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DEVELOPMENT OF AN AUTOMATED IOT-BASED SYSTEM FOR MONITORING AND CONTROL OF ELECTRICAL ENERGY CONSUMPTION

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Abstract—The article addresses the problem of monitoring and control of electrical energy consumption using Internet of Things technologies. A conceptual architecture of an automated system integrating electrical parameter measurement devices, microcontroller-based control, wireless communication technologies, cloud services, and remote load management mechanisms is proposed. Existing energy monitoring solutions are analyzed, and their major limitations related to insufficient integration of automatic control functions, high deployment costs, and dependence on proprietary platforms are identified. The general system architecture and automation structure are developed based on a closed-loop control system with negative feedback. The residential electrical network is considered as the controlled object, while active power consumption is selected as the controlled variable. A measurement subsystem based on the HLW8032 energy metering integrated circuit is proposed for real-time acquisition of voltage, current, power, and energy consumption parameters. Algorithms for data acquisition, transmission, processing, and automated load disconnection under overload conditions are developed. The proposed approach can be applied to the development of intelligent energy management systems for residential and small-scale commercial applications. Experimental validation and performance evaluation of the developed system are considered as subjects of future research.

Keywords—Internet of things, energy monitoring, energy management, embedded systems, ESP32, HLW8032, cloud platform, automatic control systems.

I. INTRODUCTION

The rapid growth of electrical energy consumption has become one of the major challenges facing modern power systems. The increasing number of electrical appliances, widespread adoption of smart home technologies, electric vehicles, and industrial automation systems continuously raise the demand for electrical energy worldwide [1] – [3]. According to recent energy market analyses, global electricity consumption is expected to maintain steady growth over the next decade, creating additional pressure on existing power generation and distribution infrastructures.

In parallel with the growth of electricity demand, energy prices continue to increase in many countries. Rising operational costs of energy generation, modernization of aging electrical infrastructure, and integration of renewable energy sources have significantly affected electricity tariffs for residential and industrial consumers. These factors have increased the importance of energy efficiency and

rational energy management in both domestic and industrial environments [4].

Traditional electricity metering systems are primarily designed for billing purposes and typically provide only aggregated information about consumed energy [5]. Although modern smart meters improve data accessibility, they often do not offer detailed real-time monitoring, remote control capabilities, or advanced analytical functions required for efficient energy management. As a result, users frequently lack sufficient information to identify inefficient consumption patterns, detect abnormal operating conditions, or optimize energy usage.

Recent advances in the Internet of Things (IoT) [6] have enabled the development of intelligent monitoring systems capable of continuously collecting, transmitting, processing, and visualizing energy consumption data [7], [8]. By integrating sensors, microcontrollers, wireless communication technologies, and cloud computing services, IoT-based systems provide real-time access to

electrical parameters and enable remote control of connected devices. Such systems can significantly improve energy efficiency, reduce operational costs, and increase the reliability of electrical installations.

Cloud computing plays a key role in modern IoT architectures by providing scalable infrastructure for data storage, processing, visualization, and device management [7], [9]. Various cloud platforms, including Blynk, ThingsBoard, and Microsoft Azure IoT, offer different approaches to implementing IoT applications, each with specific advantages regarding scalability, deployment complexity, functionality, and operational costs. Therefore, selecting an appropriate cloud platform becomes an important stage in the development of energy monitoring systems.

II. LITERATURE REVIEW AND PROBLEM STATEMENT

The increasing complexity of modern electrical systems and the continuous growth of electricity consumption require the implementation of advanced monitoring and control technologies [1] – [4]. Although conventional electricity meters provide information about total energy consumption, they do not support continuous real-time monitoring, remote supervision, or intelligent load management functions [5], [10] – [12]. As a result, consumers often have limited information regarding the operational state of electrical networks and the efficiency of energy utilization.

The rapid development of Internet of Things technologies has stimulated significant research activity in the field of energy monitoring and management systems. Karthikeyan and Bhuvaneswari [13] proposed an IoT-based real-time residential energy meter monitoring system that enables remote acquisition and visualization of energy consumption data. The developed solution demonstrates the feasibility of integrating energy metering devices with cloud services; however, the system is primarily focused on monitoring functions and does not provide automated load control mechanisms.

