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SYSTEMATIC LITERATURE REVIEW: THE DEVELOPMENT OF THE INTERNET OF THINGS (IoT) IN THE ENERGY SECTOR

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Abstract

This systematic literature review explores the development and application of the Internet of Things (IoT) in the energy sector, highlighting its potential to enhance efficiency and sustainability. Facing challenges like the need for higher efficiency, better resource management, and reduced environmental impact, the energy sector benefits significantly from IoT's innovative solutions. These include smart grids, home and building energy management, and industrial operations optimization, enabling real-time monitoring and control for better renewable energy integration and grid stability. Key findings show that IoT implementations can lead to substantial energy savings and environmental benefits. However, challenges such as data security, interoperability, and high implementation costs must be addressed. This review provides a comprehensive overview of IoT's role in energy efficiency and sustainability, offering insights for researchers, practitioners, and policymakers to develop effective strategies for integrating IoT in addressing global energy challenges.

Keywords— Internet of Things (IoT), Energy Sector,Energy Efficiency

INTRODUCTION

The development of information and communication technology has encouraged the emergence of various innovations that change the way we live and work. One of these innovations is the Internet of Things (IoT), a concept that connects various devices via an internet network to collect and exchange data. IoT has shown tremendous potential in various sectors, including health, transportation, agriculture, and especially the energy sector.

The energy sector faces various challenges, such as the need for higher efficiency, better resource management and reduced environmental impact. With increasing global energy demand and the need to mitigate climate change, energy efficiency and smart management are becoming top priorities. This is where the role of IoT becomes very crucial. IoT offers innovative solutions to monitor, manage and optimize energy use through integrated and automated systems.

Various IoT applications in the energy sector include smart grids, monitoring and managing energy in homes and buildings, as well as optimizing operations in the industrial sector. For example, smart grids enable more effective integration of renewable energy sources and greater electricity grid stability through real-time monitoring and control. On the other hand, IoT sensors and smart devices can identify inefficient energy use and provide recommendations for improvement.

This research aims to conduct a systematic review of existing literature regarding the development and application of IoT in the energy sector. By identifying existing trends, challenges and opportunities, this research is expected to provide a comprehensive picture of how IoT can contribute significantly to energy efficiency and sustainability. Apart from that, this research also aims to identify areas that still require further research and development to maximize the potential of IoT in this sector.

Through this systematic review, it is hoped that various innovative solutions that have been implemented can be found, as well as potential for future development. Thus, the results of

this research can be a valuable reference for researchers, practitioners and policy makers in developing more effective strategies and policies in integrating IoT to overcome global energy challenges.

RESEARCH METHODS

This research uses a systematic literature review method to examine the development of the Internet of Things (IoT) in the energy sector. This approach was chosen because it provides a structured and comprehensive framework for collecting, analyzing, and synthesizing relevant research. The research process begins with the identification of relevant studies from major academic databases such as IEEE Xplore, ScienceDirect, SpringerLink, and Google Scholar. The search was conducted using keywords such as "Internet of Things", "IoT", "energy sector", "smart grid", "energy efficiency", and "energy management", with publication time limits within the last 10 years to ensure relevance and up-to-date data.

After identification, study selection is carried out based on predetermined inclusion and exclusion criteria. Inclusion criteria include studies that discuss the application of IoT in the energy sector, are published in accredited journals or conferences, and are available in English or Indonesian. Meanwhile, studies that are not directly related to the energy sector, do not have relevant data or analysis, or are reviews without original research contributions, were excluded from the analysis.

Data were extracted from selected studies. The extracted data includes title, author, year of publication, publication source, research methodology, main results, IoT applications discussed, as well as main findings and recommendations. This data is then arranged in tables to facilitate analysis and synthesis.

Thematic analysis, which aims to identify the main themes that emerge from the literature reviewed. This analysis involves grouping research based on themes or sub-topics, analyzing trends and patterns in the application of IoT in the energy sector, as well as identifying the challenges and opportunities faced. It is hoped that the results of this analysis will provide a comprehensive picture of IoT developments in the energy sector, as well as identify areas that require further research and development.

RESULTS AND DISCUSSION

1. Application of IoT in the Energy Sector

The results of the literature review show that IoT has been applied in various aspects of the energy sector, as well as optimizing industrial operations. Each of these aspects makes a significant contribution to energy efficiency and sustainability.

