UDC 621.311.6 DOI 10.31548/energiya2021.04.039

POWER SUPPLY OF MEASURING SENSORS WHEN PERFORMING EXPERIMENTAL STUDIES OF ELECTRICAL THERMAL MECHANICAL SYSTEM

M. M. Zablodskiy, Doctor of Engineering, Professor

M. O. Spodoba, post-graduate

National University of Life and Environmental Sciences of Ukraine

E-mail: spmisha@ukr.net

Abstract. *The main part of scientific research is the results of the experiment, because they make it possible to establish the existing dependencies of the course of processes on a real object, confirm theoretical calculations and a mathematical model of an electrothermal-mechanical system. The work is devoted to the issue of experimental research of power supplies for measuring and recording equipment. According to the purpose, a technique was proposed by which experimental studies of the presence of pulses, noise and fluctuations in the output voltage of pulse and transformer power supplies were carried out. The influence of the deviation of the output voltage on the fluctuations of the voltage readings on the measuring and recording equipment has been investigated. Based on the results of experimental studies of power supplies, the proposed technique can be taken as a basis for selecting power supplies in accordance with the requirements for the required accuracy of reading indicators from the measuring equipment in accordance with their accuracy class, within the total error permissible for this type of experiment. A power source for measuring and recording equipment was selected for experimental studies of an electrothermal-mechanical system to intensify the process of methane formation in a biogas reactor in order to determine as accurately as possible the energy costs for biogas production, due to the fact that the process of producing biogas is long, therefore, a large error in determining energy costs affects an increase in actual energy costs in production in relation to the calculated and experimental data. The practical value of the work lies in the fact that the use of power supplies with a lower ripple of the output voltage in experiments will reduce the processing time of the obtained data arrays, increase the efficiency of the experiment and the accuracy of the revealed dependencies. The methodology presented in the work also makes it possible to more efficiently use financial resources for the purchase of devices in the preparation and conduct of scientific and experimental research.*

Keywords: ***power supply, voltage pulse, accuracy, scientific research, experiment, PeakTech***

Introduction. The experiment is the main part of scientific research which is based on scientific research with the most accurate registration of conditions and parameters. It is

the results of the experiment that allow us to establish the existing dependencies of certain processes on a real object. To save time and resources, experimental research must be implemented in such a way as to obtain highly accurate data for a minimum number of experiments. Which will be used in the future for practical and theoretical purposes.

The reliability of the experimental results depends on the correctness of the development of the methodology of the experiment, the choice of high-precision measuring and recording equipment and its location on the experimental setup. Since most existing measuring and recording equipment requires a 5, 12 and 24 volt DC power supply, the choice of power supply for high-precision measuring and recording equipment is an important role in preparing for the experiment and obtaining reliable results.

Analysis of recent research and publications. There are a huge number of power supplies that can be used for experimental research. However, it is known that any power source creates electromagnetic interference and oscillations [1–3], the smaller these oscillations, the more accurate the results of experimental studies. During experimental studies of transient processes, rechargeable batteries are used in combination with linear output voltage stabilizers [4]. However, with a long process of research there is a need to recharge the battery.

Recently, in the construction of automatic control systems and experimental studies have become the most common switching power supplies, which in comparison with the transformer have smaller dimensions and weight, greater efficiency and greater scope [5, 6].

Switching power supplies work on the principle of conversion of high-frequency pulses, this creates additional interference in the output voltage values, which require additional measures to neutralize interference (low and high frequency filters) [3, 6]. However, the removal of interference by filtration can make an additional error in the experimental study. The expediency of neutralization depends on the magnitude of the output voltage fluctuations, so the choice of power supply measuring and recording equipment for experimental research is one of the main conditions for obtaining highly accurate and scientifically-practical valuable results.

Purpose. Selection of power supply for measuring and recording equipment for experimental studies of the electrothermal system for intensification of the methane formation process in a biogas reactor.

Materials and methods. The experimental study compared the following power supplies: switching laboratory power supply PeakTech 6225A, switching power supply for household appliances ATX-300, transformer power supply with linear voltage stabilization which acts as a regulator 142EN5A with a fixed output voltage of 5 V and stabilization error 0.05%. The units are powered by a single-phase AC network, and at the output give a constant voltage of 5 V. During the research, the voltage of the single-phase network was measured using a PeakTech 2005 multimeter.

