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PRINCIPLES OF CONSTRUCTION OF THE INFORMATION AND CONTROL SYSTEM OF THE DEPARTMENT OF THE UNIVERSITY

Annotation. The concept of the information and control system of the university department, which trains specialists in the electrical engineering profile, is systematized. The principles of construction and the block diagram of such a system are proposed. The variants of application in the educational process are described. A feature of the proposed system is the integration of the computer and microcontroller educational infrastructure of the department with the "smart home" system of the premises of the university building.
Keywords: information and control system, department, "smart home", microcontroller boards, computer laboratory.

Formulation of the problem. The general digital transformation of society has also affected the sphere of university education. Digital transformation in the field of education and science is a priority for the Ministry of Education and Science of Ukraine. This is complex work, which includes, among other things, the creation of the necessary digital infrastructure of educational and scientific institutions, automation of data collection and analysis [1]. The achieved level of infrastructure of the university departments, with computer classes with Internet access, does not reflect all the advantages of digitalization.

Another area in which revolutionary changes are taking place is the introduction of "Smart *X*" type systems, where *X* is some object: an apartment, a house, a building, a city, a garage, a vehicle, a machine tool, etc. [2]. Unfortunately, this list does not include the university department, which increases the operating costs of the university infrastructure, reduces the level of comfort in the department's premises and the quality of the educational process.

The third component of the current situation is the full-scale introduction of distance learning with problems of remote laboratory work in technical specialties [3].

Promising for use in the information control system (ICS) of the department is the direction of the Internet of Things (IoT) [4], which implements the collection of

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information from remote sensors and remote control of actuators, which is relevant in the technological processes of education.

Analysis of publications. The work [5] describes the cyber-social system Smart Cyber University (CyUni), developed at the Kharkiv Institute of Radio Electronics, which is characterized by: the presence of a digitized space of regulatory rules, accurate monitoring and active cyber control of the addressable components of scientific and educational processes, automatic generation of operational regulatory influences, independent of managers making cyber-decisions on the management of financial and human resources, the exclusion of paper media from scientific and educational processes. At the same time, the subsystem of the smart chair is not detailed in this work. On the other hand, the works [6, 7] describe the structures of individual computer laboratories of the department, but do not cover the issues of integrating these laboratories with the information system of the department leading the training in the specialty "electrical engineering".

The purpose of this work is to increase the level of digitalization of the Department of Electrical Engineering by creating an information control system that integrates the educational process that is conducted at the department with the infrastructure of the department's premises.

Presentation of the main material. The term "department" is usually used to define an element of the organizational structure of an educational institution, but not as an object of information management. In connection with the task set, we define the department as a system that is immersed in the external environment. This environment includes:

- Open space E1, which begins outside the windows of the department premises;
- Educational building E2, along the corridors of which physical access to the department is provided;
- Heating networks E3;
- Power supply networks E4;
- University Information Network E5;
- Water supply network E6;
- University telephone network E7;
- Security network E8;
- Fire alarm network E9.

Between the department and the listed elements of the environment there are material and information flows, in relation to which the department performs certain tasks given in Table 1.

To fulfill the tasks and effectively conduct the educational process, the department has the structure shown in Fig. 1.

In accordance with the principle of integration of information flows of the department, all elements of the ICS of the department are combined into a local network. The central element in this system is a computer class, which receives information flows from other elements and, in turn, is connected to the information network of the university.

Table 1

Tasks of the ICS of the department in relation to the elements of the external environment

Element designation	Task name
E1	Temperature and humidity control. Receiving solar energy
E2	Access control to the department. Corridor lighting control. Formation and display of relevant information in the corridor
E3	Accounting for water consumption and carrier temperature
E4	Power consumption control, mains voltage and current monitoring, overload protection.
E5	Network traffic control, distribution over internal networks, access control
E6	Water consumption accounting and leak detection (not considered in this paper)
E7-E9	Maintenance (not covered in this paper))

