СЕКЦІЯ 1
ЕКОНОМІКА ТА УПРАВЛІННЯ НАЦІОНАЛЬНИМ ГОСПОДАРСТВОМ

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ENSURING SAFE RESOURCE UTILIZATION OF LIVING SPACE THROUGH CONTROL OF THE MICROCLIMATE OF A SMART HOME

The article is devoted to the research on ways of economical consumption of resources by virtue of the analysis of the accumulated history of settings of the microclimate control system of a smart home according to the HVAC system approach, depending on various factors (the presence of residents in the living space, meteorological indicators and forecasts, time of day, etc.), as well as the obtained financial and energy benefit. The relevance of the topic has been emphasized in the last two years due to the increase in the price of energy resources for the residential sector and gas blackmail from the Russian Federation, as well as the need to transform the energy consumption sector at the level of European standards and rebuild energy-independent climate-neutral cities in order to ensure the European future and Ukraine's membership in the EU. As a result of the work, the set goal was achieved: the possibility of energy-efficient remote control of actuators to reduce resource consumption is shown on the example of a designed smart home with the function of indoor microclimate control. For this purpose, an intuitive interface of the developed operator panel is proposed, which is served by a web application with a client-server architecture for the accumulation of historical data for the purpose of performing regression analysis in the future.
Keywords: energy efficiency, resource saving, smart home, statistical data, microclimate, sensor, actuator.

Барковська О.Ю., Росінський Д.М., Міхайлов І.О., Вінтонович М.С. ЗАБЕЗПЕЧЕННЯ ЗАОЩАДЛИВОГО РЕСУРСОСПОЖИВАННЯ ЖИТЛОВИМ ПРОСТОРОМ ЧЕРЕЗ КОНТРОЛЬ МІКРОКЛІМАТУ РОЗУМНОГО БУДИНКУ

Робота присвячена пошуку шляхів заощадливого споживання ресурсів завдяки аналізу накопиченої історії налаштувань системи контролю мікроклімату розумного будинку відповідно до системного підходу HVAC, залежно від різних факторів (присутності мешканців у житловому просторі, метеорологічних показників та прогнозів, часу доби тощо) а також отриманої фінансової та енергетичної вигоди. Актуальність тематики підкреслена останні два роки через здорожчення енергоресурсів для житлового сектору та газовий шантаж з боку Російської Федерації, а також через необхідність трансформації сфери енергоспоживання на рівні європейських стандартів та відбудови енергонезалежних клімат-нейтральних міст задля забезпечення європейського майбутнього України та її членства в ЄС. Однією із поставлених задач дослідження було визначення головного вектору енергозбереження та ефективного використання енергоресурсу при проєктуванні розумних будинків. На прикладі спроєктованого розумного будинку із функцією контролю мікроклімату в приміщеннях показано можливість енергоефективного віддаленого управління актуаторами для зниження ресурсоспоживання у будинку. Для досягнення поставленої мети було проаналізовано існуючі вимоги до систем «розумний будинок»; спроєктовано підсистему контролю мікроклімату; розроблено засоби дистанційного моніторингу та керування мікрокліматом будинку. Розроблений веб-застосунок є зручним та зрозумілим, надає можливість встановлювати індивідуальні показники температури, вологості та рівня вуглекислого газу у різних приміщеннях помешкання, підвищуючи тим самим ступінь комфорту та досягаючи додаткового зниження ресурсоспоживання. Отримані результати стануть основою для проведення подальшого регресійного аналізу для визначення впливу таких предикторів, як обраний режим роботи розробленої системи, обрані типи обладнання, метеорологічні показники, на регресантів – загальну кількість споживаної електроенергії, фінансові щорічні витрати за використаний ресурс.

Ключові слова: енергоефективність, ресурсозбереження, розумний будинок, статистичні дані, мікроклімат, сенсор, актуатор.

Problem statement. A “smart home” should be understood as a system that is able to recognize specific situations occurring in the building and respond to them accordingly. This is the most progressive concept of human interaction with the living space: a person sets the desired environment with one command, and the automation, in accordance with external and internal conditions, sets and monitors the operating modes of all engineering systems and electrical devices [1; 2]. An important feature and characteristic of a smart home, which distinguishes it from other ways of organizing living space, is the ability to comprehensively use energy-saving modes of operation of various subsystems, achieving high energy efficiency. In addition, such systems should be available for purchase by the majority of citizens in order to ensure energy-efficient behavior of households and the rapid achievement of energy independence of entire cities [3].