Agyeman et al. [14] developed an IoT-based energy monitoring system for smart home applications. Their research demonstrated the advantages of continuous electrical parameter monitoring and remote user access. Similarly, Hasan et al. [15] investigated the application of IoT technologies for residential energy management, showing that real-time access to consumption data can improve user awareness and support more efficient energy utilization. Nevertheless, both studies mainly focus on data acquisition and visualization while providing limited functionality for automated energy management.

More advanced approaches have been presented in intelligent energy management systems. Marinakis and Doukas [16] proposed an IoT-based platform for intelligent building energy management that combines monitoring, analytics, and optimization functions. Chinnathambi et al. [17] developed an IoT-based residential energy management system for photovoltaic-powered buildings, integrating monitoring and control functions within renewable energy installations. Although these solutions demonstrate high functionality, they are typically oriented toward specific applications and often require complex infrastructures and additional computational resources.

Cloud-based energy management solutions have also attracted considerable attention. Condon et al. [18] proposed a Cloud-IoT-based home energy management system capable of collecting, storing, and visualizing electrical parameters through cloud services. Such systems provide advanced monitoring capabilities and convenient user interfaces; however, their implementation frequently depends on proprietary cloud infrastructures, subscription-based services, or specialized hardware platforms, which may increase deployment and maintenance costs.

The analysis of the reviewed literature indicates that existing solutions predominantly focus on energy consumption visualization, data collection, and cloud-based monitoring. Existing commercial energy monitoring solutions often provide limited capabilities for automated load control and integration with low-cost hardware platforms [14] – [18]. Furthermore, many proprietary systems require expensive infrastructure, subscription-based services, or specialized equipment, which restricts their applicability in residential and small-scale commercial environments.

Another important limitation is the lack of unified solutions that combine electrical parameter measurement, cloud-based monitoring, remote user interaction, and automatic load management within a single architecture. As a result, users are often unable to promptly detect abnormal operating conditions, excessive energy consumption, or overload situations that may negatively affect both energy efficiency and electrical system reliability.

Therefore, there is a need for the development of an affordable IoT-based system capable of continuously monitoring electrical parameters, transmitting measurement data to cloud services, providing remote access to operational information, and supporting automated control of electrical loads.

The aim of this paper is to develop the conceptual architecture of an automated Internet of Things based system for monitoring and control of electrical energy

consumption. The proposed system is intended to provide continuous measurement of electrical parameters, cloud-based data visualization, remote user access, and automated load control functions.

To achieve this aim, the following tasks are addressed:

- 1) Analysis of existing IoT-based energy monitoring and management systems.
- 2) Development of the structural architecture of the proposed system;
- 3) Development of the electrical schematic of the system.
- 4) Development of algorithms for energy monitoring and load control.

Unlike existing IoT-based energy monitoring solutions, the proposed system combines real-time electrical parameter measurement, cloud-based visualization, remote user interaction, and automatic overload protection within a single low-cost hardware platform based on ESP32 and HLW8032 components.

The research focuses on the development of the system architecture, hardware configuration, electrical schematic, and operation algorithms. Experimental validation and performance assessment of the proposed solution are considered as subjects of future research.

III. SYSTEM ARCHITECTURE

A General Structure of the Proposed System

The proposed automated system is intended for continuous monitoring and control of electrical energy consumption in residential electrical networks [19]. The system combines electrical parameter measurement devices, a microcontroller-based control unit, wireless communication technologies, cloud services, and a remote load control mechanism within a unified Internet of Things architecture.

The general structure of the proposed automated energy monitoring and control system is presented in Fig. 1.

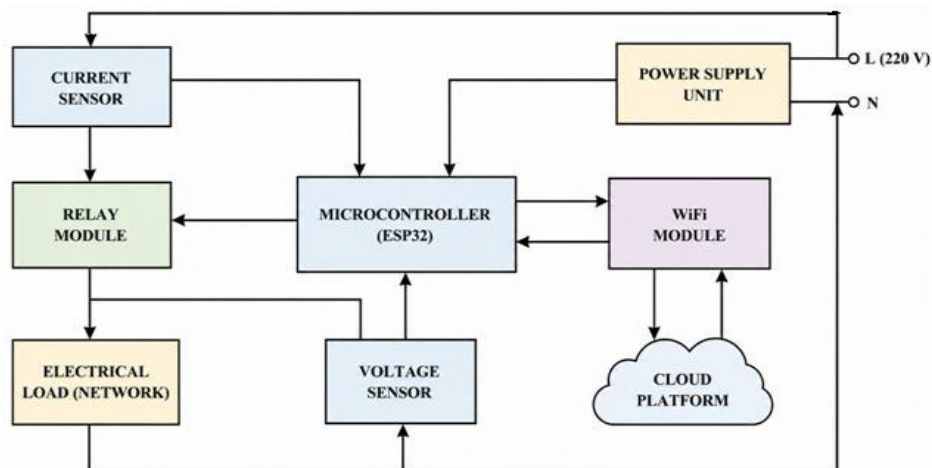


Fig. 1. General architecture of the proposed IoT-based electrical energy monitoring and control system