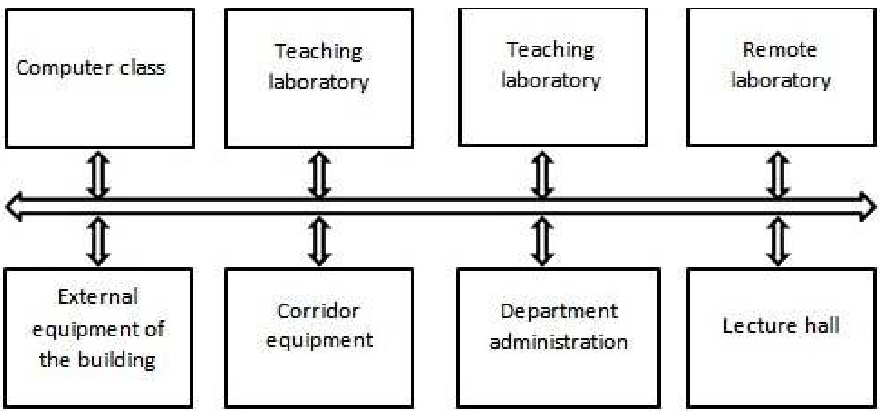

Figure 1 – The structure of the department

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Educational laboratories are classrooms with special laboratory stands that do not currently have nodes with a computing resource in their composition. For example, there is the laboratory of high-voltage electrical devices.

Auditoriums are rooms in which, at the moment, there is no laboratory equipment. Under the external equipment of the building is meant the equipment placed on the outer wall or roof of the educational building. The equipment of the corridor is mounted on its walls. In the premises of the remote laboratory there are stands for laboratory work by remote students, that is, students who are in other rooms or outside the university.

The administration of the department also needs to exchange information, store the archive of the department and, therefore, the administration computer is also included in the department's local network.

The structure of the computer class is shown in Fig. 2. When building a class, the principle of integrating the processes of managing the infrastructure of the department with the educational process was used. At the same time, infrastructure management objects are studied in the educational process, and monitoring the state of infrastructure elements improves the quality of the educational process. The class structure contains three servers. WEB server provides connection with the server of the university and schedules sessions of remote experiments for students.

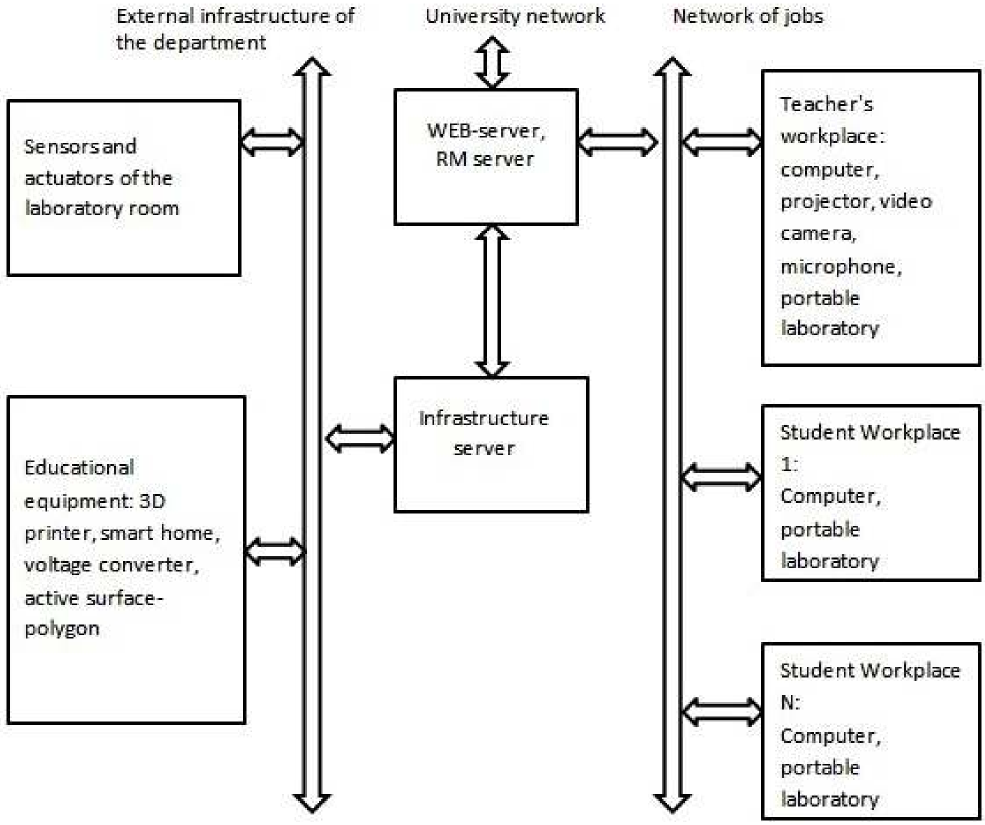

Figure 2 – The structure of the computer class of the department

The workplace server stores the necessary software, methodological materials, and results of students' laboratory work and provides Internet access for workplaces.