Being in the living space, people will require, first of all, the safety and security of the specific parameters of the microclimate (air temperature and humidity, air movement, fresh air supply) [4]. Therefore, the key definition of the "smart home" system can be considered as follows: “a complex set of technical means and software for building an integrated automation system of engineering subsystems”. These subsystems include heating, water supply, air conditioning, and lighting (Figure 1). Exactly in these subsystems that the “Smartness” of the Home is embedded – how it will react to changes in the parameters of a set of sensors and emergency situations, and how the correct operation of individual subsystems will be ensured in the event of a failure of the central control part of the system or other parts of the system.

The implementation of a smart home system provides the following advantages [5]:

– unified control system that unites all services and allows solving all tasks of a single center;

– possibility of maximum saving of energy resources;

– the possibility of convenient remote control of the building.

One of the most popular ways to realize the concept of an intelligent home is the use of the KNX standard, a communication bus widely used for the automation of buildings. This standard is a development of the earlier EIB (European Installation Bus) development. KNX products are distributed under

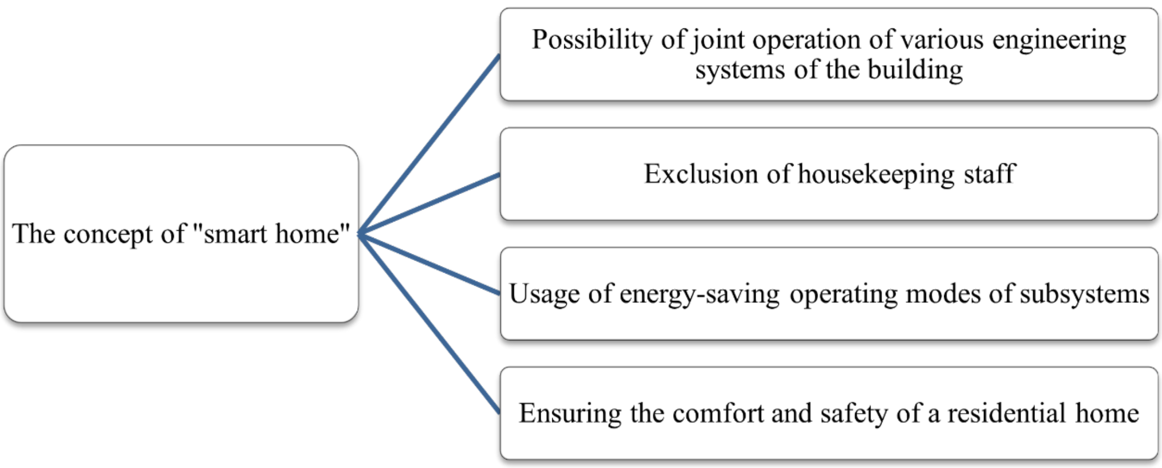


Figure 1. Component concepts of a smart home

several trademarks, such as Instabus, ABB i-Bus, Tebis, Theben. KNX is currently an open global standard supported by more than 300 manufacturers worldwide. This technology is a reflection of the logical development of requirements for engineering systems of buildings. In order to turn an ordinary home into an intelligent one, according to KNX technology, the following types of elements will be needed (Figure 2):

– controllers;
– sensors (detectors);
– actuators (executive devices).

Sensors are a mandatory receptor of a smart home [6; 7]. All sensors, used in a smart home, can be conventionally divided into two groups: those that monitor motion and those that respond to environmental parameters (Figure 3).

Analysis of recent research and publications. The creation of automated control systems for dozens of modern household devices can greatly facilitate life and make it more comfortable, which causes the spread of the "smart home" concept. In addition to the criterion of convenience, the relevance of this topic is due to the fact that every year the cost of resources consumed in everyday life increases steadily, which naturally affects the budget of every family.

One of the tasks of the research is to determine the main vector of energy saving and efficient use of energy resources when planning smart homes. One of the examples can be the use of intelligent thermostats, which adaptively respond to the climatic preferences of the residents of smart homes and, thus, reduce utility bills, allow you to control the heating and cooling system of the home by phone or voice, set temperature regime and choose energy-saving modes.