To provide remote access to measurement data and reduce computational load on the local controller, cloud technologies are utilized for data storage, processing, and visualization. Such an approach enables long-term accumulation of historical information, analysis of energy consumption patterns, and identification of peak load conditions.

Wireless communication between the local controller and the cloud platform is implemented using Wi-Fi technology, allowing direct connection to the Internet without additional communication gateways. User interaction with the system is performed through a cloud interface that provides access to real-time measurements and control functions.

To implement automated control of electrical loads, the proposed architecture incorporates a relay module acting as the final control element. The relay

can disconnect the electrical network when predefined power limits are exceeded or upon receiving a remote control command from the user through the cloud platform.

The system also includes a power supply unit that converts electrical energy from the monitored network into the voltage levels required for powering the microcontroller, sensors, communication modules, and auxiliary electronic components.

As illustrated in Fig. 1, voltage and current sensors continuously measure electrical parameters of the monitored network and transmit the acquired data to the microcontroller. After processing the measurements, the controller transfers the information to the cloud platform via the Wi-Fi communication channel. Control commands generated either automatically or by the user can be

transmitted back to the controller, enabling remote management of the electrical load through the relay module.

The proposed architecture provides the foundation for implementing IoT-based energy management functions while reducing human involvement in data collection and enabling continuous monitoring and remote supervision of electrical energy consumption.

B Hardware Architecture

The hardware architecture of the proposed system consists of a measurement subsystem, a control subsystem, a communication subsystem, and an executive control subsystem.

The measurement subsystem includes voltage and current sensors responsible for acquiring electrical parameters of the monitored network. Based on the measured values, the controller calculates active power and energy consumption indicators required for monitoring and decision-making processes.

The control subsystem is implemented using an ESP32 microcontroller, which performs data acquisition, signal processing, communication management, and execution of control algorithms. The microcontroller also compares measured values with predefined threshold limits and generates control signals when abnormal operating conditions are detected.

Wireless communication is provided through the integrated Wi-Fi functionality of the ESP32 platform, enabling bidirectional data exchange between the local controller and cloud infrastructure.

The executive control subsystem is represented by a relay module responsible for connecting or disconnecting the electrical load from the power network according to commands generated by the control subsystem.

C Electrical Measurement Circuit

The measurement subsystem represents one of the key components of the proposed energy monitoring platform. Its primary function is the continuous acquisition of electrical network parameters, including voltage, current, active power, and accumulated energy consumption.

Considering the maximum allowable residential power consumption of approximately 5 kW at a nominal network voltage of 240 V, the measurement circuit must reliably operate at currents exceeding 20 A. The maximum current can be estimated as [20], [21]

$$I_{\max} = \frac{P_{\max}}{U},$$

where $P_{\max}$ is the maximum allowable power and U is the network voltage.

For $P_{\max} = 5000$ W and $U = 240$ V, the required measurement range is

$$I_{\max} = 20.8 \text{ A}.$$

Therefore, the developed system must support measurement of currents not lower than 21 A while maintaining accurate voltage measurements up to 240 V.

To satisfy these requirements, the HLW8032 [22] energy metering integrated circuit was selected as the core element of the measurement subsystem. The device integrates dedicated analog front-end circuitry and digital processing units capable of directly calculating RMS voltage, RMS current, active power, and energy consumption. The calculated values are transmitted to the microcontroller through a UART communication interface [23], reducing computational load on the controller and simplifying firmware implementation.

The electrical measurement circuit developed for the proposed system is shown in Fig. 2.

