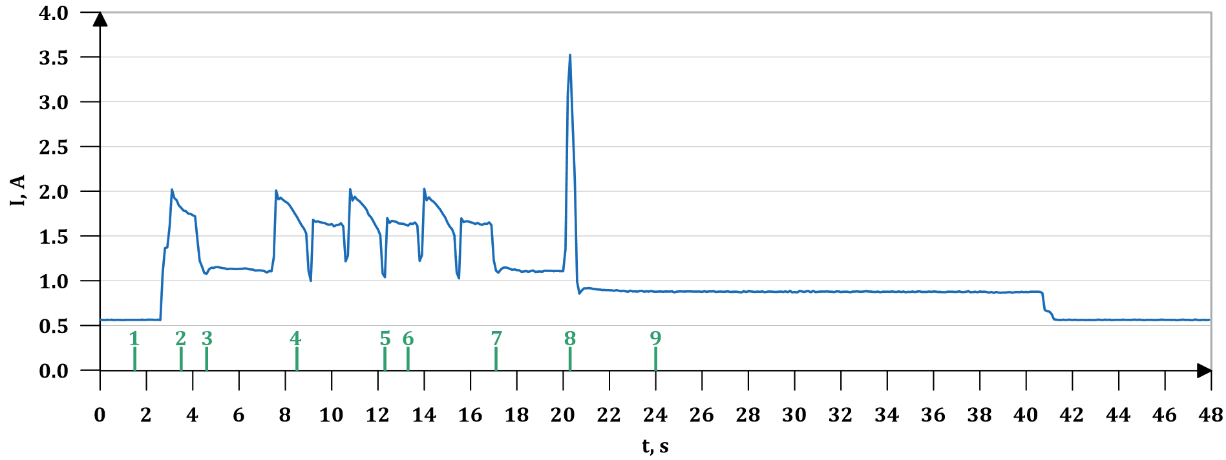

Fig. 4. Graph of changes in RMS current with additional points related to the views of the robot position during its motion (Fig. 5):
1 – t = 1.5 s; 2 – t = 3.5 s; 3 – t = 4.6 s; 4 – t = 8.5 s; 5 – t = 12.3 s; 6 – t = 13.3 s; 7 – t = 17.1 s; 8 – t = 20.3 s; 9 – t = 24.0 s