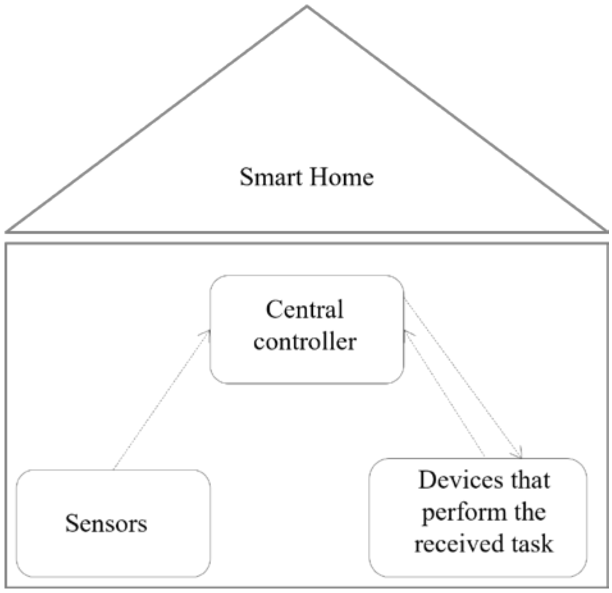


Figure 2. Structure of the "smart home" system

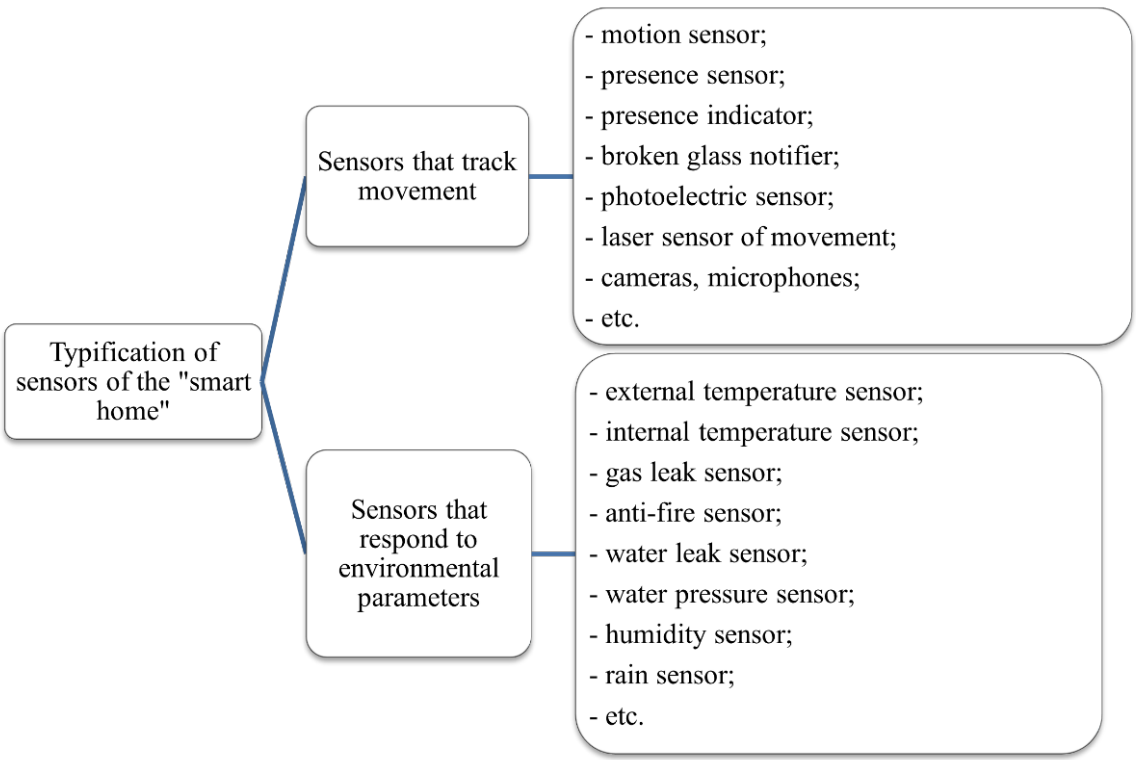


Figure 3. Typification of "smart home" sensors

If we focus on the subsystem of a smart home, which is responsible for a comfortable microclimate, the first thing to consider is the HVAC (heating, ventilation, air conditioning) system, which is responsible for normalizing the temperature regime, humidity level [8; 9]. Table 1 reviews and summarizes the main functions of climate-control in the "smart home", which are used and are relevant today.

The purpose of the article. The goal of the work is to show the possibility of energy-efficient remote control of actuators to reduce resource consumption in the home on the example of a designed smart home with the function of indoor microclimate control.

To achieve the set goal, the following tasks must be solved:

– analysis of existing requirements for "smart home" systems;

– microclimate control subsystem design;

– development of means of remote monitoring and control of the microclimate of the home.

