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Internet of Things (IoT) for the Implementation of Intelligent Energy Systems

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ABSTRACT

The use of Internet of Things (IoT) technology has become crucial in the advancement of intelligent energy systems amidst global energy transformations. This article discusses the beneficial impacts of integrating the Internet of Things (IoT) in enhancing the efficiency of monitoring, controlling, and making decisions regarding energy management. The Internet of Things, through the use of advanced sensors and connectivity, allows for real-time monitoring, the ability to adapt to changes in demand, and significant improvements in energy efficiency. The study recognises challenges related to security and privacy, but demonstrates that utilising the Internet of Things presents fresh prospects for a more adaptable, efficient, and sustainable energy system. This paper comprehensively examines the important role of the Internet of Things in shaping the future of interconnected and responsive smart energy systems, based on recent literature.

Keywords: Internet of things, energy system

1. INTRODUCTION

The industrial revolution consists of four distinct phases. Novel energy sources were discovered to propel the engine throughout its initial revolution. Notable advancements during this era included extensive coal extraction and the establishment of steam power facilities. The second industrial revolution, commonly referred to as the era of mass production and development, commenced at a time of swift industrial advancement and the widespread manufacture of iron and steel. During this period, several expansive factories and assembly lines were constructed, leading to the establishment of novel enterprises. The advent of first-generation communication technologies in the third revolution, such as computers and telecommunications networks, facilitated the mechanisation of supply chains. The fourth industrial revolution should be spearheaded by a range of novel technologies, including communication networks, intelligent robots, and internet of things (IoT). The IoT facilitates the interconnection of many entities, including objects, humans, operations, and information, by facilitating effective communication among them. The Internet of Things (IoT) has the potential to enhance this by enabling the monitoring and quantification of many activities. Through the accumulation and examination of extensive data, one can enhance their capacity to quantify and expand many aspects. The Internet of Things (IoT) has the potential to enhance the quality of life in several sectors such as health, smart cities, building and construction industry, agriculture, water management, and energy sector. This may be achieved by providing users with the necessary resources to enhance their decision-making abilities and using automated processes for making more effective judgements in real-time.

2. METHODS

As time has passed, there have been many conversations and evaluations of literature about using IoT in many areas, such as industry and the growing subject of smart energy development. Furthermore, thorough technical analysis has been conducted to examine the advantages and difficulties related to the implementation of one or more Internet of Things (IoT) technologies, such as sensors and networks. Smart Homes, Electric Vehicles, energy storage, and intelligent street lighting have shown to be better in their respective areas as they have evolved. Nevertheless, the requirement for precise computation and careful monitoring presents limitations to their execution. Most survey studies in the energy business focus on specific subsectors, such as buildings, or the technical capabilities of various IoT technologies within this industry. Research has been conducted on the use of IoT applications in Smart Homes, as well as their possible integration into surroundings that enable IoT. Hui et al. conducted research only on the energy demand side, providing a comprehensive analysis of current methodologies and advancements. The study by Khatua et al. examines the appropriateness of IoT data transmission and communication protocols for implementing smart grids. It explains how IoT might improve energy efficiency in buildings and public transportation. This research investigates the use of IoT technology in all aspects of the energy industry, including energy generation, transmission and distribution (T&D), and the demand side. This differs from the literature that has been examined, which usually concentrates on a particular subsector or IoT technology within the energy sector. The main contribution of this study is to offer a thorough review aimed at improving efficiency, sustainability, and responsiveness in smart energy management.

3. THEORITICAL FRAMEWORK

3.1 Internet of Things in the Energy Context

IoT technology in the energy industry could revolutionise energy use, efficiency, and sustainability. In the energy supply chain, IoT applications like smart grids, smart buildings, and intelligent transportation will shape energy management. Integrating devices to regulate, generate, and distribute energy is IoT in energy. Energy efficiency is improved by optimising generation and demand with this technology. Nano grids, microgrids, DERs, and electric vehicles are expected to have a major impact on the electricity and buildings industries, turning buildings into active electricity sector participants. Building professionals must lead the modernization of the electricity sector as new technologies and policies change the grid. The smart grid is turning buildings from passive electricity consumers to active energy producers. This transformation offers building management professionals many opportunities and challenges. The electricity industry and building architecture's shared goals and terminologies should lead to positive results. Solar photovoltaic (PV) systems and electric storage will shape future building design and construction. Therefore, building owners and designers must stay informed about these technologies and their effects on projects. Building-grid interactions will create new opportunities and challenges, including billing framework and incentive changes. Building operators will oversee building operations in the energy era, and policymakers will need to change regulations and standards. In conclusion, IoT in the energy industry can improve energy efficiency, reduce environmental damage, and incorporate renewable energy. It also has confidentiality, protection, and compatibility issues. To fully utilise IoT in the energy sector, all parties must collaborate and adapt to energy landscape changes.

