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Завідувач випускової кафедри

Віктор СИНЄГЛАЗОВ

« » _______ 2023 р.

КВАЛІФІКАЦІЙНА РОБОТА

(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ

«БАКАЛАВР»

Спеціальність 151 «Автоматизація та комп’ютерно-інтегровані технології»

Освітньо-професійна програма «Комп’ютерно-інтегровані технологічні процеси і виробництва»

Тема: Система енергозбереження розумного будинку

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MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

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“___” _____________ 2023

QUALIFICATION WORK

(EXPLANATORY NOTE)

BACHELOR'S DEGREE GRADUATE

Topic: Smart home energy saving system

Done by: student of the group KP-404ba Matviienko Daryna Ivanivna

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Kyiv 2023

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

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Освітній ступінь: бакалавр

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ЗАТВЕРДЖУЮ

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ЗАВДАННЯ

На виконання кваліфікаційної роботи студентки

Матвієнко Дарини Іванівни

1. **Тема роботи**: «Система енергозбереження розумного будинку».
2. **Термін виконання роботи** з 22.05.2023 р. по 15.06.2023 р.
3. **Вихідні дані до роботи**: Розробка системи енергозбереження на базі розумного будинку у однокімнатній квартирі.
4. **Зміст пояснювальної записки** (перелік питань, що підлягають розробці):
1. Аналіз існуючих систем енергозбереження на базі розумного будинку; 2. Розробка власного проекту з енергозбереження у однокімнатній квартирі.
5. **Перелік обов’язкового графічного матеріалу**: Блок схеми енергозбереження у кімнатах квартири, алгоритми роботи систем енергозбереження.

6. **Календарний план-графік**

№ п/п	Завдання	Термін виконання	Відмітка про виконнання
1.	Отримання завдання	22.05.2023-23.05.2023	
2.	Формування мети та основних завдань дослідження	22.05.2023-23.05.2023	
3.	Аналіз існуючих методів	25.05.2023-26.05.2023	
4.	Аналіз існуючих мікроконтролерів та датчиків	27.05.2023-29.05.2023	
5.	Складання структурних схем	30.05.2023-06.06.2023	
6.	Розробка алгоритмів	07.06.2023-08.06.2023	
7.	Апаратна база	08.06.2023-09.06.2023	
8.	Розробка коду	10.06.2023-15.06.2023	

7. **Дата видачі завдання** “22” травня 2023

Керівник: ______________________________ Микола ВАСИЛЕНКО

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Specialty: 151 “Automation and computer-integrated technologies”

Educational and professional program "Computer-integrated technological processes and production"

APPROVED

Head of Department

Viktor SINEGLAZOV

“___” ______________ 2023

TASK

For the student`s thesis

Matviienko Daryna Ivanivna

1. **Theme of the project:** Smart home energy saving system
2. **The term of work performance** from 22.05.2023 to 15.06.2023
3. **Output data to the project (work):** Development of an energy saving system based on a smart home in a one-room apartment**.**
4. **Contents of the explanatory note (list of questions to be developed):** 1. Analyse existing energy saving systems based on a smart home; 2. Develop your own energy saving project in a one-room apartment.
5. **List of compulsory graphic material:** Block diagram of energy saving in apartment rooms, algorithms of energy saving systems.

6. Planned schedule:

№	Task	Execution term	Execution mark
1.	Task receiving	22.05.2023-23.05.2023	
2.	Purpose formation and describing the main research tasks	22.05.2023-23.05.2023	
3.	Analysis of existing methods	25.05.2023-26.05.2023	
4.	Analysing existing microcontrollers and sensors	27.05.2023-29.05.2023	
5.	Drawing up structural diagrams	30.05.2023-06.06.2023	
6.	Development of algorithms	07.06.2023-08.06.2023	
7.	Hardware for the system	08.06.2023-09.06.2023	
8.	Code development	10.06.2023-15.06.2023	

7. Date of task receiving: “22” May 2023

Diploma thesis supervisor ______________ Mykola VASYLENKO

Issued task accepted _______________ Daryna MATVIIENKO

РЕФЕРАТ

Пояснювальна записка кваліфікаційної роботи «Система енергозбереження розумного будинку» 49 ст., 9 рис., 7 джерел.

СИСТЕМА ЕНЕРГОЗБЕРЕЖЕННЯ, РОЗУМНИЙ БУДИНОК, ОПТИМІЗАЦІЯ СПОЖИВАННЯ ЕНЕРГІЇ, ВИТРАТИ ЕНЕРГІЇ, ЕНЕРГЕТИЧНА ЕФЕКТИВНІСТЬ, НАВКОЛИШНЄ СЕРЕДОВИЩЕ.

Об'єкт дослідження – система енергозбереження розумного будинку, з фокусом на оптимізацію споживання енергії та підвищення енергетичної ефективності в однокімнатній квартирі.

Предмет дослідження – розробка та впровадження системи енергозбереження в розумному будинку.

Мета кваліфікаційної роботи - розробка та впровадження системи енергозбереження для однокімнатної квартири в контексті розумного будинку. Основним завданням є дослідження та впровадження ефективних технологій, що дозволять оптимізувати споживання енергії, забезпечуючи зручність та комфорт для мешканців. Дана робота спрямована на зменшення витрат енергії, підвищення енергетичної ефективності та зниження впливу на навколишнє середовище, сприяючи сталому розвитку житлового сектору.

Метод дослідження – теоретичний аналіз

Отримані результати та їх новизна – в ході цієї дипломної роботи було розроблено власну систему енергозбереження за технологією розумного будинку. Розумна система енергозбереження для розумного будинку поєднує інтеграцію технологій та автоматизацію, що дозволяє оптимізувати споживання енергії та знизити витрати.

Рекомендації щодо використання результатів роботи - Отримані висновки можуть бути застосовані при проектуванні та будівництві майбутніх енергоефективних будинків.

ABSTRACT

Explanatory note of the qualification work "Energy saving system of a smart home" 49 pages, 9 figures, 7 sources.

ENERGY SAVING SYSTEM, SMART HOME, ENERGY CONSUMPTION OPTIMIZATION, ENERGY CONSUMPTION, ENERGY EFFICIENCY, ENVIRONMENT.

The object of the work is a smart home energy saving system, with a focus on optimizing energy consumption and improving energy efficiency in a one-room apartment.

The subject of the work is the development and implementation of an energy saving system in a smart home.

The purpose of the qualification work is to develop and implement an energy saving system for a one-room apartment in the context of a smart home. The main task is to research and implement effective technologies that will optimize energy consumption, providing convenience and comfort for residents. This work is aimed at reducing energy consumption, increasing energy efficiency and reducing environmental impact, contributing to the sustainable development of the residential sector.

Research method - theoretical analysis

Results obtained and their novelty - in the course of this thesis, I developed my own energy saving system based on smart home technology. A smart energy saving system for a smart home combines technology integration and automation to optimise energy consumption and reduce costs.

Recommendations for the use of the results of the work - The findings can be applied to the design and construction of future energy efficient buildings.

Зробити контент і скорочення на наступній сторінці

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GLOSSARY

EMS – energy managememt system

IoT – Internet of Things

SoC – system of chip

BI – business intelligence

A-SEM – adaptive smart energy tool

HEMS – home energy management system

MIQP – mixed-integer quadric programming

CPU – control process unit

CDU- control display unit

SP – smart plug

PTD – photodiode

PS – presence sensor

DRV – driver

INTRODUCTION

Energy-saving systems in smart homes allow for the efficient use of energy resources and improve the quality of life of residents. One-room apartments, despite their limited space and resources, have significant potential for implementing such systems.

Optimizing the use of lighting and electrical appliances is one of the key benefits of implementing energy-saving systems in a one-room apartment. With the help of a smart system, lights can automatically turn off and appliances can be switched off when no people are present or when they are not needed. This helps to avoid unnecessary energy consumption and reduce electricity bills.

In addition, the smart home system can monitor and regulate the temperature in the apartment. Using sensors, the system detects the presence of people in the room and adjusts the optimal temperature depending on this factor. This approach helps to efficiently use energy for heating and air conditioning, which leads to lower heating and air conditioning costs.

The development of energy saving systems in one-room apartments using smart homes is an important step towards sustainable development and energy efficiency. This development allows us to optimize the use of energy resources to the maximum extent possible, ensures the comfort and safety of residents, and helps to reduce energy costs. Smart homes are an innovative solution that can help solve the problem of energy inefficiency and contribute to the sustainable development of the housing sector.