Presentation of the research material and its main results. Figure 4 presents a generalized structural diagram of the placement of the components of the "smart home" system for monitoring the comfort conditions of the residence. The presented scheme is built on the basis of the Arduino WeMos D1 WiFi UNO ESP8266 controller and includes the following subsystems:

– air quality control subsystem;

– room temperature and humidity control subsystem;

– monitoring and control subsystem.

A system simulation was performed to demonstrate the connection of the components and to check the functionality. Sensors are connected and tested in sequence. Connected sensors record the level of CO_2 in the room, as well as the temperature and humidity of the air. When the set range of readings is exceeded, the values are gradually corrected by turning on or off the operating devices – heater, humidifier, air conditioner. The initial settings of the system, namely, the name and password for the possibility of authorized remote monitoring of the performance and indicators of the system, as well as the recommended ranges of temperature, humidity, carbon dioxide level, are stored on the card reader and read by the controller at the start of operation. The functioning of the proposed system occurs in accordance with Figure 5.

The formalization of the logic of the system's operation in automatic mode precedes the drawing up of the layout and the performance check on the finished device of the system of automatic monitoring and control of the comfort conditions of the "smart

Table 1

Climate-control options in the "smart home" system

Function	Description
Heating control	ensuring a comfortable temperature in the rooms; reduces energy consumption by keeping the room temperature at a set minimum level or warming up the rooms before returning home
Warm floor control	automatic change of the floor temperature to the set parameters at the set time of the day to reduce heating costs
Ventilation control	continuous monitoring of the carbon dioxide level in the premises; if necessary, the ventilation system turns on automatically (if its operation is not required, the equipment switches to energy-saving mode)
Fan coil control	control of blowing power and coolant supply, which are often used in rooms with panoramic glazing; allows you to provide not only a comfortable climate, but also the most silent mode of operation of this element of the heating system
Humidity control and air purification	automatic maintenance of the optimal humidity level; air purifiers help to remove microparticles of dust, pet hair, etc., reducing the risk of possible allergic manifestations
Complex control of the microclimate	is used in the case when not only radiators can be used as a standard for heating the room, but also a warm floor, air conditioner and fan coils are connected, if the power of the radiators is not enough
Parameters, that set individually for different rooms	depending on the purpose of the room, the time of day or the presence of people, the optimal climate will be maintained (for example, guest rooms that should be in the "conservation" mode the longest)
Continuous monitoring of climate-control equipment	prevention of abnormal situations (for example, when the gas heater is turned off, the electric boiler will automatically turn on, which will prevent freezing of the coolant and notify the responsible person)