The infrastructure server controls the educational equipment of the computer class, receives the current values of the results of changes in various physical parameters in the classroom and stores them in disk memory. The educational equipment includes a 3D printer, on which students produce parts designed by them in CAD packages.

The "Smart Home" stand and outdoor portable weather station are designed for students to work out complex solutions for controlling sensors and actuators of the control object. Particular control tasks are worked out with the help of portable laboratories.

The voltage converter is used in conjunction with a solar battery (external building equipment) to study renewable energy sources.

An active surfaces-polygon is understood as a surface in a computer class room, along which, for a given purpose, models of vehicles equipped with microcontrollers for space sensors move. The polygon equipment dynamically changes the obstacles in the way of vehicles and the purpose of their movement. The purpose of training using an active polygon is to test the effectiveness of algorithms for overcoming obstacles. The principles of constructing active surfaces-polygon are considered in [8].

In addition, the infrastructure server controls the equipment of the computer room (lighting, air conditioning, video cameras, projector, acoustic system, access control systems) and the external infrastructure of the department.

A specific element of the workplace in a computer class is a portable laboratory. The main requirements for such a laboratory are to ensure low cost, functional completeness and flexibility, scalability of experiments, safety in operation, installation of experimental circuits without the use of soldering, compactness, ease of deployment, power supply of the experiment control circuit from a personal computer via a USB connector, use of a freely distributed software for designing control algorithms for objects of study. The principles of building such a laboratory include software control of the experiment, portability and reconfigurability.

The principles of building such a laboratory include software control of the experiment, portability and reconfigurability. These principles are implemented in the Smart EA portable laboratory [9], which consists of a set of individual stands. Each stand is stored in a separate organizer and connected to a personal computer for the duration of the laboratory work. The hardware part of the stand consists of a basic set and a variable part. The basic kit includes an Arduino Uno/Mega2560 microproc-

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essor board with a USB cable, an 830-point MB 102 breadboard, a set of wires, and basic radio elements.

Basic radio elements include limiting resistors, LEDs, buttons, and a potentiometer. The elements of the stand are placed in a plastic organizer that can be carried in a student's briefcase. The price of the basic set of the stand lies within 500-1000 UAH. General view of the laboratory stand is shown in Fig. 3.

Figure 3 – General view of the portable laboratory stand

The composition of the variable part of the stand depends on the topic of the laboratory work and includes additional radio elements (seven-segment indicators, piezoelectric emitters, digital and analog microcircuits), devices (various sensors, electric motors, modules with relays, displays, keyboards) and shields - boards with some functionality that are structurally are compatible with microprocessor board contacts and reduce the number of connecting wires. A fragment of the equipment of the variable part of the stand is shown in Fig. 4.

On the personal computer to which the stand is connected, the Windows operating system must be installed, with the microprocessor board driver, the freely distributed Arduino IDE [10] design environment with the necessary libraries. Work with a real board is preceded by work with simulators of the control object. Such systems as UnoArduSim [11], TINKERCAD [12] and others, of course, are a step forward in increasing the visibility of educational experiments with programming control algorithms.

Another important direction, which is supported by the equipment of the Smart EA stand, is the study of programming languages for industrial controllers. The main problem in the field of engineering training in programming industrial controllers is the unavailability, for economic reasons, of both the controllers themselves and the environments for programming them in the languages of the IEC 61131-3 standard [13].


Figure 4 – Elements of the variable part of the stand

Another important direction, which is supported by the equipment of the Smart EA stand, is the study of programming languages for industrial controllers. The main problem in the field of engineering training in programming industrial controllers is the unavailability, for economic reasons, of both the controllers themselves and the environments for programming them in the languages of the IEC 61131-3 standard.

At the same time, when studying object control algorithms, controller boards of the Arduino and other families, which are available for purchase, are widely used. In this case, the C programming language is used and the languages of the IEC 61131 – 3 standards are not used, which is a disadvantage of this approach.

In the computer class, the freely distributed OpenPLC platform [14] was used to teach programming of industrial controllers in the languages of the IEC 61131-3 standard. The programs developed by students are executed both in the built-in logic controller and in real controller boards, for example, from the Arduino family.