According to research (Suarna & Sopyan, 2023), it discusses the implementation of the Internet of Things (IoT) in monitoring and controlling electricity consumption in work spaces at the General Bureau of the Regional Secretariat of West Sulawesi Province. In everyday life, electricity is one of the main needs that supports various activities, from studying, working, to electronic entertainment. However, uncontrolled use of electricity can result in energy waste. To overcome this, research was carried out with the aim of minimizing excessive use of electrical energy by utilizing IoT technology, microcontrollers and sensors. Through tests carried out in the civil service, correspondence and Urdal rooms, the designed system succeeded in monitoring and controlling electronic equipment such as lights effectively. The results show savings in electrical energy consumption of 49%, which is a significant impact in efforts to increase energy efficiency in the office environment. The research method used was qualitative with an exploratory approach, where the research location was at the temporary office of the General Bureau of the Regional Secretariat of West Sulawesi Province. The series of systems

used consists of several device components such as NodeMCU, current sensors, relays, PIR sensors, and others, which are controlled via the IoT Bylink application via smartphone. Thus, implementing IoT technology to control electricity consumption in the office can be an effective solution for reducing energy waste and increasing the efficiency of resource use.

According to research by Putra, et al. (2023). This research proposes an IoT-based smart housing concept that integrates renewable energy and information technology to improve energy efficiency and environmental sustainability. Through the use of this technology, it is hoped that it can meet household energy needs independently by utilizing renewable resources such as solar energy, thermoelectricity and biogas. Taking into account a household's daily energy needs, the system is designed to optimize energy use by connecting household appliances to an IoT network, enabling real-time monitoring and regulation via smart devices. This concept also considers environmental aspects by reducing dependence on fossil fuels and producing lower greenhouse gas emissions, in line with sustainable development goals. It is hoped that this IoT-based smart housing can become a model for environmentally friendly and sustainable residential development in the future.

According to research by Fitriyah, et al. (2023) Using the Blynk application as a tool to monitor electrical energy consumption in a single-door refrigerator offers an innovative solution in optimizing energy use in the household environment. By utilizing IoT technology, users can control the refrigerator efficiently remotely based on temperature parameters. Test results show that using the Blynk application can result in electrical energy savings of up to 50%, with a potential value of around 39,088.3 rupiah per month for one 1-door refrigerator with an electricity tariff of Rp. 1,200/kWh. The integration of the Blynk application in monitoring electrical energy is an important step in overcoming the challenges of household energy consumption, as well as encouraging changes towards a more sustainable lifestyle.

According to research by Dinata & Sutabri, et al. (2023) This research makes a significant contribution to the development of an Internet of Things (IoT) based smart home system using the ESP32 platform. In an era of ever-evolving technology, IoT has become the pinnacle of innovation that enables the integration of physical devices to exchange information, creating synergy between operators, services and devices in one integrated system. This research explores the application of a smart home that allows users to control electronic devices at home via smartphone applications, providing convenience in energy management. Tests were carried out at a distance of 20 meters and the results showed that the electronic device control was effective even on different networks. Implementation of this smart home system not only increases energy efficiency, but also provides added value in terms of household comfort and security. The development methodology using Extreme Programming (XP) enables an efficient and responsive software development process, consisting of planning, designing, coding and testing stages. With its intuitive user interface and adaptability to varying network conditions, the app offers a significant advancement in smart home technology, with the potential for widespread adoption due to the reliability, ease of use and efficiency it offers. Although there is some lag time in the device's response to commands from the application, this system is responsive enough for everyday smart home needs. With further adjustments and improvements, especially in optimizing response times, this system could become a more powerful and versatile smart home solution for the future.

2. Challenges in IoT Implementation

Although IoT offers many benefits, there are several challenges that need to be overcome in its application in the energy sector. These challenges include:

a. Security and Privacy

   Data security and privacy are key issues in IoT applications. IoT devices are vulnerable to cyber attacks that can cause disruption to energy systems. Therefore, it is important to develop strong security standards and ensure that user data is properly protected.

b. Interoperability
   The large number of different devices and protocols is a challenge in ensuring interoperability. To achieve effective integration, standards are needed that can be widely adopted by device manufacturers and service providers.
c. Implementation Costs
   The initial costs of implementing IoT technology can be prohibitive, especially for small and medium-sized organizations. Investments in IoT infrastructure, hardware and software require a significant amount of funds. While the long-term benefits of IoT may outweigh the initial costs, initial financing remains a challenge.