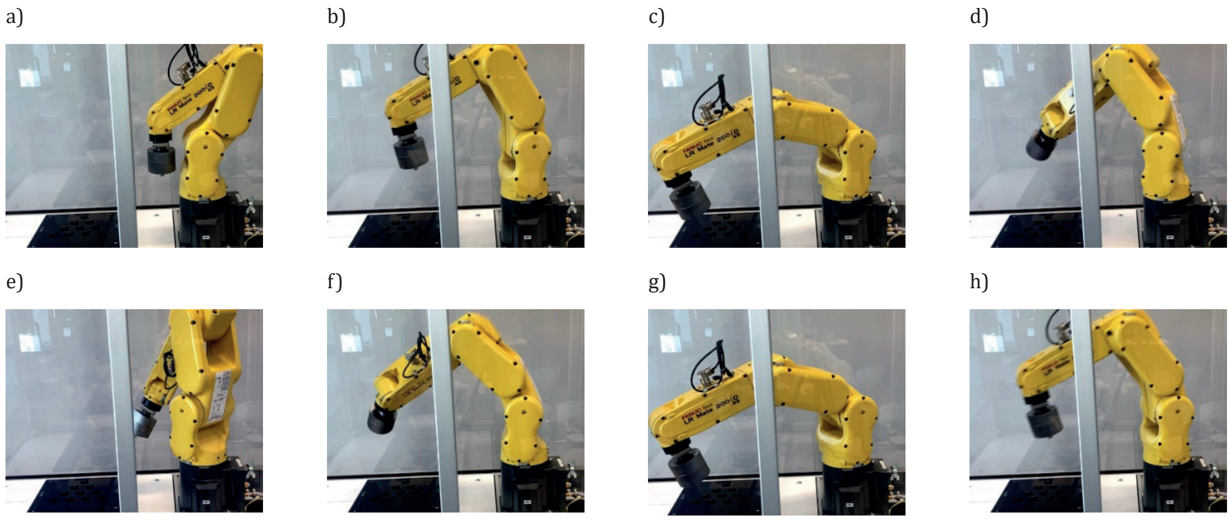

Fig. 5. View of robot positions at different moments of the program execution (see Fig. 4): a) HOME position – points 1,9; b) point 2; c) point 3; d) point 4; e) point 5; f) point 6; g) point 7; h) point 8

Analysis of transient states were carried out in the time intervals shown on the Figure 6.

Figure 7 presents a graph of changes of instantaneous voltage values in the robot's power supply system for time window **H**, which corresponds to return of robot arm to the main resting position (HOME).

It can be noted that even for significant changes of RMS current value in the moment when robot arm returns to the main resting position, deformation of sinusoidal shape of voltage is not observed. These deformations of voltage are also not found in other time intervals during robot work.

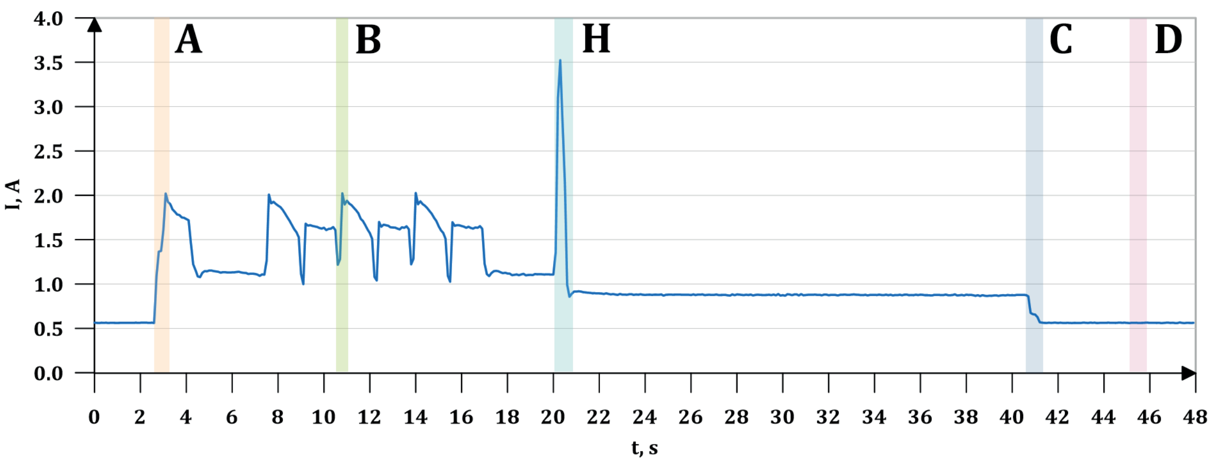

Fig. 6. Graph of changes in RMS current values in the power supply system of the studied robot realizing a test cycle of work