CHAPTER 1

JUSTIFICATION OF THE NEED FOR DEVELOPMENT

Today, the issue of energy conservation is becoming increasingly important around the world. This is not only an economic benefit for consumers and a reduction in the load on the power grid, but also, and most importantly, the preservation of the environment for future generations.

The problem of energy conservation has arisen due to the excessive use of natural resources, as well as the negative impact of human activity on our planet, such as greenhouse gas emissions.

The European Union has committed to reducing its annual primary energy consumption by 20% by 2020. Ukraine, as well as other former Soviet countries, has not yet reached a satisfactory level of energy saving measures, and the situation in the housing and utilities sector is critical.

Therefore, practical steps towards energy saving are evidence of the culture and high level of consciousness of both society as a whole and each of its members. Given the constant increase in the number of household appliances and rising electricity tariffs, the implementation of energy-saving measures in everyday life is becoming even more important.

Energy conservation covers various types of activities, such as organizational, scientific, practical and informational, aimed at the rational use and economical consumption of primary and converted energy and natural energy resources. These actions are carried out using technical, economic and legal methods. The energy efficiency of a building is defined as the amount of energy required to create comfortable living conditions or human activity in that building. Energy efficiency projects are aimed at reducing energy consumption by reconstructing supply networks and systems, regulating and metering the use of water, gas, heat and electricity, as well as modernizing building envelopes and production processes. The main benefits of energy saving:

– reducing the use of natural resources;
– reduced energy costs;
– ensuring energy security;
– improving air quality and health.

Ukraine has a comprehensive state energy saving program, which has the following objectives: to analyze the current state and forecast economic development, determine the main directions of state energy saving policy, create a regulatory framework for energy saving, form a favorable economic environment, and create a coherent and effective system of state energy saving management. The strategic goal of this program is to overcome the energy and economic crisis in Ukraine and reach the level of advanced countries in terms of energy consumption.

Also, the issues of efficient energy consumption in buildings are regulated by DSTU B EN 15232:2011 "Energy efficiency of buildings - Impact of automation, monitoring and control of buildings". This standard is a translation of EN 15232:2007 "Energy performance of buildings - Impact of Building Automation, Controls and Building Management", developed by the European Technical Committee for Standardization CEN/TC 247 Building Automation, Controls and Building Management, and includes requirements that are in line with the current legislation of Ukraine.

Given all of the above, it is clear that the problem of energy conservation in Ukraine is an urgent one. It is impossible to achieve great success at once, but it is easier to start with yourself. Specific examples of energy saving include the use of energy-efficient household appliances; saving on lighting; and proper operation of existing household appliances. However, despite the fact that even these measures can yield results, there is a more effective and modern solution - a smart home.

First, it would be useful to understand the definition of a smart home. A smart home is a residential structure that uses advanced technologies and interconnected devices to facilitate, optimize, and provide convenience, efficiency, comfort, and safety in the living environment. These intelligent systems and devices automate various aspects of everyday life, including home management, energy management, entertainment, security, and environmental control. Through the use of sensors, connections, and intelligent automation, a smart home enables residents to remotely monitor their homes, optimize resource use, and customize their living environment to meet their personal preferences and needs. There are many benefits to using smart home technology, such as:

- the ability to control all devices from one place;
- maximizing home security by integrating security and video surveillance functions;
- improving the energy efficiency of your home;
- the ability to obtain valuable information about home management, and so on.

However, there are also some disadvantages:

- connecting systems from different manufacturers can be a difficult task;
- systems can be expensive;
- these devices have security vulnerabilities and can be hacked.

Thus, the main goal of this research is to develop and implement an energy saving system for smart homes with a focus on optimizing energy consumption while providing comfort and convenience for residents. The main objective of the work is to reduce energy consumption, increase energy efficiency and reduce the negative impact on the environment in order to promote the sustainable development of the modern residential sector. This study aims to identify the potential and benefits of smart energy saving systems, as well as to develop recommendations for further implementation in construction and smart home design. The implementation of this work will open up prospects for improving the energy efficiency of smart homes and make an important contribution to the development of modern society.

CHAPTER 2

ANALYSIS OF EXISTING SYSTEMS USING SMART HOME TECHNOLOGY AND A SELECTION OF DEVICES

2.1 Analysis of existing systems

Today, there are many different approaches in the scientific literature aimed at ensuring high energy efficiency and energy saving in the context of smart buildings.

2.1.1 Analysis of the benefits and risks of smart homes.

The article "Benefits and risks of smart home technologies" analyzes the benefits and risks associated with the use of smart home technologies from different perspectives. It is noted that the main risks are the possibility of losing autonomy and independence in the home due to the growth of technological control. An additional risk is the lack of attention of smart home technology developers to measures to increase consumer confidence in data security and privacy.

To effectively manage these risks and support the energy efficiency potential of smart home technologies, an adequate risk management policy is needed. Such policies could include design and operational standards, data and privacy guidelines, quality control, and regional research programs. These measures will contribute to the development of the smart home technology market.

2.1.2 Analysis of the smart home concept and the interaction of residents with the building management system

The article "An Overview of the Smart Home Concept and the Interaction of Residents with the Building Management System" [2] provides a detailed analysis of the current smart home concept. In recent years, the emphasis in energy efficiency has been on promoting the use of devices and components that are more efficient. However, it should be understood that home automation plays a key role in achieving efficient and stable operation. Smart home automation is especially important for ensuring sustainable indoor comfort and energy-efficient management of the home system. These goals are achieved through the following methods:

- detecting and eliminating energy losses;
- rationalizing energy use according to need, place, and time;
- properly controlling the functional level of the system to ensure it is applied correctly in the right place.

2.1.3 Analysis of the energy management system usingIoT and big data analytic approach

The paper "A smart home energy management system using IoT and big data analytics approach" [3] presents an Energy Management System (EMS) for a smart home. In this system, each home device is connected to a data collection module that is part of the Internet of Things (IoT) and has a unique IP address, and all devices form a wireless network. The System on Chip (SoC) collects energy consumption data from each device in each smart home in different residential areas and transmits this data to a centralized server for further processing and analysis. This information is accumulated on the server in the form of large amounts of data (Big Data). To manage energy consumption and meet consumer demand, the EMS uses Business Intelligence (BI) and Big Data analytics software packages. For the experimental study of the proposed system, heating, ventilation and air conditioning devices were used.

The developed system allows for effective energy management in a smart home by collecting, analyzing, and using large amounts of data. It provides convenient and efficient management, allowing users to reduce energy consumption, optimize its distribution, and ensure comfortable living conditions. The use of IoT and big data technologies allows the system to collect a significant amount of information, and Business Intelligence analytical tools make this information accessible and useful for energy management decision-making. Experimental studies using heating, ventilation, and air conditioning devices confirm the operability and efficiency of the proposed energy management system in a smart home.

Disadvantages of a Smart Home Energy Management System using IoT and Big Data Analytics Approach:

- implementing a smart home energy management system requires an upfront investment in IoT devices, sensors, and infrastructure. The cost of these components can be a barrier for some homeowners, potentially limiting widespread adoption.

- setting up and maintaining a smart home energy management system can be technically challenging for some homeowners. It requires expertise in IoT devices, network configuration, data analytics, and system integration. Users may need assistance from professionals or support services to overcome technical difficulties;

- dependence on internet connectivity and reliable communication between IoT devices is crucial for the smooth functioning of a smart home energy management system. Any disruptions in connectivity or device malfunctions can impact the system's effectiveness, potentially causing inconvenience or energy wastage.

2.1.4 Analysis of an adaptive smart energy management testbed for shiftable loads optimization in smart home

Ensuring efficient energy consumption often affects the level of comfort, which is quite important for users. The paper "An adaptive smart energy management testbed for shiftable loads optimization in the smart home" [4] presents an adaptive intelligent energy management tool known as the Adaptive-Smart Energy Management Tool (A-SEM), which aims to balance comfort and energy efficiency.

This approach uses an adaptive energy limitation algorithm based on an analysis of average daily energy consumption over 30 days. Energy consumption also depends on user behavior, which is monitored by the system. To monitor energy consumption, the system uses various sensors and is able to recognize user behavior in order to adapt the limits and ensure a comfortable level.

The smart home user can set a monthly energy consumption budget, which affects the initial daily energy limits. A-SEM performs real-time monitoring and control, with a focus on the parameters that were evaluated during testing. This approach allows the system to provide optimal energy management, ensuring user comfort and energy efficiency. The advantages of the adaptive smart energy management (A-SEM) tool include:

- the energy efficiency achieved through A-SEM leads to cost savings for users. By optimizing energy consumption, the tool helps to minimize energy bills, making it financially advantageous for both residential and commercial users.

