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ХАРАКТЕРИСТИКИ ДАТЧИКОВ В СИСТЕМАХ АВТОМАТИЧЕСКОГО КОНТРОЛЯ
CHARACTERISTICS OF SENSORS IN AUTOMATIC CONTROL SYSTEMS

Аннотация. В данной статье рассматриваются характеристики датчиков в системах автоматического управления и контроля. В современную эпоху стремительное развитие промышленности, энергетики и систем автоматизированного управления еще больше повысило значимость сенсорных технологий. Точное управление, оперативное регулирование и надежная защита всех процессов, как в повседневной жизни, так и на сложных промышленных и энергетических объектах, зависят от возможностей датчиков. Датчики измеряют различные физические, химические и технологические параметры и преобразуют их в электрические сигналы, на основе которых обеспечивается корректная работа систем управления и контроля. Сложность процессов в энергетических системах, режимы высоких нагрузок и риски, связанные с авариями, делают роль датчиков еще более актуальной. В частности, точный контроль таких параметров, как температура, ток, напряжение и вибрация в электрических сетях и силовых трансформаторах, повышает эксплуатационную надежность оборудования и предотвращает аварии. В результате развития сенсорных технологий стало возможным включение дополнительных параметров в управление (1-14).

Abstract. This article discusses the characteristics of sensors in automatic control and monitoring systems. In modern times, the rapid development of industry, energy and automated control systems has further increased the importance of sensor technologies. Precise control, operational control and reliable protection of all processes, both in everyday life and in complex industrial and energy facilities, depend on the capabilities of sensors. Sensors measure various physical, chemical and technological parameters and convert them into electrical signals, and based on these signals, the correct operation of control and monitoring systems is ensured. The complexity of processes in energy systems, high load modes and risks associated with accidents make the role of sensors even more relevant. In particular, accurate monitoring of parameters such as temperature, current, voltage and vibration in electrical networks and power transformers increases the operational reliability of equipment and prevents accidents. As a result of the development of sensor technologies, it has become possible to involve additional parameters in control (1-14).

Ключевые слова: Датчик, система управления, автоматический контроль, характеристика, параметр, точность, моделирование, погрешность, критерий, программа.

Keywords: Sensor, control system, automatic control, characteristic, parameter, accuracy, modeling, error, criterion, program.

The relevance of the topic is closely related to the digitalization processes of modern energy. "Smart Grids", automated distribution systems, telemechanics and SCADA technologies cannot function without operational data from sensors. Therefore, the correct selection of various types of sensors, the development of application methodologies and their integration into management and control systems are of great importance both from a theoretical and practical point of view. The reliability of modern control, monitoring and automation systems depends on the correct selection and application methodology of sensor technologies. The sensor should be considered not only as a measuring device, but also as a functional element of the information system. Therefore, the methodological approach involves scientific justification of sensor selection, assessment of accuracy and reliability, as well as proper integration of information flows [1-6]. The definition of the main criteria, typical ranges and engineering significance of the sensors are summarized in Table 1.

Table 1.

Main criteria for sensor selection

Criterion	**Definition and explanation**	**Typical range/example**	**Significance**
measuring range	minimum–maximum quantity received by the sensor	0…2000 A (current), -50…+250 °C	ensuring system compliance
accuracy	the limit of deviation of the measurement from the real value	±0.1–1 %	impact on steering accuracy
resolution	the smallest change that the sensor can detect	0.01 °C, 0.001 A	detecting small changes
response time	reaction time to signal change	1 ms – 1 s	important in control and automation
drift and stability	signal changes during long-term operation	±0.1 °C/year, ±0.5 %/year	reliability and predictability
reliability	mean time between failures	50 000 – 200 000 clock	ensuring system reliability
energy consumption	energy required for sensor operation	1–100 mW	important in autonomous and remote facilities
economic factor	price, calibration, maintenance costs	50 – 500 USD (typical)	compliance with the project budget

According to the methodological approach, sensor selection is based on a comparison of each of these criteria with the system requirements. The reliability of the data provided by sensors is determined not only by technical parameters, but also by the nature and size of errors. Even the smallest errors in control and monitoring systems can lead to incorrect decisions. Therefore, accuracy and error analysis constitute a special methodological stage in the application of sensors. An example of an automatic control circuit is shown in figure 1.