Results

Based on the research summary that has been presented, several significant conclusions can be drawn regarding the implementation of the Internet of Things (IoT) in controlling and monitoring electrical energy consumption in various contexts, from office environments to households:

1. Energy Efficiency: All research shows that implementing IoT in controlling electrical energy consumption can result in significant savings. Research conducted in office environments recorded savings of 49%, while research related to households recorded savings of up to 50%.
2. Application of IoT Technology: The use of IoT technology, including sensors, microcontrollers, and smartphone-based applications, has proven effective in monitoring and controlling energy use in real-time. This allows users to intervene or adjust directly to improve energy efficiency.
3. Environmental Sustainability: Research also emphasizes the importance of considering environmental sustainability aspects in energy management. By utilizing renewable resources and reducing greenhouse gas emissions, implementing IoT in the context of smart homes and smart housing can be a step towards a more sustainable lifestyle.
4. Development Skills: Development methods like Extreme Programming (XP) have been used to design IoT systems with intuitive and responsive user interfaces. Although there is some lag time in the device's response, research shows that the system is reliable and efficient in daily use.
5. Wide Application Potential: The conclusion of the overall research shows that the implementation of IoT technology in electrical energy management has the potential to be widely adopted in both office and household environments. With further adjustments and improvements, these systems could become more robust and versatile solutions for the future.

Research on the implementation of the Internet of Things (IoT) in the energy sector shows that IoT technology makes a significant contribution to increasing energy efficiency and environmental sustainability. Research by Suarna and Sopyan (2023) highlights the success of IoT in monitoring and controlling electricity consumption in office environments, resulting in energy savings of up to 49%. The IoT-based smart housing concept proposed by Putra et al. (2023) integrate renewable energy to meet household energy needs, reduce dependence on fossil fuels, and reduce greenhouse gas emissions. Meanwhile, research by Fitriyah et al. (2023) shows the efficiency of energy use in households with the Blynk application, resulting in electrical energy savings in refrigerators of up to 50%. Research by Dinata and Sutabri et al. (2023) demonstrated the benefits of an IoT-based smart home system using the ESP32 platform in controlling electronic devices remotely, increasing energy efficiency as well as household comfort and security. Overall, the application of IoT technology in the energy sector offers effective solutions to reduce energy waste, optimize resource use, and promote environmental sustainability through the development of innovative and adaptive systems.

CONCLUSION

This research examines various applications of the Internet of Things (IoT) in the energy sector, showing that IoT technology makes a significant contribution to improving energy efficiency and environmental sustainability. Some of the key findings from the research reviewed include:

1. Implementation of IoT in managing electrical energy in office and household environments has been proven to produce significant savings, with research showing energy savings of up to 49% in offices and 50% in households.
2. The use of sensors, microcontrollers and smartphone-based applications enables real-time monitoring and control of energy consumption, which helps in interventions and adjustments to improve energy efficiency.
3. IoT plays a role in reducing dependence on fossil fuels and reducing greenhouse gas emissions, especially through smart housing concepts that integrate renewable energy sources.
4. Development methods such as Extreme Programming (XP) are used to design intuitive and responsive IoT systems, although some challenges in device response time still need to be overcome.
5. Implementation of IoT technology in electrical energy management has great potential for widespread adoption in various contexts, both in office and household environments, with further adaptation and improvement.

SUGGESTION

Based on the results and findings of this research, here are several suggestions for further research and development in the application of IoT in the energy sector:

1. There needs to be more in-depth research to develop strong security standards and better data protection for IoT device users, given the vulnerability to cyberattacks.
2. There is a need to develop interoperability standards that can be widely adopted by device manufacturers and service providers to ensure effective integration between diverse IoT devices.
3. Further research is needed to find solutions that can reduce the initial costs of IoT implementation, especially for small and medium organizations, so that the long-term benefits of IoT can be more easily achieved.
4. Additional research to optimize IoT device response times and improve system reliability is critical to ensure optimal performance in everyday use.
5. There needs to be more research focused on the integration of IoT with other renewable energy sources and new ways to minimize environmental impacts, so that it can better support sustainable development goals.

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