- A-SEM can be integrated with demand response programs. These programs incentivize users to reduce their electricity consumption during peak demand periods, helping to balance the grid and avoid power shortages. A-SEM enables automated load shedding or load shifting based on demand response signals, allowing users to participate and contribute to grid stability.

- A-SEM offers a high level of customization to meet individual user requirements. It can adapt to the specific energy needs and preferences of users, considering factors such as occupancy patterns, weather conditions, and user-defined constraints. This adaptability enhances user comfort while optimizing energy usage.

Also, when analyzing the Adaptive-Smart Energy Management Tool (A-SEM), it is important to note the following risks:

- the success of A-SEM relies on user acceptance and willingness to adapt energy consumption behaviors. Some users may be resistant to change or may not actively engage with the tool, limiting its potential energy-saving benefits. Educating and incentivizing users to embrace energy-efficient practices is crucial for maximizing the tool's effectiveness.

- A-SEM needs to be compatible with existing energy-consuming devices and infrastructure within a building. Compatibility issues or the need for additional retrofits may arise, requiring careful consideration during implementation.

2.1.5 Analysis of a cyber-physical cloud-oriented multi-sensory smart home framework for elderly people.

The paper "Cyber-physical cloud-oriented multi-sensory smart home framework for elderly people: An energy efficiency perspective" [5] proposes an energy-efficient multi-sensory cyber-physical smart home system targeting the needs of the elderly, which takes advantage of cloud computing and big data technologies. Considering that it can be difficult for the elderly to perform complex actions to maintain energy efficiency, a smart multimedia assistant software was developed. This assistant allows a person to monitor various energy-efficient processes, control smart home devices using gestures, receive notifications about the status of devices, and more.

The server uses low-dimensional features available from sensors and multimedia sources to process data. To support the decision-making process, the server also automatically classifies events. To save energy, an automatic system has been developed to control the switching on/off of devices using speech or gestures. The control commands are keywords that are directly extracted from the spoken or performed gesture.

Experimental results show an encouraging potential for deploying the proposed framework on a large scale, demonstrating its effectiveness and suitability for use among the elderly. The main advantages of a Cyber-Physical Cloud-oriented Multi-Sensory Smart Home Framework for Elderly People are:

- the framework incorporates real-time energy monitoring capabilities, allowing elderly residents and caregivers to track energy consumption patterns. This visibility enables better awareness of energy usage and promotes conscious decision-making to reduce energy waste;
- the framework can integrate with renewable energy sources, such as solar panels or wind turbines. By optimizing the utilization of renewable energy and balancing it with the energy demands of the smart home, it enhances overall energy efficiency and promotes sustainability;
- the framework can provide personalized energy consumption feedback to elderly residents, offering insights on their energy usage habits and suggesting energy-saving measures. This feedback loop encourages energy-conscious behavior and empowers residents to make informed choices.

However, it is worth noting that, in addition to the initial investment, this technology is dependent on connectivity and can be difficult to adapt and accept by users.

2.1.6 Analysis of HEMS-IoT

The study "HEMS-IoT: A Big Data and Machine Learning-Based Smart Home System for Energy Saving" [6] proposes a HEMS-IoT system that provides smart home energy management with a focus on home comfort, security, and energy savings. This system combines the power of smart home devices and IoT connectivity to create a comprehensive energy management system. It provides seamless communication between various IoT-enabled devices such as smart appliances, thermostats, and energy meters, allowing you to effectively control and monitor your energy consumption.

HEMS-IoT enables remote control and automation of smart home devices. Users can remotely manage their appliances, adjust thermostat settings, and schedule energy-intensive activities to align with off-peak hours or when renewable energy sources are readily available. This convenience leads to energy savings and increased comfort for homeowners.

However, implementing this system may require initial setup efforts, including device installation, network configuration, and data integration. The complexity of integrating different devices and ensuring interoperability can be a challenge, especially for non-technical users. Proper support and user-friendly interfaces are essential to overcome these challenges.

The system uses the J48 machine learning algorithm and the Weka API to learn user behavior and energy consumption patterns. The application of these methods allows to classify buildings depending on their energy consumption. RuleML and Apache Mahout are used to create energy-saving recommendations that ensure the comfort and safety of a smart home, taking into account user preferences.

This integration allows the HEMS-IoT system to analyze large amounts of data, learn user habits and behavior, and make intelligent energy management decisions based on this. As a result, optimal energy consumption is achieved, ensuring the comfort, safety, and efficiency of a smart home.

It's important to note that the advantages and drawbacks of a HEMS-IoT system can vary depending on the specific implementation, device compatibility, and user requirements. Assessing individual needs, understanding the system's capabilities, and addressing security concerns are crucial steps in leveraging the benefits of a HEMS-IoT system while mitigating potential drawbacks.

2.1.7 Analysis of smart home energy management using mixed-integer quadric programming

The study "Comprehensive smart home energy management system using mixed-integer quadratic programming" proposes a comprehensive approach to energy management in a smart home. This approach is based on the construction of a partial-integer quadratic programming model that uses forecasting based on the temperature model of the building and the energy management system.

A key feature of the proposed predictive controller model is the ability to compute optimal solutions while taking into account continuous binary constraints and variables, as well as to take into account the thermal and electrical components of a smart home. The system also includes prediction of loads, building functions, and individual user requirements, with the prediction of building functions based on an unsupervised method.

This system allows you to control various devices, such as heating, battery, freezer, dishwasher, photovoltaic systems, as well as make purchases and sales through the smart grid. Optimal use of the building's heat capacity helps to minimize the need for battery capacity, which contributes to more efficient energy use. However, this system also has some limitations and drawbacks. Here are a few notable disadvantages:

- MIQP is a complex optimization technique that involves solving mathematical models with mixed-integer variables and quadratic objective functions. The computational complexity of solving these models can be high, especially for large-scale smart home systems with numerous appliances, energy sources, and constraints. The time required to find an optimal solution using MIQP can be significant, making real-time or near real-time decision-making challenging.

Limited Scalability: The complexity and computational requirements of MIQP may limit its scalability in large-scale smart home environments. As the number of devices, appliances, and energy sources increases, the optimization problem becomes more complex, requiring more computational resources. The system's scalability can be constrained by the computational limitations of the MIQP approach, making it less suitable for managing energy in extensive smart home deployments.

- MIQP models often require pre-defined optimization objectives, constraints, and assumptions. This lack of flexibility can be a disadvantage in dynamic smart home environments where energy demand, pricing, and availability fluctuate rapidly. Adapting the MIQP model to accommodate changing conditions or incorporating new energy management strategies may require significant modifications to the mathematical formulation, which can be time-consuming and challenging to implement.

- the effectiveness of an MIQP-based energy management system heavily relies on the accuracy of input data, including appliance power profiles, energy pricing, user preferences, and external factors like weather conditions. Any inaccuracies or uncertainties in the input data can lead to suboptimal or unreliable optimization results.

Despite these limitations, MIQP-based smart home energy management systems can still provide significant benefits in terms of energy optimization and cost savings. It is important to carefully assess the specific requirements and constraints of a smart home environment before implementing an MIQP approach and consider the trade-offs between computational complexity, scalability, and flexibility to determine its suitability for a given scenario.

2.2 A selection of devices.

Ensuring energy efficiency and the rational use of energy resources is a pressing issue in the development of smart homes and intelligent systems. One of the key aspects in achieving energy savings is the use of high-performance microcontrollers and sensors that monitor, control, and optimize energy consumption. This section will provide an overview of existing microcontrollers and sensors, their characteristics and capabilities in terms of energy saving. Highlighting the advantages and disadvantages of different devices will help you choose the most suitable components for implementing an effective energy management system in a smart home.

2.2.1 Selection of microcontrollers.

Arduino Uno: the Arduino Uno microcontroller is one of the most popular controllers in the smart home world. It is based on the ATmega328P chip from Microchip. The Arduino Uno attracts attention due to its ease of use and extensive programming capabilities. It has a large user community that makes it easy to find support and additional resources. However, the main disadvantage of the Arduino Uno is its limited energy saving capabilities due to the lack of low-power modes and a limited set of functionalities.

Raspberry Pi: the Raspberry Pi is another popular microcomputer that can be used to implement energy-saving systems in smart homes. The Raspberry Pi offers many input and output ports, wireless connectivity, and programming flexibility. In addition, it provides convenient access to the Linux operating system, which allows you to use a wide range of programs and services. However, the Raspberry Pi has a higher power consumption than other microcontrollers, which may not be appropriate for battery-powered systems.