Measuring equipment has digital or analog signals, so they are used in combination with microprocessor devices and personal computers. During experimental studies, for greater information on the effect of power supply noise on the readings of measuring sensors, it was decided to use an analog-to-digital converter.

To date, in the market of microcontrollers intended for general use, three types have become popular: PIC, AVR and STM [7, 8]. AVR microcontrollers have become the most widespread thanks to Arduino programming platforms, which are based on AVR microcontrollers. To study the power sources, we used an Arduino Nano V 3.0 board, which is based on the AVR family of microcontrollers – Atmega328, which contains a 10-bit analog-to-digital converter (ADC).

The ADC resolution is calculated by the formula:

$$h = \frac{U_{in}}{2^n}, \tag{1}$$

where U_{in} – rated maximum input voltage of the ADC, V; n – bit ADC.

10-bit ADC resolution Arduino Nano V 3.0 $h = 0{,}0049\ B$. The schematic diagram according to which was the study of power supplies shown in Fig. 1.

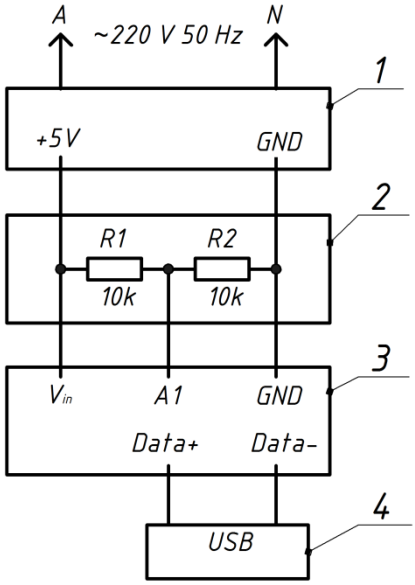

Fig. 1. Schematic diagram of the study of power supplies:

1 – power supply; 2 – resistive voltage divider; 3 – microcontroller Arduino Nano V 3.0; 4 – notebook HP EliteBook 8440p; R1, R2 – constant resistors 10 kOm, 0,25 W, ±0,1%; A1 – input of analog-to-digital converter of the microcontroller Arduino Nano V 3.0.

The study was performed as follows. The power supply (1) was connected to a single-phase AC source, to the output of the power supply (5 V) was connected a resistive voltage divider built on 10 kOm constant resistors (2), which acts as a static measuring sensor. The initial value of the rated voltage (U_{out}) from the resistive divider is calculated by the formula:

$$U_{out} = \frac{R_2}{R_1 + R_2} \cdot U_{in}, \tag{2}$$

where U_{in} – input voltage, $U_{in} = 5\ V$; R_1, R_2 – constant resistors, $R_1 = R_2 = 10\ kOm$.

$$U_{out} = \frac{10}{10 + 10} \cdot 5 = 2.5\ V.$$

The voltage drop across the resistive divider was measured using an analog-to-digital converter microcontroller Arduino Nano V 3.0 (3). Information from the ADC via USB, using the Arduino IDE program was displayed on the monitor of the laptop HP EliteBook 8440p (4). The study time for each power supply is 1000 milliseconds. The frequency of the ADC output poll is 6.67 ms.

Results and discussion. The results of experimental studies of the switching power supply for household appliances ATX-300 are shown in Fig. 2.

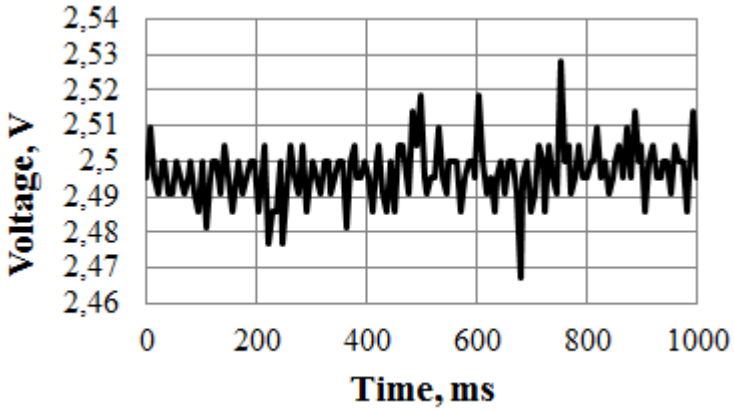

Fig. 2. Fluctuations of voltage readings on the resistive divider when powering the latter from the switching power supply ATX-300

Analyzing the graphical dependence (Fig. 2), it is noticeable that the measured ADC voltage drop on the resistive divider has a pulsating character throughout the study, with a peak amplitude of 0.06 V.