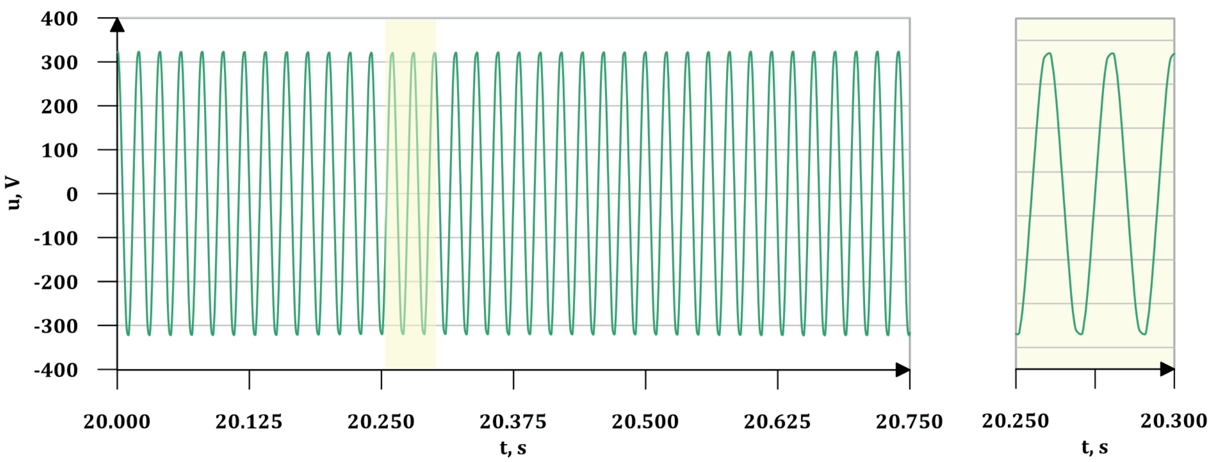

Fig. 7. Graph of instantaneous values of voltage for time window **H** with its zoomed part on the right side

The waveform of instantaneous current values in the robot power supply system in time window **H** is presented in Figure 8. Analysis of this graph gives information that during return of the robot arm to the resting position with set 50% rotational speed of maximum speed, the time of transient state has a value of about 500 ms. Additionally, the maximum peak-peak value of current is over three times higher than the peak-peak values before and after the occurrence of the transient state. The waveform of the current is significantly deformed from the shape of a sinusoid.

Figures 9–12 present the graphs of instantaneous current values for time windows: **A**, **B**, **C** and **D**.

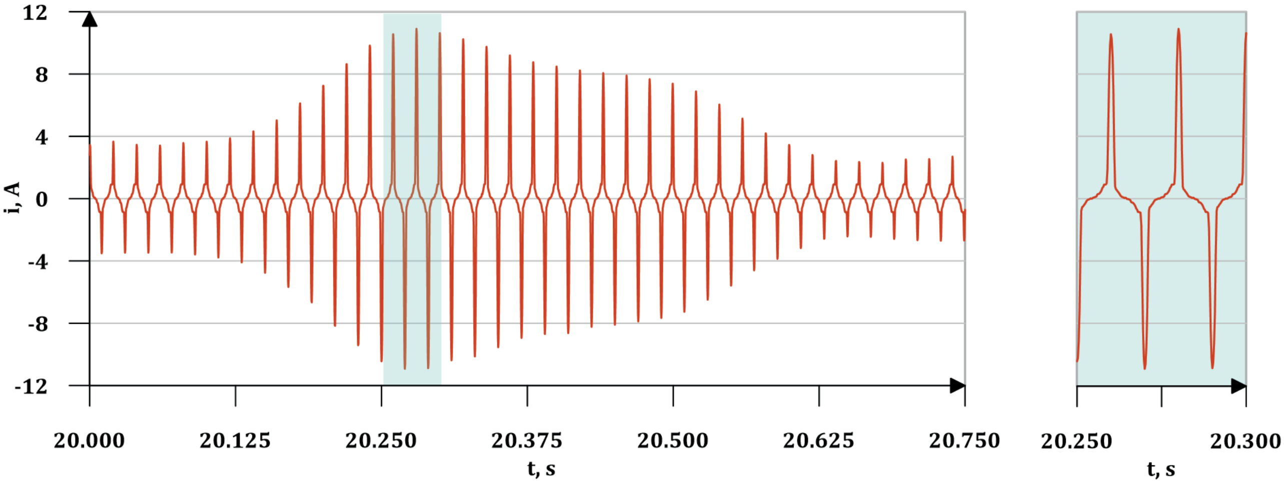

Fig. 8. Graph of instantaneous values of current for time window **H** with its zoomed part on the right side