ESP8266: the ESP8266 is a low-cost Wi-Fi microcontroller that provides the convenience of wireless communication in a smart home. It has low power consumption and a large number of input and output ports. The ESP8266 also supports the Arduino platform, which makes it quite easy to use and program. However, the ESP8266 may be limited in power for large systems and has some memory limitations.

STM32: STM32 microcontrollers from STMicroelectronics are powerful and reliable devices for energy saving systems in smart homes. They are based on the ARM Cortex-M architecture and have a wide range of features and capabilities. The STM32 offers different models with different levels of power consumption, which allows you to choose the best one for a particular project. However, STM32 programming can be more difficult compared to other microcontrollers.

2.2.2 Selection of presence detectors.

Infrared (PIR) sensors: Passive Infrared (PIR) presence sensors are one of the most common sensors used in smart home energy saving systems. They detect motion by observing changes in thermal radiation within a specified range. The advantages of PIR sensors are high reliability, fast response time, and low cost. They are effectively used to automatically turn on and off lights and other devices in rooms where motion detection is key. However, PIR sensors cannot accurately detect the presence of a person and do not respond to stationary objects.

Ultrasonic sensors: Ultrasonic presence sensors use sound waves to detect objects in space. They measure the time it takes for the sound signal to return after being reflected from an object and calculate the distance to the object based on this. Ultrasonic sensors can accurately detect the presence of people even if they are not moving, and they work regardless of lighting or temperature. However, they require more power to operate and can be vulnerable to obstacles that affect the reflection of sound waves.

Microwave sensors: Microwave presence sensors use electromagnetic waves to detect motion and presence. They differ from PIR sensors in that they do not respond to thermal radiation, but instead focus on the movement of objects in space. Microwave sensors can penetrate obstacles and work in different lighting and temperature conditions. However, they consume more power compared to PIR sensors and can be sensitive to unwanted flashes, such as moving trees or vehicles.

2.2.3 Selection of photodiodes.

Photodiodes with infrared (IR) sensitivity spectrum: are used to measure the light level in a room. They can respond to infrared radiation, which allows them to detect the presence of people in a room. This can be used to automatically turn lights on or off based on the presence of people.BPW34: The model is a low-consumption photodiode with a high response speed, making it effective for detecting fast-moving light. This photodiode is also characterized by high light sensitivity. The use of BPW34 in energy-saving applications can provide a fast and accurate response to lighting changes. However, it should be kept in mind that this model can be sensitive to noise and requires a high quality signal amplifier to achieve reliable measurement.

Photodiodes with a visible sensitivity spectrum: can be used to control the brightness of light in a room. They can detect light levels and transmit signals to control the lighting. This allows for optimal light brightness depending on user needs and natural light levels.

Photodiodes with motion sensors: some photodiodes can be combined with motion sensors to detect the movement of people in a room. They can be used to automatically turn on or off lights and other electrical appliances, which helps to use energy efficiently.

CHAPTER 3

SCHEMES AND ALGORITHMS

3.1 Structural schemes of energy saving

After analyzing some of the energy saving systems and conducting research, I present my proposals for implementing an energy saving project using smart home technology on the example of a one-room apartment. The presented energy saving system is able to recognize the presence of a person in the room and, accordingly, control the lighting and regulate the air temperature. The main goal of this project is the rational use of energy resources, in particular light and heat. In the diagram below (Fig. 3.1), you can see the structure of the energy saving system throughout the apartment. You can clearly see the connection between all the rooms, provided by Ethernet and a computer. Let's take a closer look at each room.

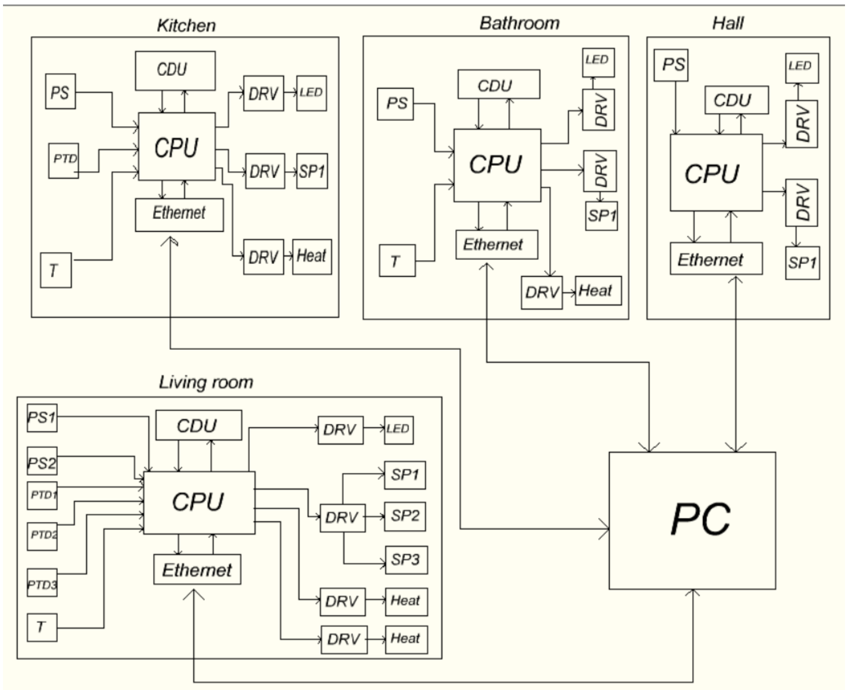


Fig. 3.1 Block diagram of energy saving system in a one-room apartment

To ensure an efficient energy saving system in the living room (Fig. 3.2) , a variety of components are used to form a complex and branched structure. At the entrance to the room from the corridor and balcony, there are infrared presence sensors that reliably detect the presence of people in the room. Unlike the motion sensors used in this project, infrared sensors are more effective because they take into account situations when a person is in the room without moving, for example, while reading a book or watching a film.

In order to control the lighting in the living room, photodiodes are placed on the windows and the entrance door from the balcony, collecting and transmitting data on the light level in the room. This avoids the unnecessary use of artificial lighting during the day, when there is sufficient natural light. The main source of light in the living room is a lamp that can be adjusted to provide the required level of illumination, varying from minimum to maximum.

In addition, the living room is equipped with two smart sockets that can be activated or deactivated as needed. The sockets, the lighting device, and the two heaters in the room are connected to the microcontroller via drivers that perform the control function. The drivers are activated in the event of an emergency, ensuring safe operation of the system and preventing possible hazards.

In general, this structure of the living room energy saving system allows you to use energy efficiently and provide comfortable living conditions, while reducing energy consumption and conserving resources.

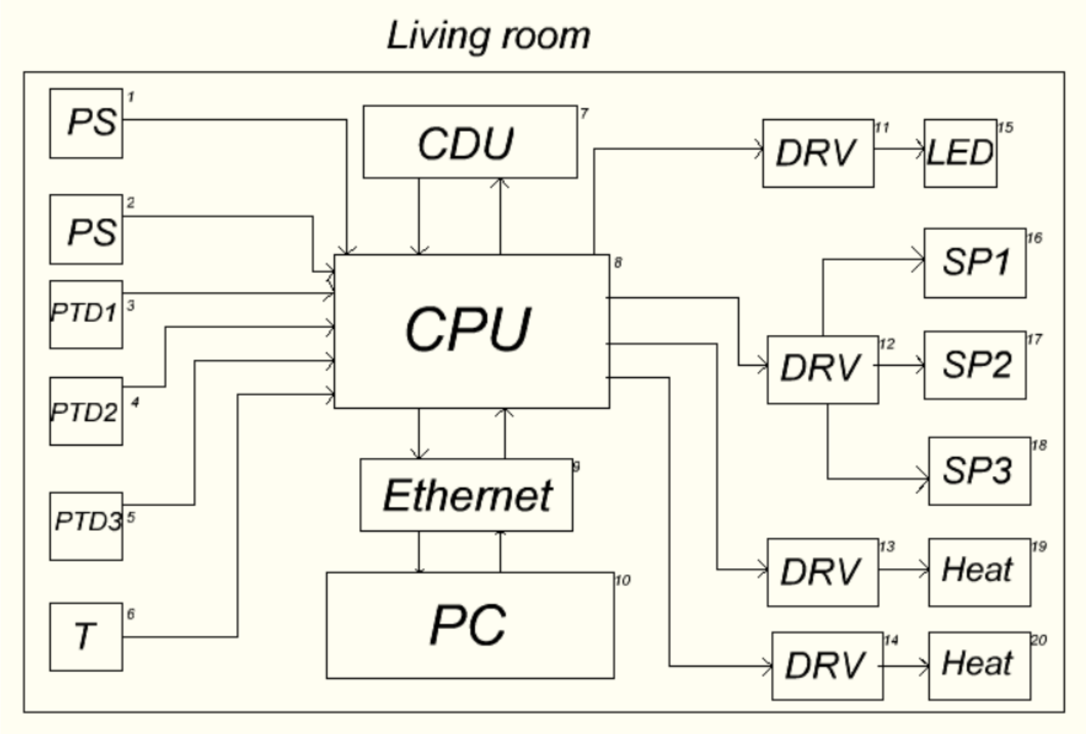


Fig. 3.2 Block diagram of energy saving system in the living room

The structure of the energy saving system in the kitchen (Fig. 3.3) is similar to that of the living room, using a variety of components to manage energy efficiently. An infrared presence sensor is placed at the entrance to the room to detect the presence of people in the room. This allows the system to monitor activity and adjust energy modes accordingly.