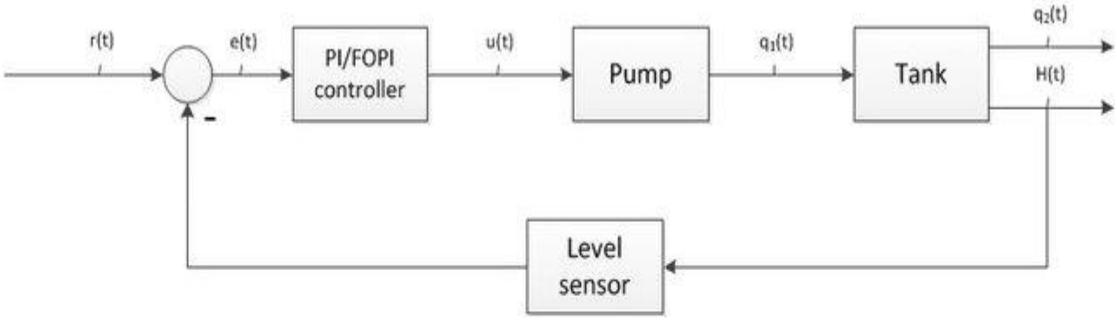

Figure 1. Diagram of an automatic control system

Figure 2. Graphs of voltage, deformation and temperature in the automatic control system

Software is the most important component of automatic control systems. When selecting software, it's important to consider functionality, versatility, compatibility with specific sensor types, scalability, and other parameters, as software creates a unified information environment from disparate hardware to ensure the continuity and integrity of measurements. All sensors are automatically polled using specialized data collection systems, which transmit measurement results and diagnostic information (figure 2).

The main function of sensor technologies in energy facilities is to ensure system reliability, detect emergencies in a timely manner, and optimize management processes. The role of sensors in electrical networks is particularly important. Here, current and voltage sensors measure the loading of lines and transformers, record short circuits with millisecond accuracy, and transmit signals to the SCADA system. In addition, power quality sensors monitor harmonic distortions, frequency deviations, and voltage fluctuations, which ensures that the energy supplied to consumers complies with standards. In recent years, fiber-optic sensors have also found wide application. They increase the safety of lines by measuring the temperature and mechanical stress of long-distance high-voltage lines. Sensor technologies in substations are more complex and multifaceted. Here, temperature sensors monitor the heating of transformer windings and insulating oil, while gas analysis sensors detect potential malfunctions before an accident occurs by determining the composition of gases dissolved in the oil. Vibration sensors monitor the mechanical condition of circuit breakers and transformer cores, while insulation monitoring sensors record leakage currents in cable lines and insulators. These technologies not only control substations in real time, but also provide pre-accident diagnostics and increase the service life of equipment. One of the important conditions for the reliable operation of electromechanical equipment is the correct design of their protection systems. In this regard, one of the most widely used methods is maximum current protection [7-12]. In modern operating conditions, the limitations of this approach are revealed, since additional factors that affect the real state of the equipment – temperature and vibration – are not taken into account. To investigate this problem in depth, an overcurrent protection system for electromechanical equipment is modeled in the MATLAB/Simulink environment. The protection tripping process (Figure 3) shows that after a short circuit occurs, the current exceeds the tripping threshold, and when the time delay is completed, a trip signal is generated within 2.0-2.4 s and the electromechanical equipment is disconnected from the network. This confirms the ability of classical overcurrent protection to protect equipment in emergency conditions. When the presented modeling results are combined with the integration of practical measurements of sensors, it becomes clear that the protection of modern electromechanical devices should not be limited only to monitoring current limits. Temperature and vibration signals obtained from sensors are included in the protection system, ensuring its adaptive operation. As a result, the operational reliability of the equipment increases, and the probability of accidents is significantly reduced. This approach is a real example of the transition from classical protection to intelligent protection.