The OpenPLC platform includes a programming environment in a universal (not tied to a specific platform manufacturer of controller boards) language and a tool for loading a program into a real OpenPLC RunTime board. When configuring a project in the OpenPLC Editor environment, the programming language is selected.

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Language options are Instruction Language (IL), Structured Text (ST), Ladder Diagrams (LD), Function Block Diagrams (FBD), and Sequential Function Steps (SFC). At the same time, LD, FBD, SFC languages are high-level graphic languages that contain hundreds of standard instructions available for use when building control programs in a package. The program in the LD language visually resembles a relay-contact circuit of electroautomatics. An example of a simple program for implementing the self-latching relay function is shown in Fig. 5.

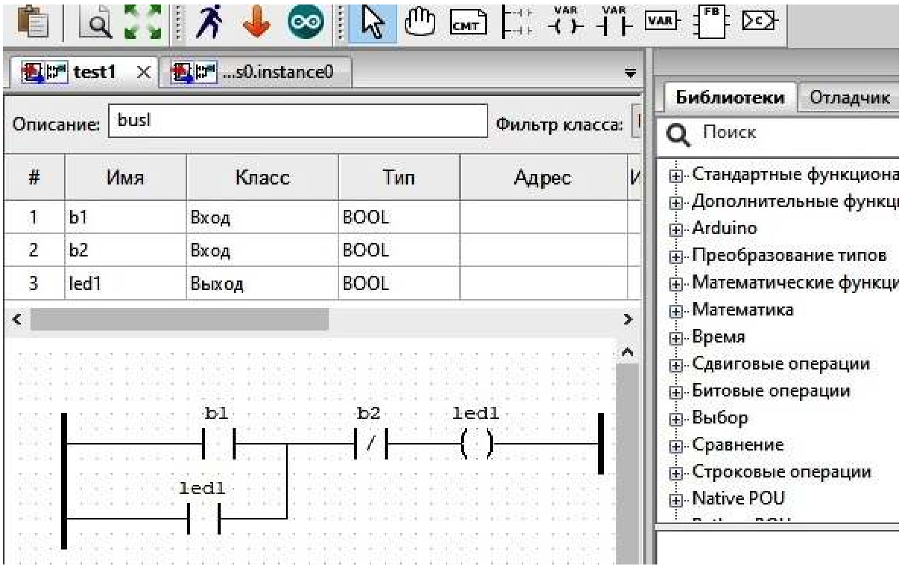

Figure 5 – Screen fragment of the OpenPLC Editor program

To bind the program variables to the pins of a specific controller board, the entries in the Address column are used. These records are generated based on the lookup tables available in the package documentation. So digital pin 2 of the Arduino Uno board configured as input will have address %IX0.0, and pin 7 configured as output %QX0.0.

The Smart EA laboratory has been introduced into the educational process of preparing bachelors in the specialties 141 - "Electric Power Engineering, Electrical Engineering and Electromechanics" and 172 - "Telecommunications and Radio Engineering" at the National University "Zaporozhye Polytechnic". In particular, laboratory work was carried out on the study of programming in the C language of the tasks of interfacing a microprocessor board with sensors and actuators, the implementation of automatic control algorithms, and on the study of programming in the Ladder Diagram language of the tasks of implementing logic functions, timers and counters with the execution of programs in a programmable logic simulator controller (with distance learning) and in a real Arduino Uno microcontroller.

Currently, work to expand the functionality of the portable laboratory continues. It is supposed to be used in the course “Fundamentals of electronics and microcircuitry to study the principles of building analog and digital nodes.

The corridor of the building in the context considered by the ICS is a place where a student spends a significant amount of time and it can carry an additional information load or contribute to psychological relief.

To implement these functions, it is supposed to use a plasma panel connected to one of the computers of the department. The screen of this panel displays information about the department, its employees, history and achievements; various schedules, announcements, assignments, teaching materials, videos of the best lectures of teachers.

An interesting idea of “immersion” in digitalization can be borrowed from colleagues from the University of Technology Ilmenau (Germany). This is a wall clock that shows the time in binary code (Fig. 6).

Figure 6 – Wall clock with binary digits (current time 08-54)

A useful element of corridor equipment is a lighting control subsystem, one of the modes of which is to reduce power consumption during lectures or when there is no movement along the corridor.