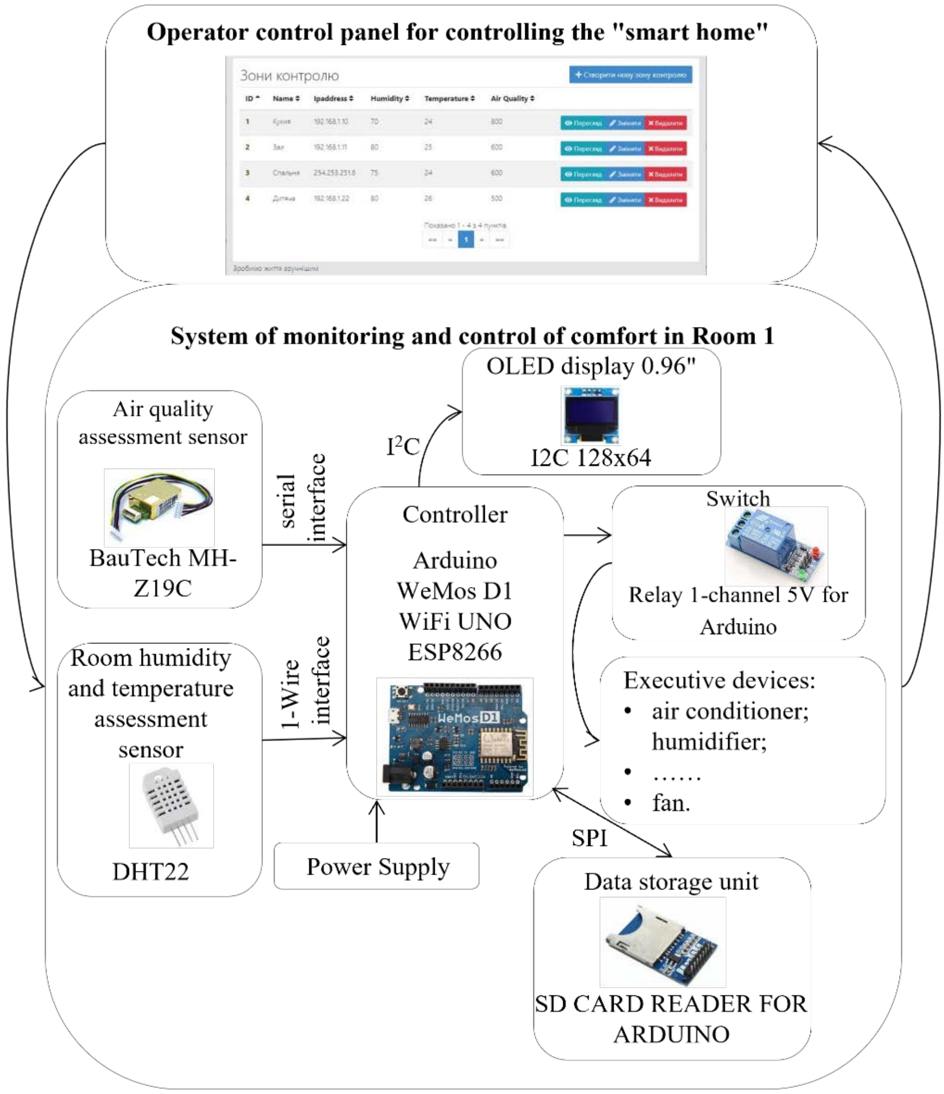


Figure 4. Generalized structural diagram of the placement of components of the "smart home" system

home" residence. Digital inputs from the 2nd to the 13th are used for connection; 0 and 1 inputs are used for data exchange between the Arduino and the computer.

Ports 2 and 3 are used to connect a sensor for determining the level of carbon dioxide in the home. A software serial port is implemented on them. Port 4 is used to connect the DHT-22 humidity and temperature sensor. Ports 5 and 6 are used to connect the OLED screen to make sure the sensors are working. Ports 7, 8 and 9 are load control outputs that control the relay modules. Each module has an amplifier on one transistor. Ports 10, 11, 12, and 13 are used to connect the memory card, which is powered by the 3.3 V pin on the Arduino board.

For testing purposes, the entire circuit can be powered by a USB cable connected to a computer. However, the platform is capable of connecting power from a source in the voltage range of 9 V to 15 V.

There are six LEDs on the layout, which symbolize turning on or off the temperature, humidity and carbon dioxide control devices.

A client-server web application was created in which the client interacts with the server (based on the controller) using a browser to implement the remote possibility of monitoring and making changes to the permissible ranges of temperature, humidity and carbon dioxide levels in the room by the user (operator). The logic of the web application is distributed between the server and the client, information exchange takes place over the network, using the capabilities of the built-in Wi-Fi module on the WeMos D1 board (Figure 6).