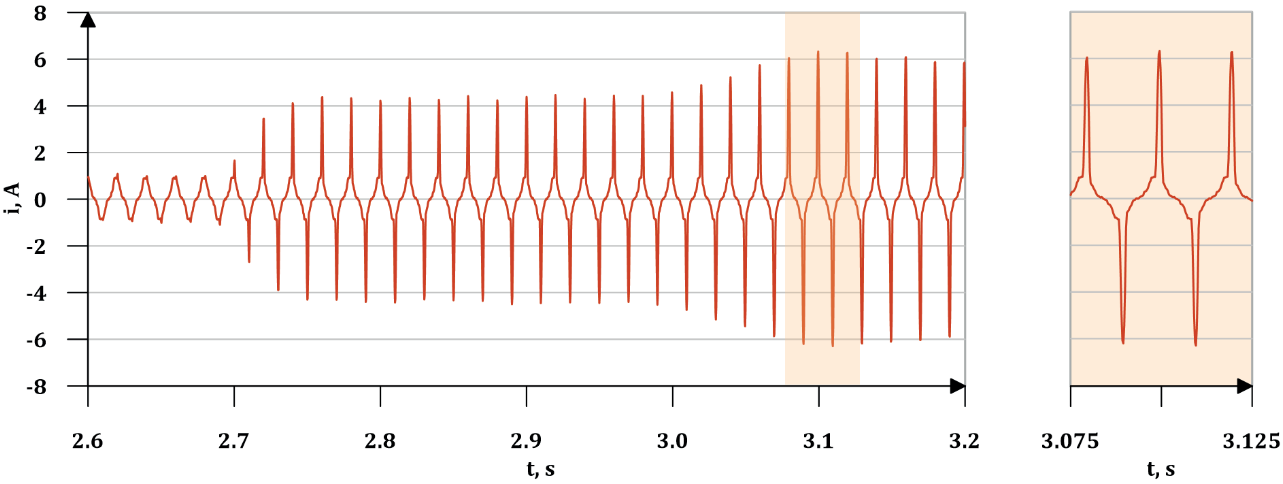

Fig. 9. Graph of instantaneous values of current for time window **A** with its zoomed part on the right side

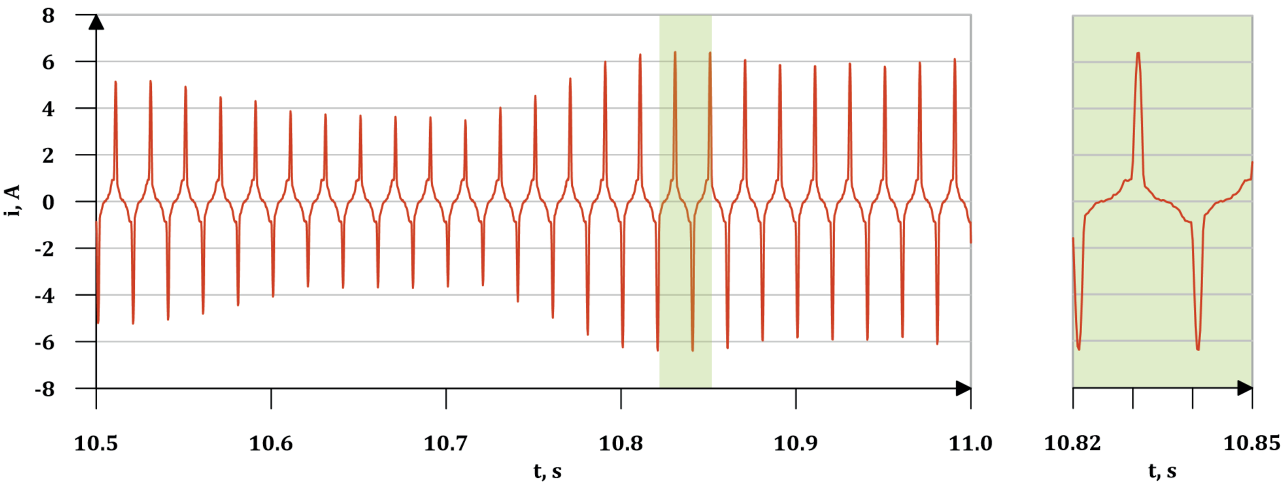

Fig. 10. Graph of instantaneous values of current for time window **B** with its zoomed part on the right side