The average value of the measured voltage per 1000 milliseconds is 2.49669 V, which is 0.132% less than the rated voltage. The number of measured values of rated voltage $(U_n = 2.5\ V)$ for the study period (1000 ms) is 28.67% of the total number of measurements. In this case, the maximum sequence of measuring the value $(U_n = 2.5\ V)$ is 13.34 ms.

The results of experimental studies of the transformer power supply with linear voltage stabilization are shown in Fig. 3.

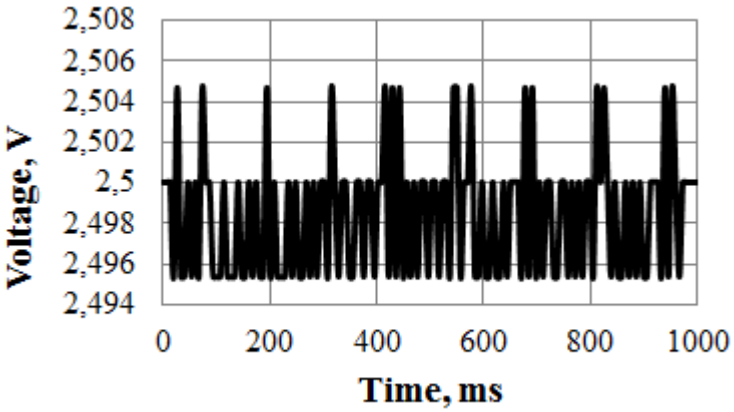

Fig. 3. Fluctuations of voltage readings on the resistive divider when powering the latter from the transformer power supply with linear voltage stabilization

In fig. 3 it is noticeable that using as a power supply transformer unit with linear voltage stabilization, the output signal from the resistive divider has a pulse character with a peak pulse range of 0.0093 V. During the study time (1000 ms) is clearly expressed accumulation of pulses in the area below $(U_n = 2.5\ V)$ and no areas with stable output voltage, the maximum sequence of nominal voltage measurement on the resistive divider $(U_n = 2.5\ V)$ is 20 ms. The average value of the measured voltage is 2.49845 V, which is 0.062% less than the rated voltage. The number of measured voltage values $(U_n = 2.5\ V)$ for the study period is 44.67% of the total number of measurements.

The results of experimental studies of the pulsed laboratory power supply PeakTech 6225A are shown in Fig. 4.

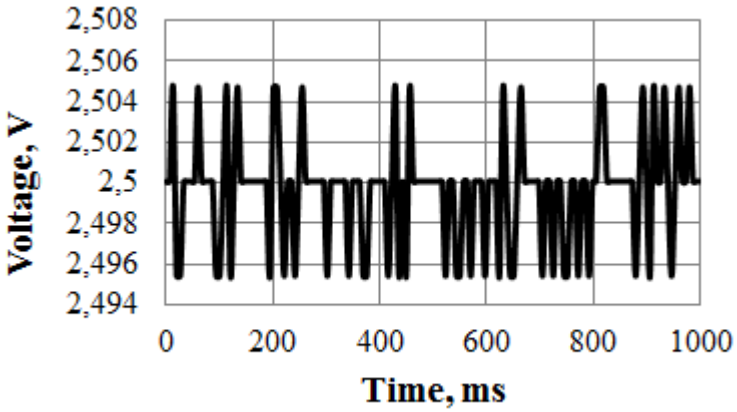

Fig. 4. Fluctuations of voltage readings on the resistive divider when powering the latter from the pulsed laboratory power supply PeakTech 6225A

From the graphical dependence (Fig. 4) it is noticeable that when using a switching laboratory power supply, the output voltage from the resistive divider has a pulsed nature with areas with stable voltage $(U_n = 2.5\ V)$. Peak pulse range 0.0093 V. The average value of the measured voltage is 2.49996 V, which is 0.0016% less than the rated voltage $(U_n = 2.5\ V)$. The number of measured voltage values $(U_n = 2.5\ V)$ for the entire study period (1000 ms) is 66% of the total number of measurements. In this case, the maximum sequence of measurements $(U_n = 2.5\ V)$ is 66.7 ms.