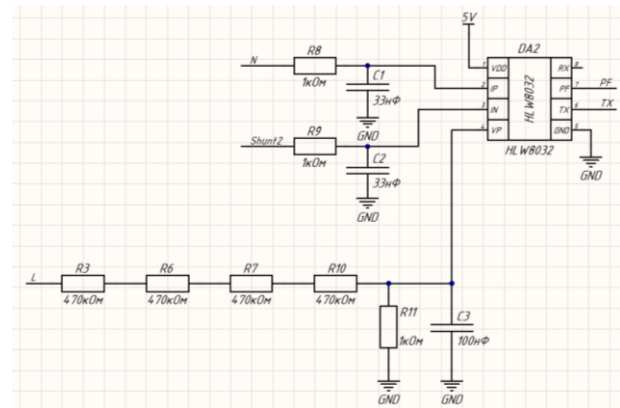


Fig. 2. Electrical measurement circuit based on the HLW8032 energy metering IC

Unlike the reference circuit proposed by the manufacturer [23], the developed design employs multiple low-resistance shunt resistors connected in parallel for current measurement. This approach improves heat dissipation and reduces thermal stress under high-load operating conditions while preserving the equivalent resistance required for accurate current sensing.

Voltage measurement is performed using a high-resistance voltage divider connected to the phase conductor of the electrical network. The divider scales the mains voltage to a safe level suitable for the analog input stage of the HLW8032. Additional RC filtering circuits are incorporated into both

measurement channels to suppress high-frequency noise and improve measurement stability.

The proposed measurement subsystem enables direct acquisition of electrical parameters from the monitored network while maintaining low component count, compact dimensions, and high measurement accuracy. Furthermore, the use of the HLW8032 significantly simplifies implementation of real-time energy monitoring functions within the proposed IoT architecture.

IV. AUTOMATION STRUCTURE

From the perspective of automatic control theory, the proposed energy monitoring platform can be represented as a closed-loop automatic control system with negative feedback. The automation structure is developed to provide continuous supervision of electrical power consumption and automatic protection of the residential electrical network against overload conditions.

Before developing the control structure, the controlled object must be formally defined. In the proposed system, the controlled object is a residential electrical network supplied from a 220 V power

source. The process occurring within the object is represented by the total electrical load generated by household appliances connected to the network.

According to the analysis of its physical properties, the controlled object can be characterized as:

- single-input single-output (SISO);
- nonlinear;
- deterministic;
- stable under normal operating conditions;
- affected by external disturbances caused by variations in electrical load.

The parametric model of the controlled object is shown in Fig. 3.

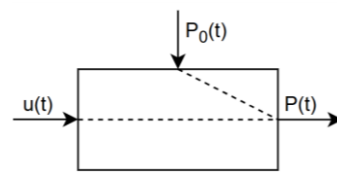


Fig. 3. Parametric model of the controlled object

The complete automation structure of the proposed system is presented in Fig. 4. Three principal variables are considered:

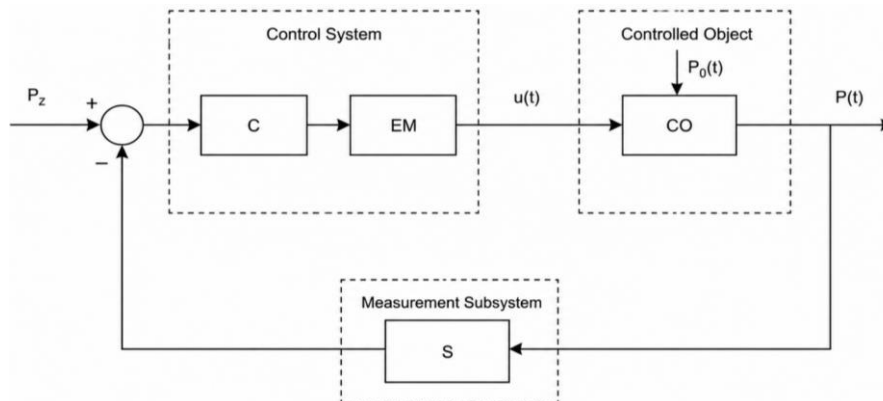


Fig. 4. Automation structure of the proposed energy monitoring and control system: $P(t)$ – active power consumption of the electrical network (controlled variable); $P_0(t)$ – disturbance input caused by changes in connected electrical loads; $u(t)$ – control signal generated by the controller and applied to the executive mechanism (Actuator)

The interaction between these variables forms the dynamic behavior of the residential electrical network. Variations in appliance operation produce disturbance signals $P_0(t)$, while the control signal $u(t)$ affects the power supply state through the relay module.

The developed control system consists of the following elements (Fig. 4): P_z is the reference power value; C is the controller implemented by the ESP32 microcontroller; EM is the executive mechanism represented by the relay module; CO is the controlled object (residential electrical network); S is the measurement subsystem including voltage and current sensors.