To make the best use of natural light, the kitchen has photodiodes that measure the level of illumination in the room. The collected data is transmitted to the control system, which allows the lighting to be adjusted according to the needs. This helps to reduce energy consumption and increase comfort in the kitchen.

The main light source in the kitchen is a lamp that is connected to the microcontroller via a driver. This driver controls the lighting modes, allowing you to vary the brightness and power consumption of the lamp according to your needs.

In addition, the kitchen is equipped with a smart socket that automatically responds to needs. For example, the smart socket does not switch on or off when a particular appliance is not needed. For example, a refrigerator that should always be switched on is not controlled by a smart socket.

In addition to lighting, the kitchen energy saving system also controls the heating. The batteries are connected to drivers, which in turn interact with microprocessors. This allows the heating system to adjust the heat intensity depending on the presence of a person in the room, avoiding unnecessary consumption of resources and ensuring a comfortable temperature.

This structure of the kitchen energy saving system helps to use energy efficiently and reduce resource consumption, providing a comfortable environment for users.

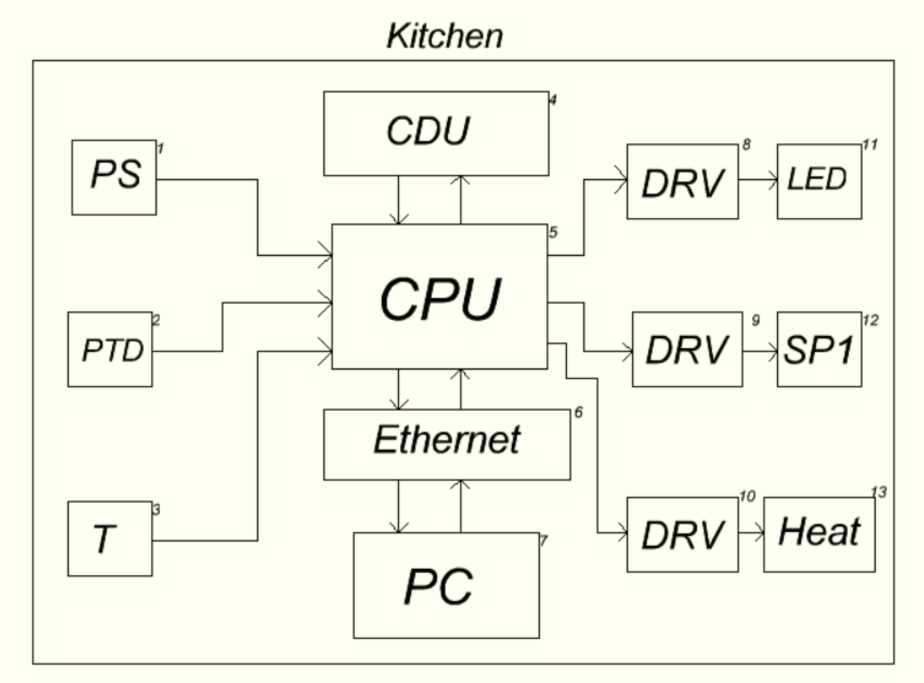


Fig. 3.3 Block diagram of energy saving system in the kitchen

Compared to the living room and kitchen, the structure of the bathroom is simplified, as it does not have the ability to receive natural light through the window. Despite this, an infrared presence sensor is installed in this room, which effectively responds to the presence of people. The heater, smart socket and lighting are controlled by drivers, which allows for optimal comfort and energy efficiency.

The bathroom also has a control panel that allows you to conveniently configure and change the parameters of automated processes. The data received from various sensors and devices is transmitted to a computer via an Ethernet connection, which provides convenient monitoring and analysis of information. This makes it possible to further optimise the operation of the bathroom energy saving system and improve its overall efficiency.

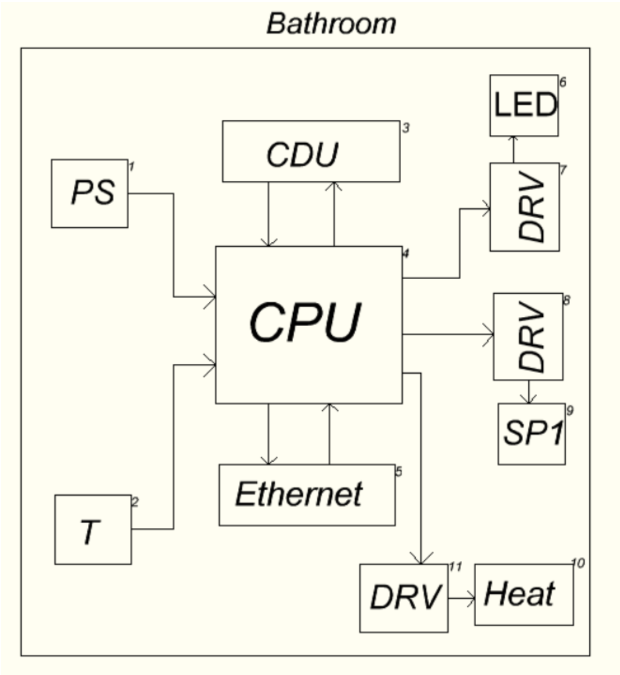
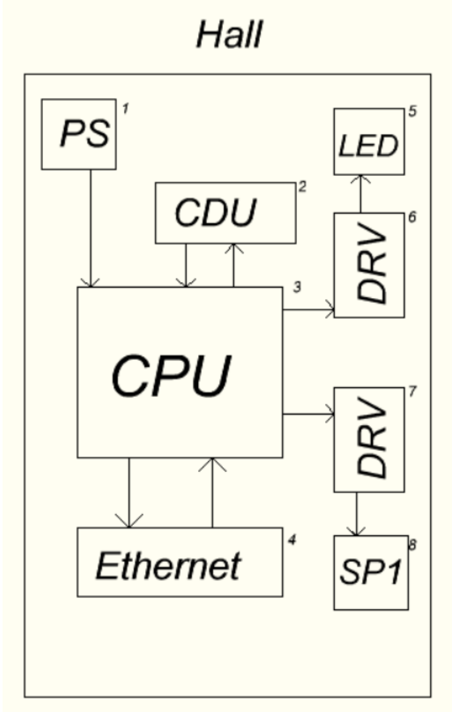


Fig. 3.4 Block diagram of energy saving system in the bathroom

In the hall, the energy-saving system's block diagram reflects the simplest principles. At the entrance to the apartment, there is a presence sensor that detects the presence of people in the room and transmits this information to the microcontroller. The microcontroller, in turn, generates a signal that controls a lamp to illuminate the room.

Additionally, the system includes a smart socket that is activated only when needed. This means that the smart socket is switched on only when a device needs to be connected.

All the data coming from the microcontroller and microprocessor interact with the computer, which allows the system to be updated and improved. This exchange of information ensures that the system operates efficiently and opens up opportunities for future improvements and updates.



3.5 Block diagram of energy saving system in the hall

3.2 Algorithms of the energy saving system

Optimal energy management is an urgent problem that requires the implementation of smart and efficient solutions. This section discusses the key algorithmic approaches that ensure the system's ability to adapt to changing conditions and perform optimal management of energy processes. Studying these algorithms helps to improve the level of energy efficiency and stability of the energy saving system. As a result of research and the use of appropriate algorithms, it is possible to achieve optimal resource use and reduce energy consumption without losing convenience and comfort for users.