During the research, the authors found that the use of the pulse unit ATX-300 to power the measuring and recording equipment in experimental studies, due to large ripples (Fig. 2), a low number of measured values of rated voltage $(U_n = 2.5\ V)$ – 28.67% and the absence of areas of stable output voltage, will not provide reliable results and significantly reduce the quality of the obtained array of experimental data.

The transformer power supply unit with linear voltage stabilization has a high frequency of pulses of the measured voltage below the value $(U_n = 2.5\ V)$ (Fig. 3), as well as a small sequence of nominal voltage measurements lasting a maximum of 20 ms (Fig. 3), this will lead to distortion of the results, which in turn will reduce the accuracy of the dependences and data sets obtained during the experiment.

According to the experimentally obtained graphical dependences of voltage fluctuations on the resistive divider using the power supply PeakTech 6225A (Fig. 4) in comparison with the switching unit for household appliances ATX-300 (Fig. 2) and transformer power supply with linear voltage stabilization (Fig. 3) will provide a small measurement error, and therefore high reliability and informativeness of the data sets obtained during the experiments and information about the existing dependencies of the object.

Transformer power supplies with linear voltage stabilization to reduce the pulsations of the latter require the installation of additional means of filtration. Due to various additional means of filtration, it is possible to reduce the level of pulsation of power supplies, thereby increasing the accuracy of the supply voltage of measuring and recording equipment [6]. However, the selection and establishment of the effectiveness of a particular filter for each object requires a number of experimental studies.

Conclusions. An experimental study of the power supply of the measuring and recording equipment connected to the analog-to-digital converter showed that the use of the PeakTech 6225A power supply will provide a small deviation of the supply voltage, and therefore high reliability of the data obtained during the experiment. The method according to which experimental researches of presence of impulses and fluctuations of output voltage of pulse and transformer power supplies are carried out is offered.

The practical value of the results obtained in this work is that the use in experimental studies of power supplies with lower output voltage ripple will reduce the time of software processing of the obtained data sets, increase the efficiency of the experiment and the accuracy of the dependences. The methodology presented in the paper also makes it possible to more rationally use financial resources for the purchase of devices in the preparation and conduct of scientific and experimental research.

References

1. Ponomarev, A. B., Pikuleva, E. A. (2014). Research methodology. Perm, Perm nat. issled. poly-tech. University, 186.

2. Gadzikovsky, V. I. (2013). Digital signal processing. Moscow, *SolonPress*, 766.

3. Zhezhelenko, I. V., Shidlovsky, A. K., Pivnyak, G. G. (2012). Electromagnetic compatibility of consumers. Moscow, *Mechanical Engineering*, 351.

4. Loveikin, V. S., Spodoba, O. O. (2020). Experimental research of modes of movement of manipulator crane with load at combination of movements. *Machinery & Energetics*, 11(3), 5-15.