3.2 Key Components of Smart Energy Systems

The fundamental elements of intelligent energy systems encompass energy management systems based on the Internet of Things (IoT), cloud computing, data analytics platforms, real-time data collection sensors, and communication technologies. These components facilitate the management and enhancement of energy production, transmission, and distribution, as well as end-use sectors. Smart buildings are essential components of smart energy systems. They offer centralised and remote control of appliances and devices, utilise data analytics to activate batteries at the most opportune moments, and employ optimal strategies for charging and discharging batteries across various time periods. Moreover, the implementation of IoT in smart cities facilitates the integration of smart factories, smart homes, power plants, and farms. This integration enables the collection of data on energy usage during various times of the day, which can be used to optimise the entire system with minimal costs and reduced risks of congestion or power outages.

4. Implementation of IoT in Smart Energy Systems

4.1 Real-Time Energy Consumption Monitoring

Sensors and communication technologies directly detect and transmit data. This facilitates rapid analysis and optimal decision-making. IoT-based systems enable the collection of large amounts of data and the use of intelligent algorithms to analyse energy consumption patterns in real-time. This monitoring process includes users and devices across different time periods. The real-time monitoring and analysis help maximise the efficient use of electrical energy and minimise the corresponding greenhouse gas emissions.

4.2 Efficient Load Management

Energy conservation is a strategic approach that seeks to reduce energy waste by using sensors and communication technologies. By utilising sensors, Internet of Things (IoT) systems identify and collect data on energy usage from different devices, transmitting it directly through communication technologies. The use of IoT allows for immediate monitoring, which allows for quick analysis of energy consumption patterns. This empowers systems to efficiently optimise energy usage for each individual device. For example, devices that are not in use can be automatically shut down or have their energy usage decreased. Moreover, Internet of Things (IoT) systems send notifications or alerts to users when there is a possibility of energy being wasted or when energy consumption surpasses predetermined benchmarks. The Internet of Things (IoT) contributes to operational efficiency and promotes sustainability by minimising energy waste and optimising the use of limited energy resources. In summary, these studies illustrate the capacity of IoT to enhance load management efficiency in smart energy systems, specifically in micro-grids. This is achieved by facilitating immediate control, regulation, and adaptive decision-making using environmental data collected by IoT devices.

5. Challenges and Opportunities

5.1 Security and Privacy Concerns

Privacy in energy systems refers to the right of energy consumers to keep their personal data private. Important to consider. IoT data collection on energy consumers and appliances could influence energy production, distribution, and consumption decisions. However, balancing data-driven decision-making and user privacy is the biggest challenge. Energy providers should get user consent before using their data to address privacy concerns. The data will remain confidential and not shared with third parties. A trusted privacy management system that gives energy consumers control over their data is another option. IoT and communication technologies in energy systems raise new security concerns, particularly in protecting data from cyberattacks across the energy supply chain. The energy industry's widespread use of IoT systems across vast regions increases cyber risk. Energy data should be encrypted to protect it from cyberattacks, according to research. Distributed control systems, which enable multi-level control, should be used in the IoT system to reduce cyber-attack vulnerability and improve security. IoT in energy systems is dynamic, so data-driven decision-making must be balanced with user privacy and system security.

5.2 Architecture Design

IoT systems consist of a range of technologies, including a growing number of intelligent interconnected devices and sensors. The Internet of Things (IoT) is anticipated to facilitate seamless and spontaneous communication for various services, regardless of time and location. IoT systems are designed with complex, decentralised, and mobile characteristics based on their application purposes. Considering the specific attributes and requirements of an Internet of Things (IoT) application, it is not possible to have a single reference architecture that can cater to all such applications. Thus, in order to accommodate IoT systems, it is necessary to employ heterogeneous reference architectures that are both open and adhere to established standards. The architectures should not impose restrictions on users, preventing them from utilising flexible and comprehensive IoT communications.