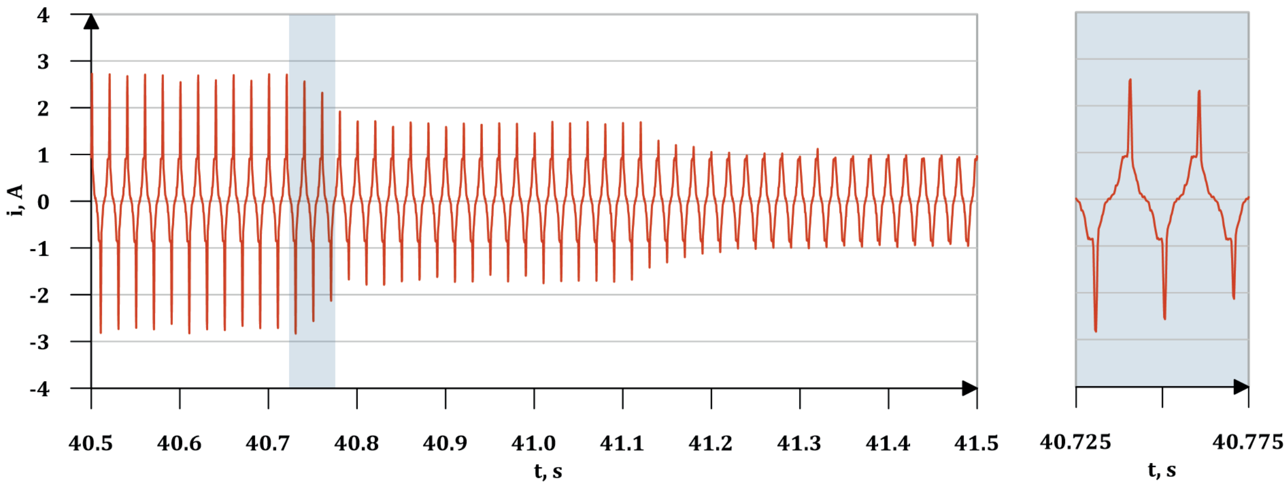

Fig. 11. Graph of instantaneous values of current for time window **C** with its zoomed part on the right side