3.2.1 Heating system algorithm.

At the figure 3.6 the algorithm is initiated with a set air temperature of 20 degrees Celsius and the set hours of absence, which reflect the length of time a person is at work, namely from 8 a.m. to 7 p.m. When a person is present in the room, the air temperature is maintained at 23 degrees Celsius. When the presence sensors are activated, the current air temperature is measured and the time is checked. If the current time does not match the hours of presence, then the air temperature is maintained at 20 degrees Celsius. However, if the time coincides with the interval of human presence in the room, the difference between the current temperature and 23 degrees is calculated and the air temperature is adjusted.

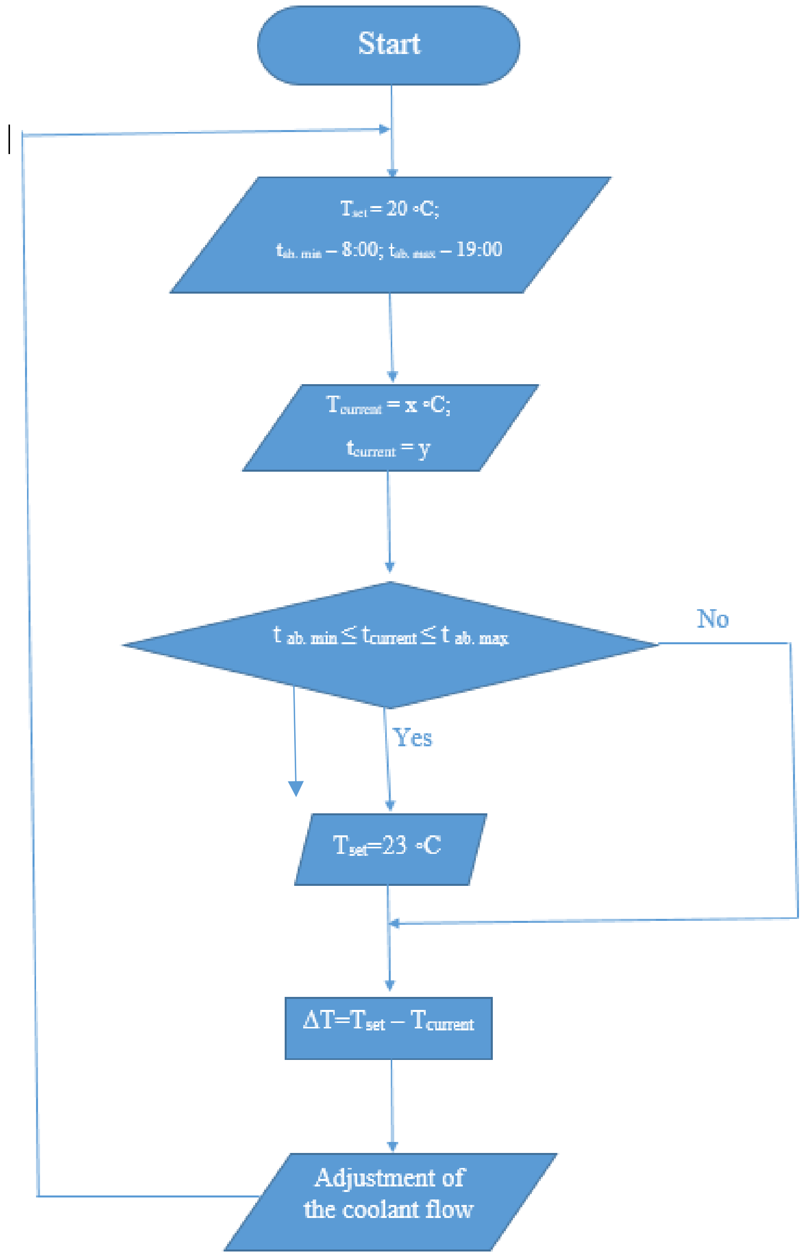


Fig. 3.6 Heating system algorithm

3.2.2 Lighting system algorithm.

As the bathroom and corridor have no natural light due to the lack of windows, it becomes obvious that these rooms are not equipped with photodiodes to measure the light level. For this reason, two individual algorithms were developed and implemented to control the lighting in the living room and kitchen, as well as the bathroom and corridor.

3.2.2.1 Lighting system algorithm for the living room and kitchen.

According to the diagram in Figure 3.7, the functioning algorithm for the living room and kitchen is initiated in the event of a lack of lighting. When the presence sensors are triggered, the current light level is measured, which is transmitted by photodiodes that measure the amount of natural light that enters the room. It is important to note that depending on the amount of light in the room, the level can vary from the lowest brightness to the highest. Based on the data obtained, the insufficient lighting level is calculated and the optimal value is set. If the motion detectors stop receiving information about the presence of a person in the room for a certain period of time, the system waits for 5 minutes for the situation to change. If the absence of presence is not confirmed during this period, the lighting is switched off.

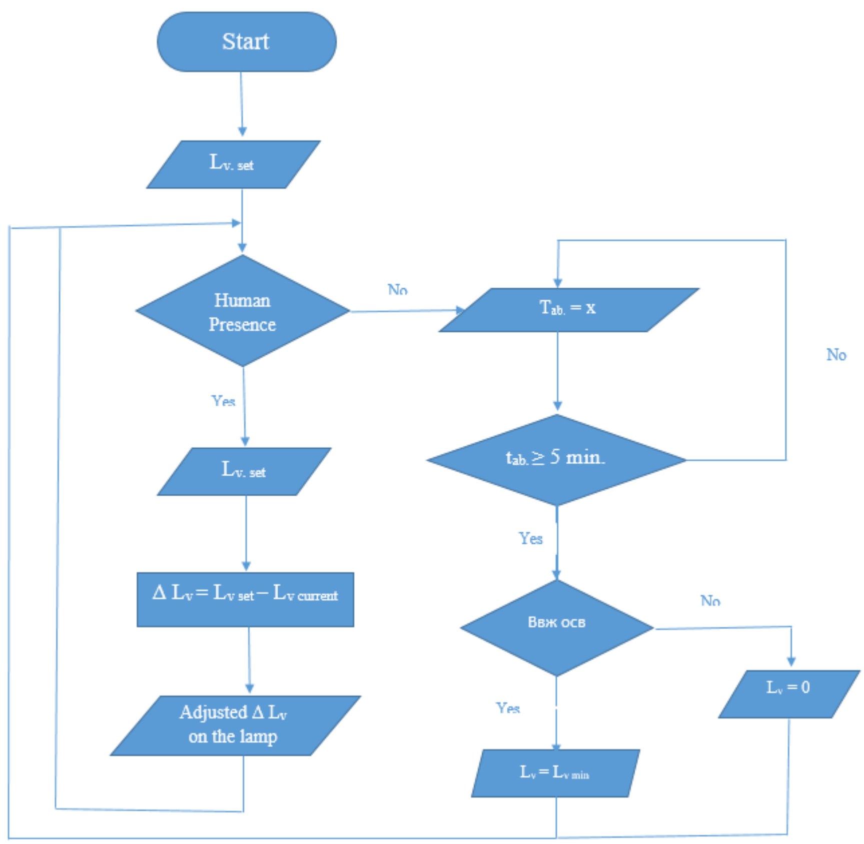


Fig. 3.7 Lighting system algorithm for the living room and kitchen

3.2.2.2 Lighting system algorithm for the bathroom and hall.

The algorithm of the lighting system in the bathroom and corridor is almost identical. But since there is no natural light source in the rooms - a window - the rooms are not equipped with photodiodes. Thus, the algorithm is more simplified because the amount of light does not vary. When a person is present in the room, the light is switched on. However, if 5 minutes have passed and the sensors do not detect presence, the light is switched off.