6. Recent Development and Future Prospects

6.1 Green IoT

One major obstacle to the potential large-scale use of these technologies is the energy consumption of Internet of Things devices. Utilizing a significant quantity of energy to power billions of Internet-connected gadgets results in the production of a significant amount of electronic trash. The notion of Green IoT (G-IoT) has surfaced as a solution to these problems; it places a focus on energy efficiency at every stage of the product's lifecycle, including design, manufacturing, implementation, and disposal. This methodology is transferable to other IoT platforms. For example, decreasing the size of Radio Frequency Identification (RFID) tags is used to address recycling issues related to surplus materials. Green Machine-to-Machine (M2M) communications is an example of how power transfer can be adjusted to minimum levels, enabling more effective communication protocols via distributed and algorithmic computing methods. When not in use, wireless sensor network nodes can be put into sleep mode. To lower node power consumption, radio optimization strategies like cooperative communication or modulation optimization can be used. Moreover, implementing energy-efficient routing strategies like multi-path routing or cluster topologies can offer practical answers. In conclusion, the methods and illustrations stated above help to lower the energy needs of Internet of Things systems.

6.2 Blockchain and IoT

Most IoT systems in use today rely on centralized cloud infrastructure. Thousands of IoT machines and devices must be connected for the majority of IoT applications, which makes synchronization difficult. Furthermore, because IoT is centralized and server-client based, any attacked server can easily compromise all connected objects, posing a risk to system security and compromising user privacy. Thankfully, blockchain technology may be able to help with this problem. Blockchain offers a democratized and decentralized platform that does not require the involvement of a third party. Every IoT node must demonstrate to the blockchain's consensus platform that it pursues the same objective as other nodes. A block containing verified transactions is also stored, which is connected to the first one in the same way that data is never lost. Furthermore, it is possible to record and make publicly available the history of each and every transaction made at each node. As a result, every participant in the blockchain is instantly informed of any modifications made to any block. Thanks to the distributed ledger of blockchain technology.

A secure distributed database can be produced via the peer-to-peer network-based consensus procedures of blockchain technology. Blockchain can deliver decentralized, private-by-design Internet of Things that can ensure privacy. What's more, blockchain allows objects to exchange and store software updates. Once an update is uploaded to the blockchain as a legitimate block, it cannot be removed or altered. Innocuousness checking nodes verify the accuracy of update information as a new node and ensure its safety from any threats. Consequently, blockchain can be used to deliver updates, availability, and innocuousness to IoT-based solutions. By offering a decentralized platform for distributed power generation and storage systems that improve energy security and efficiency, the deployment of blockchain technology in the energy industry will accelerate the effectiveness of the Internet of Things. Without the assistance of a third party, users can immediately acquire energy information and communicate real, highly validated data across devices. It's easy for neighbors to exchange energy with one another. As a result, not only will there be an increase in trust between individuals, but many of the expenses associated with connecting to centralized grids can be avoided. Another benefit is that Blockchain gives the energy distribution company the ability to remotely regulate the flow of energy to a specific location by tracking its usage statistics. Additionally, IoT solutions built on blockchain aid in the diagnosis and upkeep of smart grid equipment. Due to limited processing power and bandwidth, blockchain technology cannot currently be directly applied in an Internet of Things system.

7. CONCLUSIONS

A new transition era is poised to commence in energy systems. An integrated strategy is imperative to mitigate the socio-economic and environmental impacts of the widespread deployment of Variable Renewable Energy (VRE) in distributed energy systems and to achieve efficient energy consumption. A comprehensive energy system is required to reduce the systemic effects on society, economy, and the environment. In this context, cutting-edge technologies such as the Internet of Things (IoT) can facilitate the energy sector's transition from a centralized, hierarchical supply chain to a decentralized, intelligent, and optimized system. Various use cases of IoT in each segment of the energy supply chain, spanning from generation to end-use sectors, are classified. The benefits of IoT-based energy management systems in enhancing energy efficiency and incorporating renewable energy are examined, with findings summarized upon discussion. Diverse components of IoT systems, including communication and sensor technologies, are discussed in their application to the energy sector. Examples include temperature, humidity, light, speed, passive infrared, and proximity sensors. Cloud computing and data analytic platforms, serving as tools for data analysis and visualization in smart energy applications from buildings to smart cities, are also addressed. The application of IoT in the energy supply chain across different levels, including smart cities, smart grids, smart buildings, and intelligent transportation, is reviewed. Challenges related to IoT implementation in the energy sector, such as object identification difficulties, big data management, connectivity issues, uncertainty, subsystem integration, security and privacy concerns, and energy requirements of IoT systems, are discussed. Potential solutions for these challenges, such as Blockchain and Green IoT, are highlighted as future research directions.

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