The operation of the system is based on continuous feedback. The measurement subsystem acquires electrical parameters from the controlled object and transmits them to the controller. The controller compares the measured power consumption with the predefined reference value P_z and determines whether corrective action is required.

If the measured power exceeds the allowable threshold, the controller generates the control signal $u(t)$, which activates the relay module. The relay disconnects the electrical load from the network, preventing overload conditions and protecting electrical equipment from potential damage.

Unlike conventional monitoring systems that only provide information about energy consumption, the proposed architecture integrates monitoring, communication, and automatic control functions within a unified IoT-based framework. This approach enables autonomous protection of the electrical network while simultaneously providing remote access to operational data through cloud services.

V. SYSTEM OPERATION ALGORITHMS

The functionality of the proposed energy monitoring and control system is determined not only by the hardware architecture but also by the operation algorithms implemented in the microcontroller firmware. The developed software is responsible for initialization of hardware modules, acquisition and processing of electrical parameters, communication with cloud services, and execution of automatic control actions. The overall operation of the system is divided into three main stages: general system operation, electrical parameter measurement, and relay control. The general operation algorithm of the proposed system is shown in Fig. 5a.

After power is applied to the device, the microcontroller performs system initialization, including configuration of hardware peripherals, communication interfaces, and network connectivity

parameters. Once initialization is completed, the system enters an infinite monitoring loop responsible for continuous supervision of the electrical network.

During each iteration of the operating cycle, the measurement subsystem acquires electrical parameters from the monitored network and transfers the obtained data to the controller. The measured values are processed and transmitted to the cloud platform, where they become available for remote visualization and analysis. Subsequently, the controller evaluates the measured parameters and executes relay control functions according to predefined protection rules and user commands received from the cloud interface.

A fixed delay interval is introduced at the end of each cycle to ensure stable operation and to avoid excessive communication traffic. The continuous execution of this algorithm enables uninterrupted monitoring of energy consumption and provides the foundation for intelligent energy management.

The electrical parameter measurement algorithm is presented in Fig. 5b. The proposed system employs the HLW8032 energy metering integrated circuit as the primary measurement device. The chip continuously acquires voltage and current information from the monitored electrical network and performs preliminary signal processing internally.