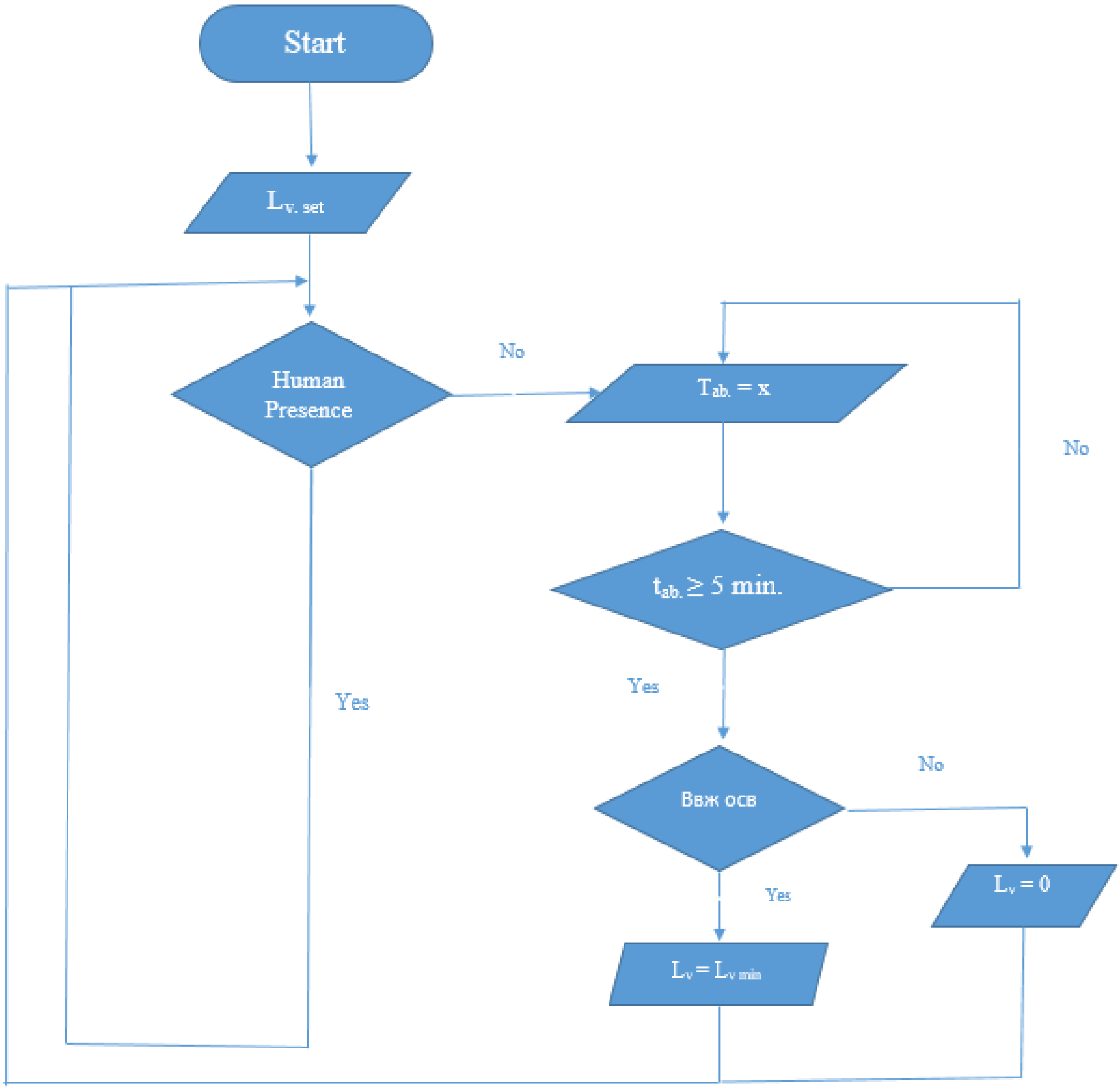


Fig. 3.8 Lighting system algorithm for the bathroom and hall

3.2.3 Algorithm of work for the smart plugs.

The algorithm of the smart socket system is initiated by setting the parameters of a person's absence from work for a period of 8 to 19 hours. If a person is detected in the room, the system activates the functionality of smart sockets. When a person is absent from the room, the algorithm checks the current time and whether it matches the specified absence intervals. If the current time does not match the absence intervals, the system waits for up to 5 minutes, after which the smart sockets automatically turn off.

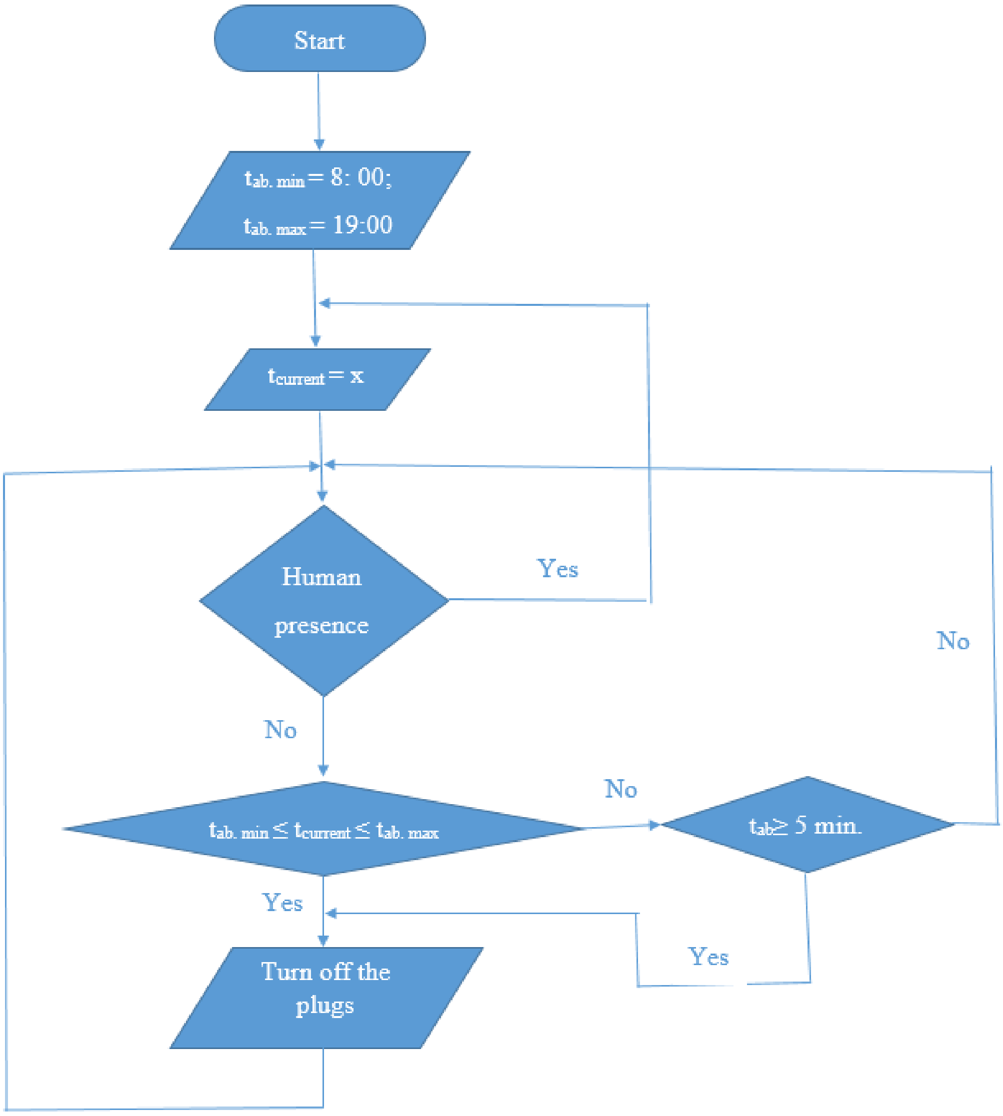


Fig. 3.9 Algorithm of work for the smart plugs

CHAPTER 4

HARDWARE FOR THE PROJECT

In the process of choosing devices, the microcontroller is the most important component. For my project, I have chosen two microcontrollers - Arduino Mega and Arduino Uno. The Arduino Mega microcontroller is planned to be used in the living room and kitchen, as these rooms require a larger number of connected devices. The Arduino Mega, based on the ATmega2560 microcontroller, is a powerful development platform with a significant number of digital and analog input and output pins, which provides ample opportunities for connecting various sensors, devices, and modules. The Arduino Uno microcontroller will be used to implement the functionality of the kitchen and corridor. It is worth noting that the Arduino Uno has a significant advantage in ease of use and ease of learning, thanks to its intuitive programming interface and the available range of libraries and application examples.

I want to use TSL2561 as photodiodes. It is widely used in many light measurement applications. One of the advantages of the TLS2561 is its high light sensitivity. This photodiode is capable of responding to even low light levels, which allows it to accurately measure illumination in low light or natural light conditions. In addition, the TLS2561 has a wide dynamic range. It can effectively measure both very dim and very bright light sources, allowing it to adapt to different lighting conditions.