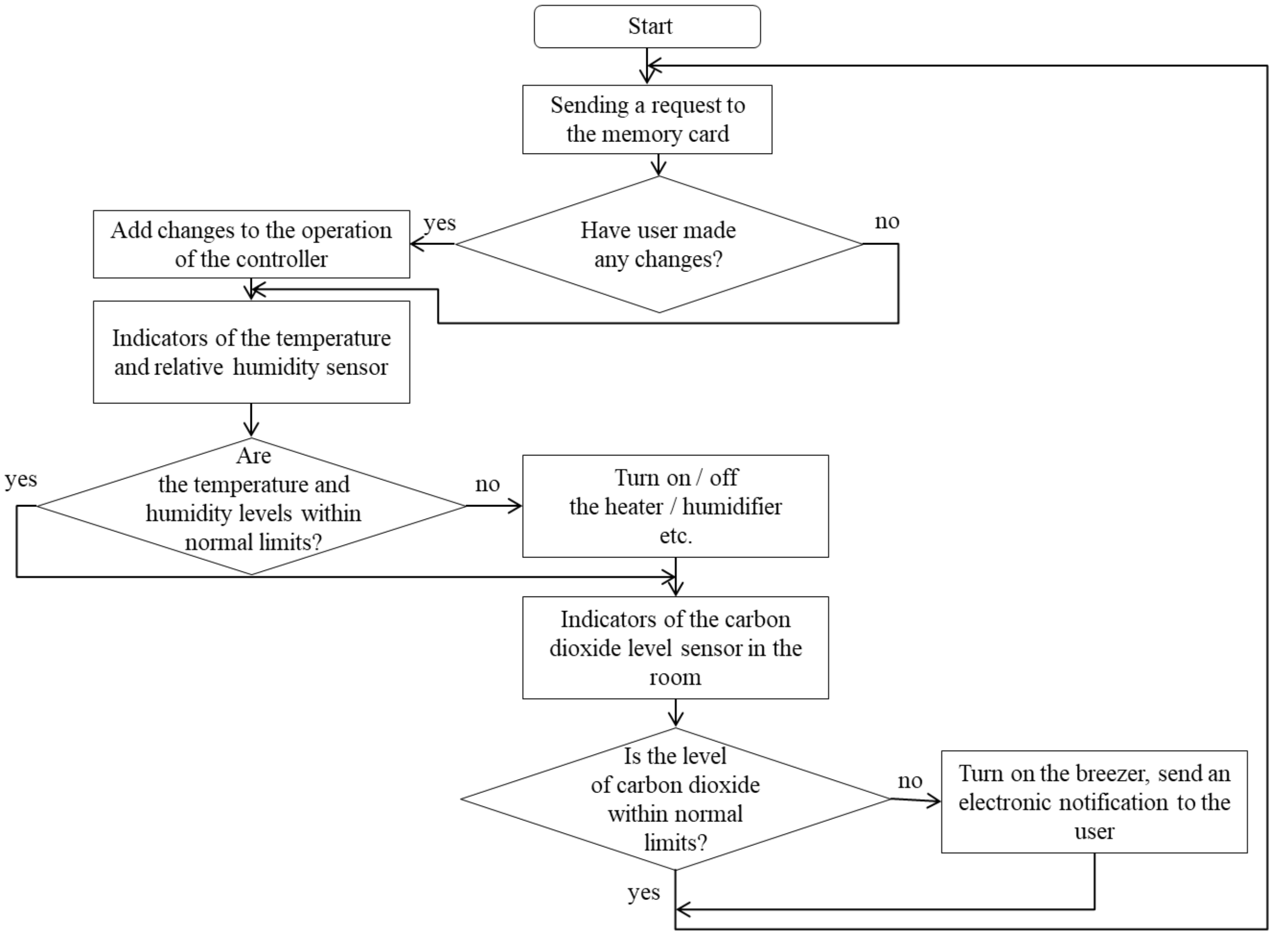


Figure 5. Functioning of the system for monitoring and controlling microclimate parameters in the premises of the "smart home"

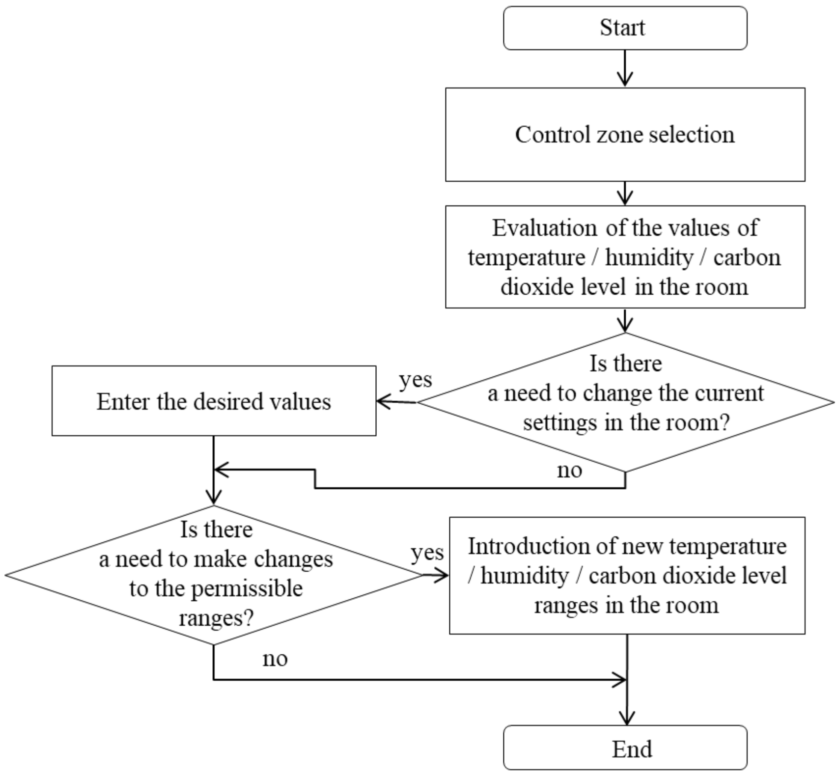
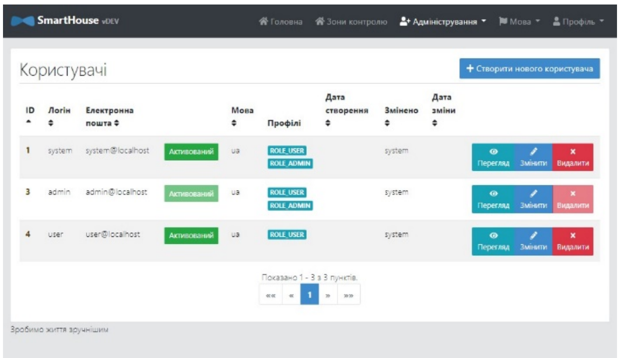
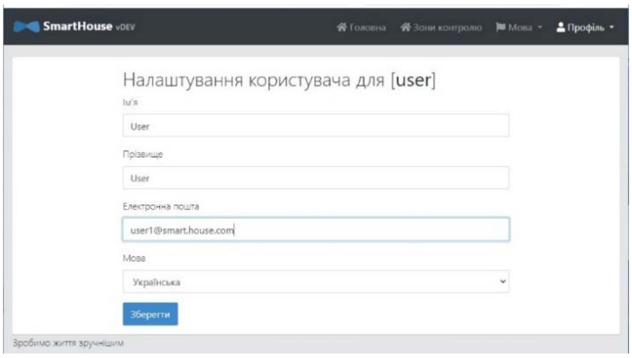