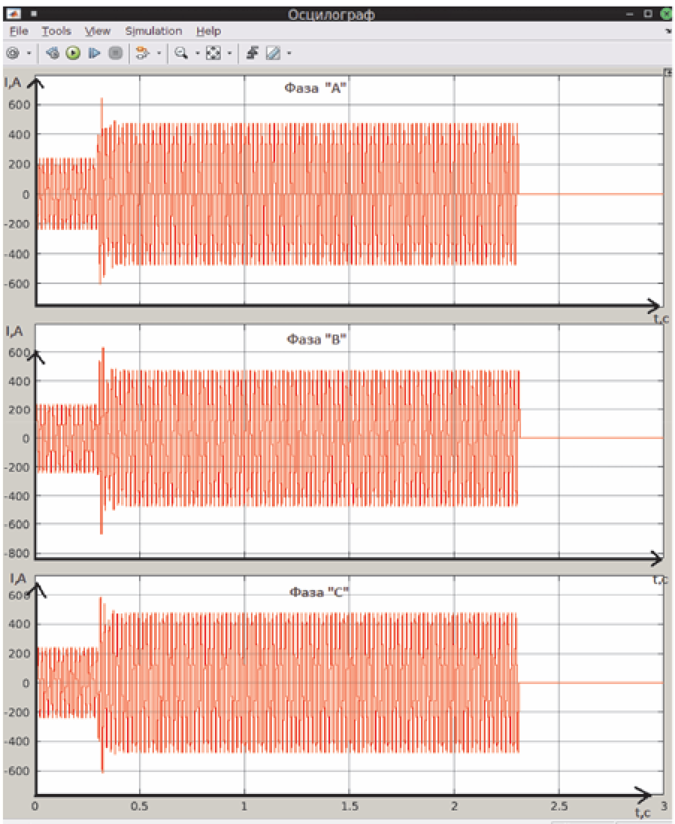

Figure 3. Classic overcurrent protection tripping process

Modeling shows that integrating sensor data makes classical protection more flexible and effective. Modeling results conducted in the MATLAB/Simulink environment prove the practical effectiveness of sensor integration, and simulations show that a protection system enriched with sensor data protects electromechanical equipment from both electrical and mechanical risks faster and more reliably. In case of temperature increase, the starting current limit is automatically reduced, and in case of vibration increase, the delay time is shortened. As a result, the protection system works more flexibly and the electromechanical device adapts to the actual operating conditions (Figure 4).

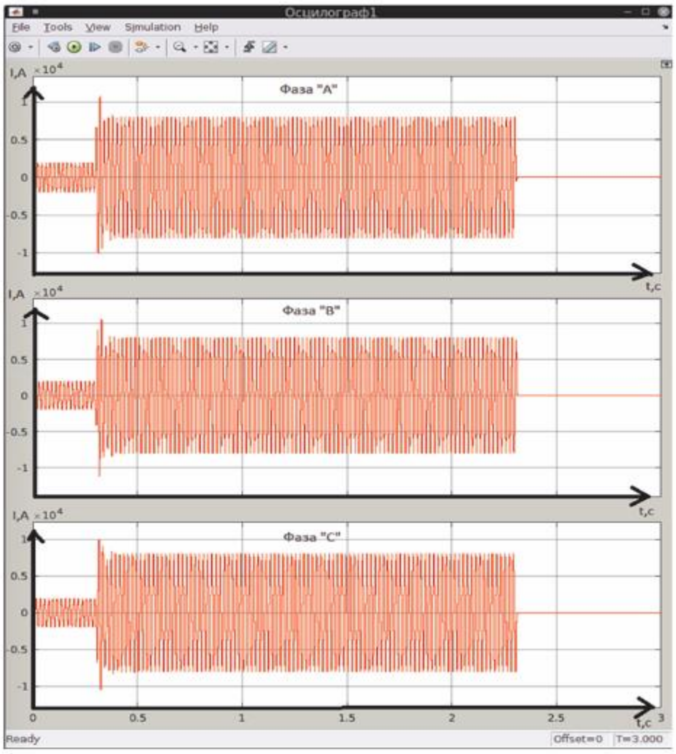

Figure 4. Adaptive overcurrent protection concept:
taking into account temperature and vibration parameters.