To create smart sockets, I chose a regular socket and an IoT Power Relay. IoT Power Relay has a built-in Wi-Fi adapter that allows you to connect it to the Internet. It has built-in relay channels that can switch power to devices or sockets. IoT Power Relay allows you to control the power of connected devices via the Internet from anywhere. You can turn power outlets on or off using a smartphone, computer, or other device with an Internet connection.

To ensure the integration of LEDs and heating batteries, it was decided to use TLC5940 drivers. These drivers were specifically designed to drive a large number of LEDs and other devices that require precise current control. One of the important aspects of the

TLC5940 is its built-in overcurrent protection, which helps prevent possible damage to the circuit or connected devices in the event of errors or incorrect connections.

The control panel in this project is a custom-made device. The advantage of such a device is customization. Because I can create a control panel that meets my specific needs and requirements.

AM312 Mini PIR Motion Sensor was chosen among the available options for presence detectors. This detector is a compact device that uses the principle of passive infrared (PIR) detection and is characterized by low power consumption. The AM312 is characterized by high motion sensitivity, which ensures its ability to accurately detect even minimal movements in the monitored area. This allows you to reliably detect the presence of people or moving objects with the required timeliness.

After a detailed analysis of the available Ethernet interface options, it was decided to choose the Ethernet Shield W5100. This widely used Ethernet shield provides the ability to establish an Ethernet network connection using the Wiznet W5100 controller. The use of a built-in RJ45 connector simplifies the connection of the Ethernet cable to the device.

CONCLUSIONS

In this diploma, I analyzed existing energy-saving systems in smart homes and developed my own system based on microcontrollers, sensors, and program code. Various aspects of energy saving were analyzed, including efficient use of lighting, optimal temperature control, and energy supply.

The analysis revealed the main problems encountered in traditional energy saving systems, such as inefficient use of electricity and insufficient adaptability to user needs. These problems required a new approach, which was implemented in the developed system.

To ensure the system's operation, we selected the best microcontrollers and sensors that best met the project's requirements. The selection was based on the criteria of reliability, performance, and energy efficiency. The use of these components allows for accurate data reading and efficient control of energy devices in the building.

We also developed structural diagrams for a one-room apartment to integrate the energy saving system at the design stage of the building. This makes it possible to maximize the benefits of a smart home with minimal costs for additional modernization.

Separate algorithms have been developed for each room to optimally control lighting, heating, and air conditioning. These algorithms take into account various factors, such as the time of day, the presence of people in the room, and the outside weather conditions, which allows for efficient energy use.

To implement the system, we selected the appropriate device models that meet the project requirements. These models include energy-efficient lamps, thermostats and programmable air conditioners to optimize energy consumption.

The system's program code was developed using the Arduino IDE, which is a powerful tool for programming microcontrollers. The use of Arduino simplifies the programming process, provides ample opportunities for using libraries and additional modules, facilitating the development and expansion of the system's functionality.

As a result, the developed energy saving system in a smart home has the potential to improve energy efficiency and ensure comfortable living conditions for users. It takes into account various factors affecting energy consumption and uses advanced technologies to optimize system performance. The results of this study can be used in the design and implementation of energy-efficient buildings of the future.

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Below is the code for the Arduino Mega microprocessor in the Arduino IDE.

```
#include <Wire.h>

#include <Adafruit_Sensor.h>

#include <Adafruit_TSL2561_U.h>

#include <Tlc5940.h>

#include <SPI.h>

#include <Ethernet.h>


// Foams for sensors and devices

const int presencePin = 2; // Pin for presence detector

const int sdaPin = 20; // SDA foam for the light sensor

const int sclPin = 21; // SCL foam for the light sensor

const int relayPin = 22; // Pin for the relay module

const int redPin = 3; // Pin for the red channel of the TLC5940 driver

const int greenPin = 4; // Pin for the green channel of the TLC5940 driver

const int bluePin = 5; // Pin for the blue channel of the TLC5940 driver


// Constants for setting up

const int minimumLightLevel = 500; // Minimum light level

const int maximumLightLevel = 2000; // Maximum light level

const int targetTemperature = 23; // Optimum temperature

const int defaultTemperature = 20; // Temperature of human absence

const int presenceDelay = 300000; // Absence delay to switch off the lights
and lower the temperature (5 minutes)


// Variables for storing state
```

```
boolean presenceDetected = false;
boolean lightOn = false;
int currentLightLevel = 0;
int currentTemperature = defaultTemperature;
unsigned long lastPresenceTime = 0;

// Objects for sensors
Adafruit_TSL2561_Unified tsl = Adafruit_TSL2561_Unified(TSL2561_ADDR_FLOAT);

void setup() {

  Serial.begin(9600);

  // Initialising the presence detector
  pinMode(presencePin, INPUT);

  // Initialising the light sensor
  Wire.begin(sdaPin, sclPin);
  if (!tsl.begin()) {
    Serial.println("Failed to initialize TSL2561 sensor!");
    while (1);
  }
  tsl.enableAutoRange(true);
  tsl.setIntegrationTime(TSL2561_INTEGRATIONTIME_13MS);

  // Initialising the relay module
  pinMode(relayPin, OUTPUT);
```

```
  // Initialising the TLC5940 driver
  Tlc.init();
}

void loop() {
  // Reading sensor values
  int lightLevel = getLightLevel();
  boolean presence = detectPresence();

  // If the presence is detected
  if (presence) {
    presenceDetected = true;
    lastPresenceTime = millis();

    // Lighting control depending on the light level
    if (lightLevel < minimumLightLevel && !lightOn) {
      setLightLevel(maximumLightLevel); // Set the maximum lighting level

      lightOn = true;
    } else if (lightLevel > maximumLightLevel && lightOn) {
      setLightLevel(minimumLightLevel); // Set the minimum lighting level

      lightOn = false;
    }

    // Temperature control
```

```
    setTemperature(targetTemperature); // Встановлюємо оптимальну температуру
  }

  // If the absence is detected and the required minimum time value has passed
  if (!presence && presenceDetected && (millis() - lastPresenceTime) >= presenceDelay) {
    presenceDetected = false;

    // Change the state of lighting and temperature to the original values
    if (lightOn) {
      setLightLevel(minimumLightLevel);
      lightOn = false;
    }
    setTemperature(defaultTemperature);
  }

}

// Function for obtaining the light level
int getLightLevel() {
  sensors_event_t event;
  tsl.getEvent(&event);
  if (event.light) {
    currentLightLevel = event.light;
  }
  return currentLightLevel;
}
```

```
// Function for presence detection
boolean detectPresence() {
  return digitalRead(presencePin) == HIGH;
}

// Function for setting the light level
void setLightLevel(int level) {
  // Setting the appropriate driver channel
  Tlc.set(redPin, level);
  Tlc.set(greenPin, level);
  Tlc.set(bluePin, level);
  Tlc.update();
}

// Function for setting the temperature
void setTemperature(int temperature) {

}
```

Below is the code for the Arduino Uno microprocessor in the Arduino IDE.

```
#include <Tlc5940.h>

#include <Time.h>


const int motionPin = 2;

const int temperaturePin = A0;

const int relayPin = 3;

const int brightness = 1023;


boolean motionDetected = false;

boolean isWorkingHour = false;

unsigned long lastMotionTime = 0;


void setup() {

  pinMode(motionPin, INPUT);

  pinMode(relayPin, OUTPUT);

  Tlc.init();


}


void loop() {

  // Reading the status of a motion detector

  motionDetected = digitalRead(motionPin) == HIGH;


  // Check the time and set the operating mode

  int hour = hour();
```

```
int minute = minute();
isWorkingHour = (hour >= 8 && hour < 19 && minute >= 30);

// Lighting control
if (motionDetected || !isWorkingHour) {
  Tlc.set(brightness);  // Switch on the lights
} else {
  Tlc.set(0);  // Switch off the lights
}

// Temperature control
int temperatureValue = analogRead(temperaturePin);
int mappedTemperature = map(temperatureValue, 0, 1023, 0, 255);

if (motionDetected || !isWorkingHour) {
  analogWrite(relayPin, mappedTemperature);  // Switch on the heating
} else {
  analogWrite(relayPin, 0);  // Switch off the heating
}

// Checking the inactivity interval and returning to the initial state
if (!motionDetected && (millis() - lastMotionTime) > 300000) {
  Tlc.set(0);  // Switch off the lights
  analogWrite(relayPin, 0);  // Switch off the heating
}

// Remembering the last time motion was detected
```

```
  if (motionDetected) {
    lastMotionTime = millis();
  }


  // Delay before the next iteration
  delay(100);
}
```