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The subsystems for monitoring the temperature and humidity conditions and controlling the lighting of the premises of the department, which have already been discussed above, should be integrated into the computer network of the department. In justified cases, student access to the premises of the department should be organized using radio frequency identification technology (RFID, Radio Frequency IDentification) and the RFID RC522 module connected to the Arduino board [15].

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To automate the process of experiment in the educational laboratory of the electrical profile, stands are used that contain microcontroller boards, current, voltage, temperature sensors and electricity meters. For example, it is a stand for studying thermal processes in a coil when an electric current flows through it. The stand contains a coil with built-in thermocouples. These thermocouples are connected to the analog inputs of the Arduino board. The received information is accompanied by timestamps and transferred to the server for storage and analysis. The exchange of information with the server occurs via a serial channel.

Due to the fact that almost 100% of students have laptops, and the experimental objects are small and have low power consumption, lectures and laboratory experiments can be alternated in the classrooms of the department, even within the same lesson, using the Smart EA laboratory.

In the direction of electrical engineering, students study about 10-15 departmental disciplines, for each of which, as a rule, they perform 5-10 laboratory work. If we also take into account that classes are held simultaneously for students of different years of study, not only laboratory, but also research work of students is carried out, and up to 20 students are present at one lesson, then we can estimate the scale of the problem. At present, the main ways to solve it are: cooperation of laboratories within the university, an increase in the duration of the working week of laboratories, the use of portable stands by students outside the university, cooperation of remote laboratories between universities, the use of laboratory stands based on multifunctional modules, the use of reconfigurable laboratory stands.

The key elements of the remote laboratory of the department are laboratory stands with the ability to remotely configure the electrical circuit of the experiment. Configuration involves changing the parameters and/or structure of the electrical circuit under test, input sources, loads and meters. The set of elements of such a stand is determined by the type of research object in the student’s laboratory work. The reconfiguration of digital circuits is solved by forming prohibitions / permissions for the passage of logical signals in the object of research by the controller circuit of the laboratory stand. A remotely controlled change in the structure of an analog node is made using relay modules interfaced with a microcontroller, Arduino. A microcontroller-controlled change in the resistance of electrical circuits is performed, for example, using modules based on digital potentiometers (RDAC, digital POT) from leading manufacturers of integrated circuits [16].

Conclusions. The main factors influencing the process of creating information and control systems of the university department are: digitalization requirements from the Ministry of Education and Science and university management; achievement of "smartization" of industrial, office, household facilities; internet of things; the need to adapt the laboratory complex to the conditions of online learning.

The main direction of the creation of ICS is: integration of all laboratories, classrooms, computer classes and administration of the department into a local network; the use of the computing power of the department to build a "smart space" in which the educational process takes place; transition to portable microprocessor laboratories for use both in the computer class and outside it; creation of modular remotely reconfigurable remote laboratories.

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Принципи побудови інформаційно-керуючої системи кафедри університету

Завдання цифровізації університету вирішуються як на верхньому кіберсоціальному рівні, так і на нижньому рівні автоматизації лабораторного обладнання. Кафедра, як об'єкт управління інформацією, що займає середній рівень в управлінській ієрархії, у відомих роботах не розглядається. Мета роботи – підвищити рівень цифровізації кафедри електротехніки шляхом створення сис-

теми управління інформацією, яка поєднують навчальний процес, що проводиться на кафедрі, з інфраструктурою приміщень кафедри. Систематизовано концепцію інформаційно-управляючої системи кафедри університету, яка здійснює підготовку фахівців електротехнічного профілю. Запропоновано принципи побудови та структурну схему такої системи, в якій об'єднані в локальну мережу комп'ютерний клас, навчальні лабораторії, адміністрація, аудиторії, віддалена лабораторія і навіть коридор навчального корпусу. Описано варіанти використання елементів ІКС у навчальному процесі та процес моніторингу параметрів обладнання та приміщень кафедри. Це включає опис портативної лабораторії для вивчення електроніки, мікропроцесорів, програмованих логічних контролерів та електричних пристроїв. Таким чином, основним напрямком цифровізації кафедр університету є створення ІКС, яка об'єднує всі лабораторії, аудиторії, комп'ютерні класи та адміністрацію кафедри в локальну мережу; використання обчислювальної потужності кафедри для побудови «розумного простору», в якому відбувається навчальний процес; перехід на портативні мікропроцесорні лабораторії для використання як в комп'ютерному класі, так і поза ним; створення модульних дистанційно реконфігурованих віддалених лабораторій.

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