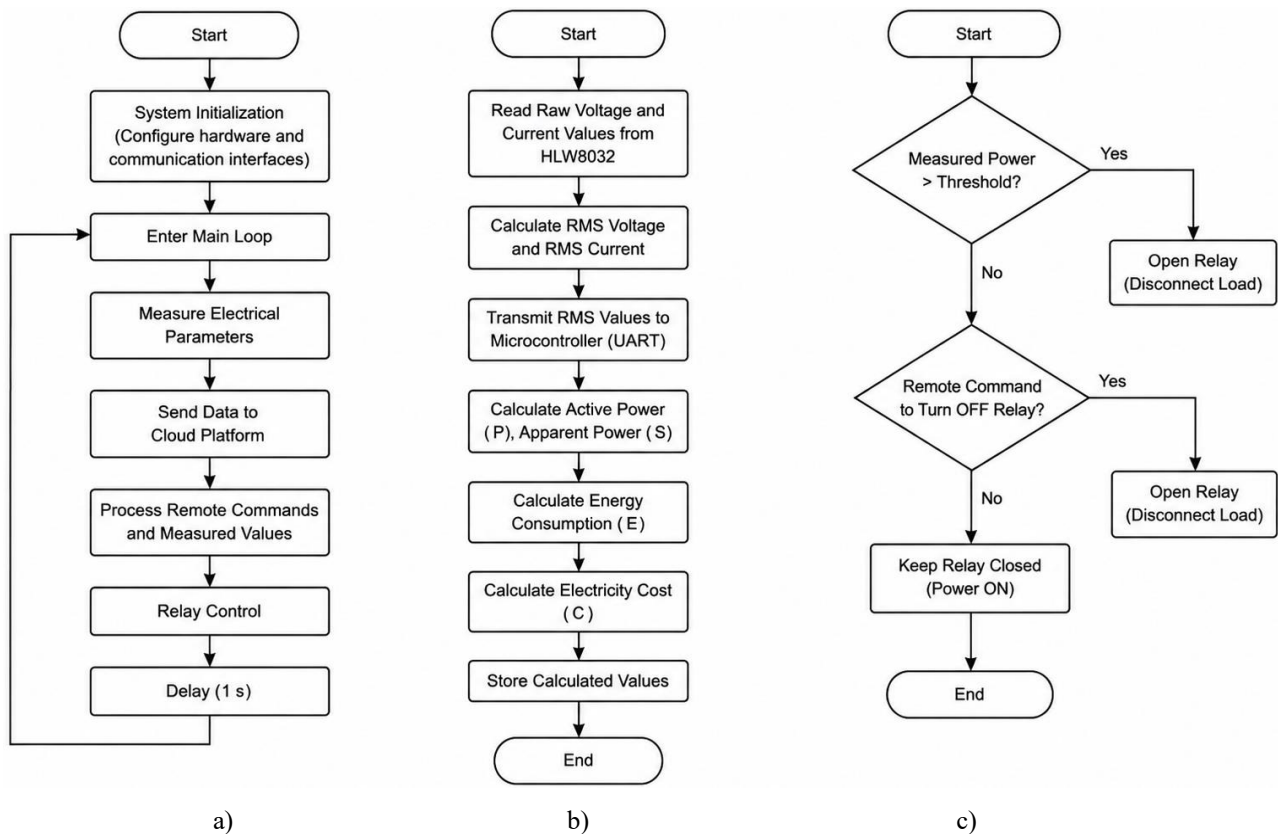


Fig. 5. System operation algorithms: (a) general system operation algorithm; (b) electrical parameter measurement algorithm; (c) relay control algorithm

At the first stage, raw voltage and current values are obtained from the measurement channels. The metering circuit then calculates the root-mean-square (RMS) values of voltage and current, which represent the effective electrical quantities used for further analysis. These values are transmitted to the ESP32 microcontroller through the UART communication interface.

Based on the acquired measurements, the controller calculates additional electrical parameters, including active power, apparent power, accumulated energy consumption, and estimated electricity cost. The calculated values are stored in memory and prepared for transmission to the cloud platform.

The continuous execution of the measurement algorithm allows the system to provide real-time information about electrical network conditions while maintaining low computational complexity due to the use of a dedicated metering integrated circuit.

The relay control algorithm is illustrated in Fig. 5c. The primary objective of this algorithm is to protect the electrical installation against overload conditions while simultaneously supporting remote user control. During each operating cycle, the controller compares the measured active power consumption with a predefined threshold value corresponding to the maximum allowable load of the residential electrical network.

If the measured power exceeds the specified threshold, the controller immediately generates a control signal that disconnects the relay. As a result, the electrical load is isolated from the power source, preventing potential damage to electrical equipment and reducing the risk of overheating of conductors and protective devices.

In parallel with the overload protection mechanism, the controller continuously checks for remote commands received from the cloud platform. If the user issues a command to disconnect the load, the relay is opened regardless of the current operating conditions. Otherwise, if no overload condition exists and no remote shutdown command is received, the relay remains energized and the electrical network continues operating normally.

The proposed control strategy combines autonomous protection functions with cloud-based supervisory control. Such an approach improves operational safety while providing users with flexible remote management capabilities through a mobile application or web interface.

VI. CONCLUSIONS

In this paper, the conceptual architecture of an automated Internet of Things based system for monitoring and control of electrical energy

consumption has been developed. The proposed solution integrates electrical parameter measurement, cloud-based monitoring, remote user interaction, and automatic load control within a unified hardware and software platform.

The developed system is based on an ESP32 microcontroller, an HLW8032 energy metering integrated circuit, a Wi-Fi communication interface, and a relay control module. The proposed architecture enables continuous monitoring of electrical network parameters, including voltage, current, active power, apparent power, accumulated energy consumption, and estimated electricity cost.

A structural diagram of the system and an automation structure based on closed-loop control principles have been developed. The residential electrical network was considered as the controlled object, while active power consumption was selected as the controlled variable. The proposed control structure provides automatic protection against overload conditions through relay-based load disconnection.

According to the design requirements and current residential electrical regulations, the developed system is intended for operation in single-phase 220–240 V electrical networks with maximum power consumption up to 5 kW, corresponding to a maximum current of approximately 21 A. The proposed measurement subsystem therefore provides the necessary functionality for monitoring typical residential electrical installations.

The hardware architecture, electrical measurement circuit, and system operation algorithms have been developed. Three main algorithms were proposed, including the general system operation algorithm, the electrical parameter measurement algorithm, and the relay control algorithm. Together, these algorithms provide continuous monitoring, cloud communication, and automatic load management capabilities.