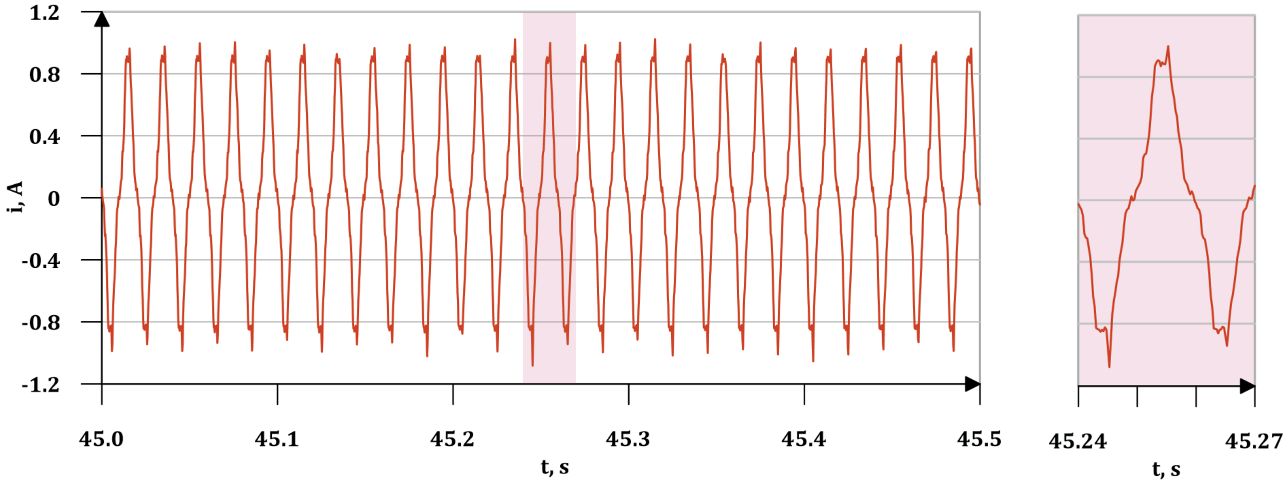

Fig. 12. Graph of instantaneous values of current for time window **D** with its zoomed part on the right side

The duration of the transient states on the graphs of the instantaneous value of current in time windows **A**–**D** also does not exceed the value of 500 ms. In time window **A** the maximum peak-peak value of the current is approximately 12.2 A, meaning that it is approximately six times higher than the peak-peak values in the steady state. This proportion is higher than in time window **H**, where the absolute peak-peak value of current has a value which is close to 22.0 A.

4. CONCLUSIONS

The application of a recorder to record instantaneous values of voltage and current in the robot power supply system allows us to carry out an analysis of transient states which is a result of:

a) determining the maximum peak-peak values of voltage and current in various moments of the robot's work,
b) finding the duration of every occurred transient state,
c) determining the deformation of sinusoids from waveforms of voltage and current, also including the analysis of FFT,
d) calculating the values of RMS voltage and current with consider of values of power consumed.

Taken measurements and calculations for chosen industrial robot allows to formulate following conclusions:

a) During the full cycle of robot work very small deformations are found from sinusoid for recorded values of instantaneous voltages,
b) Rotations of different robot axes at a changing programmed position causes the occurrence of current transient states with a duration of approximately 500 ms,
c) Maximum peak-peak values in the waveforms of current during duration of transient state are many times higher than the maximum values of peak-peak current at other time intervals.
d) The highest peak-peak value of current in the transient state occurs during the returning of the robot arm to the resting position with a set speed of 50% of the maximum speed value for every working axis.

The aforementioned analyses and conclusions allow to determine the voltage and current characteristics in the robot power supply system according to approved assumptions and enables the development of correct protection and eventual harmonic filtering [8].

REFERENCES

[1] FANUC Europe Corporation main web page. Retrieved from https://www.fanuc.eu/eu-en/ [16.05.2025].

[2] FANUC Europe Corporation. Technical datasheet of LR Mate 200*i*D/4S (Short arm). Retrieved from https://www.fanuc.eu/pl/pl/roboty/robot-strona-filtrowania/lrmate-series/lr-mate-200id-4s [16.05.2025].

[3] FANUC Corporation. FANUC Robot *i* Series GENERAL CATALOG. Retrieved from https://www.fanuc.co.jp/en/product/catalog/robot-catalog.html [16.05.2025].

[4] LEM International SA. Product list – Voltage Transducer Model LV 25-600. Retrieved from https://www.lem.com/en/product-list/lv-25600 [16.05.2025].

[5] LEM International SA. Product list – Current Transducer Model LA 25-NP. Retrieved from https://www.lem.com/en/product-list/la-25np [16.05.2025].

[6] LEM International SA. main web page. Retrieved from https://www.lem.com/en [19.05.2025].

[7] Ziółkowski E. & Skrzyński M. (2018). Monitoring of selected energy parameters in the supply system of a model vibratory unit. *Archives of Foundry Engineering*, 18, 145–150. DOI: https://doi.org/10.24425/118828.

[8] Kowalski Z. (2007). Jakość energii elektrycznej. Monografie Politechniki Łódzkiej. Łódź: Wydawnictwo Politechniki Łódzkiej.