Figure 6. Logic of interaction with the system in remote mode





a) b)

Figure 7: a) user roles on the administration panel; b) adding a new user by the administrator

Before starting work, an administrator account is first created, which is granted the following rights:

– add, configure rights and edit user rights (Figure 7a);

– add control zones;

– set and change the permissible ranges of indicators.

After creating a new account in the system and setting up the user profile, it is possible to log in automatically or using a login and password. Adding control zones, as well as setting comfort indicators of temperature, humidity and carbon dioxide level for different control zones, is provided only for the system administrator (Figure 8).

While in zone creation or editing mode, the administrator can set the zone name and desired ranges depending on the purpose of the room (Figure 9). A user with rights other than administrator rights can view statistics and changes in indicators over the last time (Figure 10).

Conclusions. “Smart home” is able to comprehensively use energy-saving modes of operation of various subsystems, achieving high energy efficiency. One of the first needs of a person who is in a living space is to ensure certain parameters of the microclimate. If we focus on the subsystem of a smart home, which is responsible for a comfortable microclimate, then the HVAC (heating, ventilation, and air conditioning) system, which is responsible for normalizing the temperature regime and humidity level, is primarily considered.

One of the tasks of the research was to determine the main vector of energy saving and efficient use of energy resources in the design of smart buildings. Using the example of a designed smart home with the function of indoor microclimate control, the possibility of energy-efficient remote control of actuators to reduce resource consumption in the home is shown. To achieve the goal, existing requirements for “smart home” systems were analyzed; microclimate control subsystem was designed; tools for remote monitoring and control of the microclimate of the home have been developed.

The developed web application is convenient and understandable, provides an opportunity