The proposed design demonstrates the feasibility of implementing an affordable IoT-based energy management platform using low-cost hardware components. Future research will be focused on prototype implementation, experimental validation of measurement accuracy, evaluation of communication reliability, and assessment of the effectiveness of the proposed control algorithms under real operating conditions.

REFERENCES

- [1] M. Gupta, "Global Electricity Demand Set to Grow 3.6 Percent Annually as Solar Drives Energy Transition: IEA Report," *SolarQuarter*, Feb. 2026.

- Available:
<https://solarquarter.com/2026/02/11/global-electricity-demand-set-to-grow-3-6-percent-annually-as-solar-drives-energy-transition-ia-report/>
- [2] International Energy Agency (IEA), Electricity 2025. Available:
<https://www.iea.org/reports/electricity-2025>
- [3] CountryEconomy, “Ukraine – Electricity Consumption,” 2025. Available:
<https://countryeconomy.com/energy-and-environment/electricity-consumption/ukraine>
- [4] Ministry of Energy of Ukraine, “Tariffs and Prices,” 2026. Available:
<https://www.mev.gov.ua/storinka/taryfy-ta-tsiny>
- [5] V. C. Gungor, D. Sahin, T. Kocak, S. Ergut, C. Buccella, C. Cecati, and G. P. Hancke, “Smart Grid Technologies: Communication Technologies and Standards,” *IEEE Transactions on Industrial Informatics*, vol. 7, no. 4, pp. 529–539, 2011. <https://doi.org/10.1109/TII.2011.2166794>
- [6] R. Minerva, A. Biru, and D. Rotondi, “Towards a Definition of the Internet of Things (IoT),” *IEEE Internet Initiative*, 2015, 86 p.
- [7] A. Botta, W. De Donato, V. Persico, and A. Pescapé, “Integration of Cloud Computing and Internet of Things: A Survey,” *Future Generation Computer Systems*, vol. 56, pp. 684–700, 2016. <https://doi.org/10.1016/j.future.2015.09.021>
- [8] T. Tabassum, S. A. Hossain, M. A. Rahman, M. F. Alhamid, and M. A. Hossain, “An Efficient Key Management Technique for the Internet of Things,” *Sensors*, vol. 20, no. 7, Art. no. 2049, 2020. <https://doi.org/10.3390/s20072049>
- [9] P. Borra, “Impact and Innovations of Azure IoT: Current Applications, Services, and Future Directions,” *International Journal of Recent Technology and Engineering*, vol. 13, no. 2, pp. 21–26, 2024. <https://doi.org/10.35940/IJRTE.B8111.13020724>
- [10] P. O. Ajiboye, K. O. B. O. Agyekum, and E. A. Frimpong, “Privacy and Security of Advanced Metering Infrastructure (AMI) Data and Network: A Comprehensive Review,” *Journal of Engineering and Applied Science*, vol. 71, Art. no. 91, 2024. <https://doi.org/10.1186/s44147-024-00422-w>
- [11] T. F. Anthony and F. M. Dahunsi, “Survey on Wi-Fi and Cellular Communication Technology for Advanced Metering Infrastructure (AMI) in a Developing Economy,” *The African Journal of Information Systems*, vol. 15, no. 4, 2023.
- [12] O. Kebotogetse, R. Samikannu, and A. Yahya, “Review of Key Management Techniques for Advanced Metering Infrastructure,” *International Journal of Distributed Sensor Networks*, vol. 17, no. 10, 2021. <https://doi.org/10.1177/15501477211041541>
- [13] S. Karthikeyan and P. T. V. Bhuvaneswari, “IoT Based Real-Time Residential Energy Meter Monitoring System,” *2017 Trends in Industrial Measurement and Automation (TIMA), IEEE*, 2017, pp. 1–5. <https://doi.org/10.1109/TIMA.2017.8064790>
- [14] M. O. Agyeman, Z. Al-Waisi, and I. Hoxha, “Design and Implementation of an IoT-Based Energy Monitoring System for Managing Smart Homes,” *2019 Fourth International Conference on Fog and Mobile Edge Computing (FMEC), IEEE*, 2019, pp. 253–258. <https://doi.org/10.1109/FMEC.2019.8795363>
- [15] M. R. Hasan, E. Hossain, H. M. R. Faruque, and T. Sultan, “IoT Based Smart Energy Management in Residential Applications,” *2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT), IEEE*, 2019, pp. 1–6. <https://doi.org/10.1109/ICASERT.2019.8934523>
- [16] V. Marinakis and H. Doukas, “An Advanced IoT-Based System for Intelligent Energy Management in Buildings,” *Sensors*, vol. 18, no. 2, Art. no. 610, 2018. <https://doi.org/10.3390/s18020610>
- [17] N. D. Chinnathambi, K. Nagappan, C. R. Samuel, and K. Tamilarasu, “Internet of Things-Based Smart Residential Building Energy Management System for a Grid-Connected Solar Photovoltaic-Powered DC Residential Building,” *International Journal of Energy Research*, vol. 46, no. 2, pp. 1497–1517, 2022. <https://doi.org/10.1002/er.7264>
- [18] F. Condon, J. M. Martínez, A. M. Eltamaly, Y.-C. Kim, and M. A. Ahmed, “Design and Implementation of a Cloud-IoT-Based Home Energy Management System,” *Sensors*, vol. 23, no. 1, Art. no. 176, 2023. <https://doi.org/10.3390/s23010176>
- [19] B. V. Lishchyna and O. A. Povshenko, “Automated System for Measuring and Monitoring Energy Consumption Based on Internet of Things Technologies,” in *Proceedings of the XXI All-Ukrainian Scientific and Practical Conference ‘Efficiency and Automation of Engineering Solutions in Instrument Engineering’*, Kyiv, Ukraine, Dec. 10–11, 2025, pp. 170–172.
- [20] National Energy and Utilities Regulatory Commission of Ukraine (NEURC), “Resolution on Approval of Amendments to Certain NEURC Resolutions,” Mar. 17, 2021. Available:
<https://www.nerc.gov.ua/acts/pro-zatverdzhennya-zm-in-do-deyakikh-postanov-nkrekp-8>
- [21] eEnergy, “Electricity Consumption Calculation,” 2018. Available:
<https://eenergy.com.ua/korysni-porady/rozrahunok-sp-ozhyvannya-elektroenergiyi/>