The main purpose of the presented work is to analyze the characteristics of sensors in automation control systems, to substantiate their practical importance in energy and to demonstrate their application possibilities based on modeling in the MATLAB/Simulink environment. For this purpose, the study of the application areas of sensors, the analysis of the selection criteria, accuracy and error parameters, reliability indicators of various sensors used in energy, the practical processing of sensor signals, the development of methodological foundations for their use in control systems, the modeling in the MATLAB/Simulink environment and the integration of sensor data into the adaptive protection concept, the generalization of the results obtained and the identification of future application possibilities were considered. The scientific significance of the work is that the systematic analysis conducted on various types of sensors creates a theoretical basis for their integration in modern energy, and the practical significance is related to the inclusion of sensor signals in protection and control systems. This approach increases the reliability of electromechanical devices and networks, reduces the risk of accidents and extends the life of equipment [10-14]. In addition, models built in the MATLAB/Simulink environment allow for the replication of real conditions and the testing of new technologies. The conducted analyses show that sensor technologies have become an integral part of modern energy and automation systems. They enable more accurate and reliable control, not limited to traditional current and voltage measurements, but also covering temperature, vibration and other parameters. This increases the flexibility of control and management systems, reduces the risk of accidents and extends the service life of equipment. The development of the correct selection and application methodology of sensors directly affects the quality of the results.

References:

1. Kerimzade G.S.“Calculation of parameters of control induction support”.// PRZEGLAD Elektrotechniczny Publishing house of magazines and technical literature SIGMA-NOT. ISSN 0033-2097,R.100 NR 05/2024.Warszawa.pp.219-221.

2. Kerimzade G.S. ” Method for optimizing parameters of an AC stabilizer with induction levitation”.// 09-IJ TPE Journal, ISSN 2077-3528. ISSUE 58.Volume 16. Number 1. March,2024, pp.58-62.

3. Kerimzade G.S.“ Method for determining the overall dimensions of an induction control support”.// PRZEGLAD Elektrotechniczny Publishing house of magazines and technical literature SIGMA-NOT. ISSN 0033-2097,R.100 NR 06/2024.Warszawa.pp.235-237.

4. Kerimzade G.S.“Structure of the monitoring and tracking electromechanical control system”.// PRZEGLAD Elektrotechniczny Publishing house of magazines and technical literature SIGMA NOT. ISSN 0033-2097,R.100 NR 07/2024.Warszawa.pp.295-297.

5. Kerimzade G.S., Mamedova G.V.”Design parameters for electromechanical devices with a levitation element”.// PRZEGLADElektrotechniczny Publishing house of magazines and technical literature SIGMA NOT. ISSN 0033-2097,R.100 NR 09/2024.Warszawa.pp.111-113.

6. Kerimzade G.S., Mamedova G.V.” Research of electromechanical devices with levitation elements in control systems”.// Journal “Reliability: Theory & Applications”. ISSN 1932-2321.Volume 19, № 2 (78). Yune 2024.pp.85-90.

7. Kerimzade G.S., Mamedova G.V.”Relay contactor system as a means of controlling a linear electric drive”.// Journal “Reliability: Theory & Applications”. ISSN 1932-2321.Volume 20, № 1 (82). March 2025.pp.388-396.

8. Kerimzade G.S. ”Features of hanging the parameters of induction control support”.// IJ TPE Journal, ISSN 2077- 3528 ISSUE.Number 1. March,2025. pp.69-80.

9. Kerimzade G.S. ”Electromechanical devices with levitation elements for control of non-electrical parameters”.// Journal “Reliability: Theory & Applications”. ISSN 1932-2321. Volume 20, № 2 (84). June 2025.pp. 648-654.

10. Kerimzade G.S., Rzayeva S.V.“Engineering solutions for the integration of Internet of Things devices and sensors,”Tekhnichna Elektrodynamika, Publ.PH “Akademperiodyka” of NAS of Ukraine, 2025 – № 5, pp. 89–98.

11. Kerimzade G.S., Mamedova G.V.“Application of magnetic levitation technologies to enhance the efficiency of wind energy systems”.//International Scientific Journal for Alternative Energy and Ecology (ISJAEE).Scientific Technical
Center «TATA»,2025. № 01 (430).pp.90-104.

12. Kerimzade G.S.,Rzayeva S.V. “Methods of research of linear motors used in cutting systems”.//International Scientific Journal for Alternative Energy and Ecology (ISJAEE).Scientific Technical Center «TATA»,2025. № 04 (433).pp.134-144.

13. Mamedova G.V., Kerimzade G.S.”Determination of dependencies for calculation method of an induction levitator of cylindrical design”.// IJ TPE Journal, ISSN 2077-3528. ISSUE 66. Volume 18. Number 1. March, 2026.

14. Kerimzade G.S., Rzayeva S.V.”Optimization and control of lineardrives for precision cutting applications ”.// IJ TPE Journal, ISSN 2077-3528. ISSUE 66. Volume 18. Number1, March, 2026.