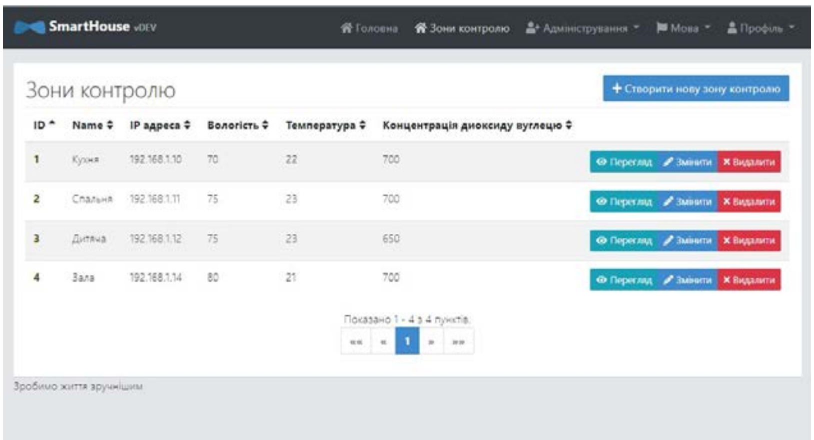


Figure 8. Administrative panel

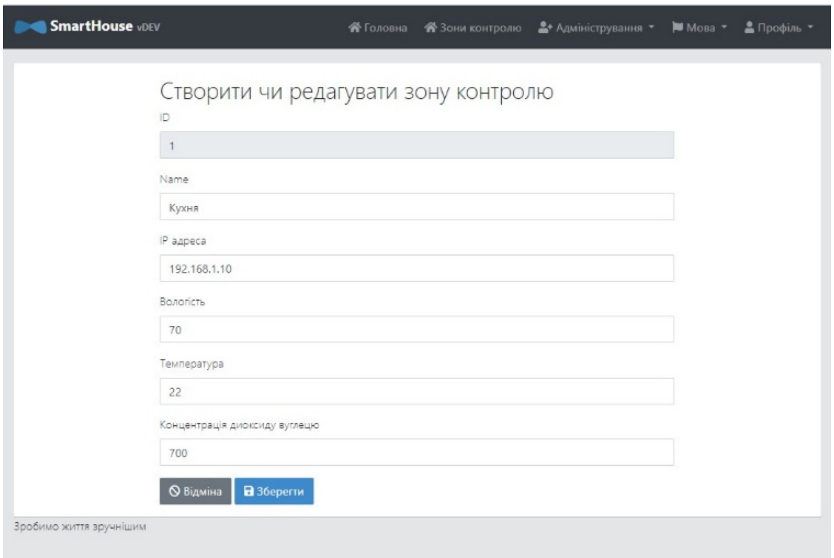
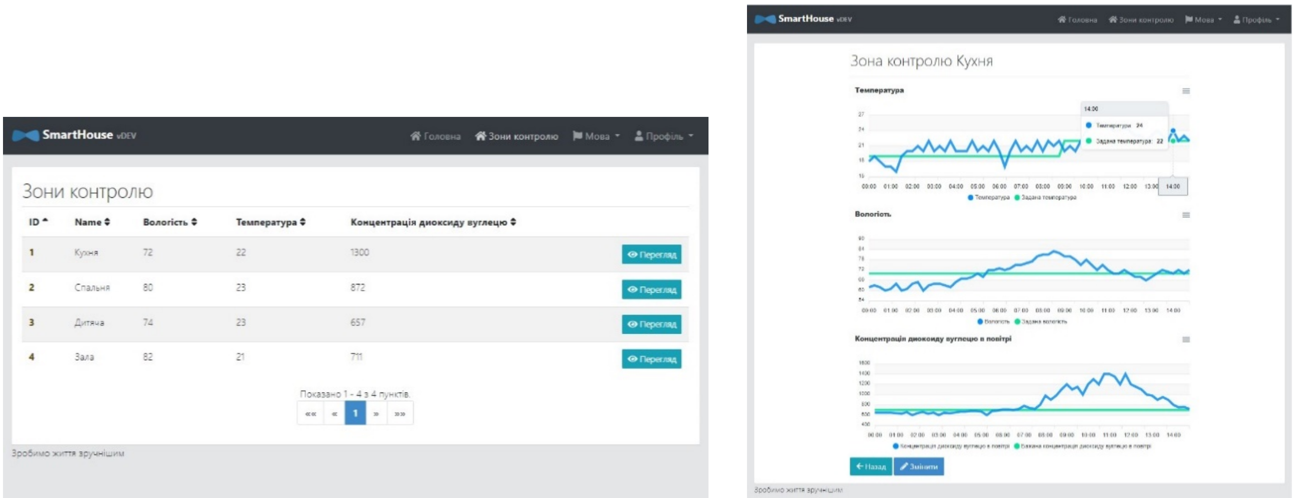


Figure 9. Parameters for setting desired humidity, temperature and carbon dioxide levels for different control zones



a) b)

Figure 10. User panels: a) view indicators; b) statistical analysis

to set individual indicators of temperature, humidity and carbon dioxide level in different rooms of the home, thereby increasing the degree of comfort and achieving an additional reduction in resource consumption.

The obtained results will be the basis for further regression analysis to determine the impact of such predictors as the selected operating mode of the developed system, selected types of equipment, meteorological indicators, on the regressors – the total amount of consumed electricity, annual financial costs for the used resource.

Further research will focus on:

– determination of the efficiency ratio of the system according to established schedules;

– determining optimal system settings depending on external weather conditions and meteorological indicators (for example, the possibility of using an air conditioner or a boiler as a heater), as well as depending on the presence of residents of the house (for example, based on the presence of the MAC address of the device of the residents of the house in the list of devices, connected to local Wi-Fi);

– forecasting annual savings to increase financial motivation of consumers.

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