- [22] ESPHome, “HLW8032 Power Sensor Documentation.” Available: https://datasheet.lcsc.com/lcsc/2307271600_Hiliwei-Tech-HLW8032_C128023.pdf
<https://esphome.io/components/sensor/hlw8032/> Received: June 21, 2026
- [23] Hiliwei Technology, HLW8032 Energy Metering IC Datasheet. Available: Published: September 18, 2026
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О. А. Повшенко, Б. В. Ліщина, О. Я. Паздрій. Розробка автоматизованої системи моніторингу та керування енергоспоживанням електричної мережі на основі технологій Інтернету речей

Розглянуто проблему моніторингу та керування енергоспоживанням електричної мережі на основі технологій Інтернету речей. Запропоновано концептуальну архітектуру автоматизованої системи, яка поєднує засоби вимірювання електричних параметрів, мікроконтролерне керування, бездротовий зв'язок, хмарні сервіси та механізми дистанційного керування навантаженням. Проведено аналіз існуючих рішень у сфері енергомоніторингу та визначено їх основні обмеження, пов'язані з недостатньою інтеграцією функцій автоматичного керування, високою вартістю впровадження та залежністю від пропріетарних платформ. Розроблено структурну схему системи та структурну схему автоматизації, що реалізує замкнений контур керування із від'ємним зворотним зв'язком. Як об'єкт керування розглянуто електричну мережу квартири, а регулюванням параметром визначено активну потужність навантаження. Запропоновано вимірювальну підсистему на основі мікросхеми HLW8032 для вимірювання напруги, струму, потужності та енергоспоживання в режимі реального часу. Розроблено алгоритми збору, передавання та обробки даних, а також алгоритм автоматичного відключення навантаження у випадку перевищення встановлених порогових значень потужності. Отримані результати можуть бути використані під час створення інтелектуальних систем енергоменеджменту для житлових та малих комерційних об'єктів. Експериментальна перевірка та оцінювання характеристик запропонованої системи є предметом подальших досліджень.

Ключові слова: IoT, моніторинг енергоспоживання, вбудовані системи, мікроконтроллер, хмарна платформа, системи автоматичного керування, розумний будинок.

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Наукові інтереси: Інтернет речей, вбудовані системи, системи автоматизації, інтелектуальні системи моніторингу, робототехніка.

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