5. Topilskiy, V. B. (2013). Microelectronic measuring transducers. 2nd ed. Moscow, *BINOM, Knowledge Laboratory*, 493.

6. Brown, M. (2007). Power Supply Cookbook - 2nd Edition. Calculation and design. Kyiv, *MK-Press*, 288.

7. Shchuplyaka, N. M. (2014). Fundamentals of electronics and microelectronics. Drogobich, 443.

8. Kvitka, O. G., Yakovlev, V. F., Nikitina, O. V. (2010). Electronics and microcircuitry. Kyiv, *Agrarna osvita*, 329.

ДЖЕРЕЛО ЖИВЛЕННЯ ВИМІРЮВАЛЬНИХ ДАТЧИКІВ ПРИ ВИКОНАННІ ЕКСПЕРИМЕНТАЛЬНИХ ДОСЛІДЖЕНЬ ЕЛЕКТРОТЕПЛОМЕХАНІЧНОЇ СИСТЕМИ

М. М. Заблодський, М. О. Сподоба

Анотація. *Головною частиною наукових досліджень є результати експерименту, адже вони дозволяють встановити існуючі залежності протікання процесів на реальному об'єкті, підтверджують теоретичні розрахунки та математичну модель електротепломеханічної системи. Робота присвячена питанню експериментального дослідження блоків живлення для вимірювально-реєструючого обладнання. Відповідно до мети, було запропоновано методику, за якою проведено експериментальні дослідження наявності імпульсів, шумів та коливань вихідної напруги імпульсних та трансформаторних блоків живлення. Досліджено вплив відхилення вихідної напруги на коливання показів напруги на вимірювально-реєструвальному обладнанні. За результатами експериментальних досліджень блоків живлення запропонована методика може прийматися за основу для підбору джерел живлення за вимогами необхідної точності зняття показників з вимірювального обладнання відповідно до їх класу точності в межах сумарної*

похибки допустимої для даного типу експерименту. Вибрано джерело живлення вимірювально-реєструювального обладнання для експериментальних досліджень електротепломеханічної системи для інтенсифікації процесу метаноутворення в біогазовому реакторі з метою максимально точного визначення енергетичних витрат на виробництво біогазу. У зв'язку з тим, що процес вироблення біогазу довготривалий, тому велика похибка визначення енерговитрат впливає на збільшення фактичних енерговитрат на виробництві відносно до розрахункових та експериментальних даних. Практична цінність роботи полягає в тому, що використання при експериментах блоків живлення з меншою пульсацією вихідної напруги дозволить знизити час обробки отриманих масивів даних, підвищить ефективність експерименту та точність виявлених залежностей. Наведена у роботі методика також дає можливість більш раціонально використовувати фінансові ресурси на придбання приладів при підготовці та проведенні наукових експериментальних досліджень.

Ключові слова: ***блок живлення, імпульс напруги, точність, наукові дослідження, експеримент, PeakTech***

ИСТОЧНИК ПИТАНИЯ ИЗМЕРИТЕЛЬНЫХ ДАТЧИКОВ ПРИ ВЫПОЛНЕНИИ ЭКСПЕРИМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ ЭЛЕКТРОТЕПЛОМЕХАНИЧЕСКОЙ СИСТЕМЫ

Н. Н. Заблодский, М. А. Сподоба

Аннотация. *Главной частью научных исследований являются результаты эксперимента, поскольку они позволяют установить существующие зависимости протекания процессов на реальном объекте, подтверждают теоретические расчеты и математическую модель электротепломеханической системы. Работа посвящена вопросу экспериментального исследования блоков питания для измерительно-регистрирующего оборудования. Соответственно с целью была предложена методика, по которой проведены экспериментальные исследования наличия импульсов, шумов и колебаний выходного напряжения импульсных и трансформаторных блоков питания. Исследовано влияние отклонения выходного напряжения на колебания показаний напряжения на измерительно-регистрирующем оборудовании. По результатам экспериментальных исследований блоков питания предложена методика, которая может приниматься за основу для подбора источников питания согласно требованиям необходимой точности снятия показателей с измерительного оборудования в соответствии с их классом точности в пределах суммарной погрешности, допустимой для данного типа эксперимента. Выбран источник питания измерительно-регистрирующего оборудования для экспериментальных исследований электротепломеханической системы для интенсификации процесса метанообразования в биогазовом реакторе с целью максимально точного определения энергетических затрат на производство биогаза. В связи с тем, что процесс выработки биогаза длительный, поэтому большая погрешность определения энергозатрат влияет на увеличение фактических энергозатрат на производстве соответственно к расчетным и экспериментальным данным. Практическая ценность работы состоит в том, что*

использование при экспериментах блоков питания с меньшей пульсацией выходного напряжения позволит снизить время обработки полученных массивов данных, повысит эффективность эксперимента и точность выявленных зависимостей. Приведенная в работе методика также дает возможность более рационально использовать финансовые ресурсы на приобретение приборов при подготовке и проведении научных экспериментальных исследований.

Ключевые слова: ***блок питания, импульс напряжения, точность, научные исследования, эксперимент, PeakTech***