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IMPLEMENTATION OF IOT PLATFORMS IN ENERGY MONITORING SYSTEMS

Abstract. *The rapid advancement of the Internet of Things (IoT) has revolutionized the energy sector by enabling real-time monitoring, automation, and intelligent decision-making. IoT-based energy monitoring systems connect physical devices—such as sensors, meters, and controllers—to digital platforms for continuous data acquisition and analysis.*

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ВНЕДРЕНИЕ ПЛАТФОРМ IoT В СИСТЕМЫ МОНИТОРИНГА ЭНЕРГИИ

Аннотация*.Стремительное развитие Интернета вещей (IoT) произвело революцию в энергетическом секторе, обеспечив возможность мониторинга в режиме реального времени, автоматизации и интеллектуального принятия*

решений. Системы мониторинга энергии на основе IoT подключают физические устройства, такие как датчики, счетчики и контроллеры, к цифровым платформам для непрерывного сбора и анализа данных.

Global energy systems are undergoing a fundamental transformation driven by technological innovation, sustainability goals, and the growing demand for efficient energy use. The increasing complexity of modern power systems requires continuous monitoring and intelligent control to maintain reliability and efficiency. The Internet of Things (IoT) has emerged as one of the most powerful enablers of this digital transformation (IEA, 2023).

IoT connects physical energy assets—such as transformers, meters, and circuit breakers—to the digital environment through embedded sensors and communication networks. These devices collect real-time operational data that are transmitted to cloud-based platforms for analysis and decision-making. Through IoT integration, utilities and industries can detect faults earlier, optimize energy consumption, and improve asset management.

The implementation of IoT platforms represents a major step toward the creation of smart energy ecosystems, where data-driven insights enhance operational efficiency and sustainability.

The Internet of Things (IoT) refers to a network of interconnected devices capable of sensing, transmitting, and analyzing data without human intervention. In the energy sector, IoT forms the backbone of smart grids, smart meters, and automated control systems (Gupta et al., 2022).

IoT architecture in energy management typically consists of three core layers:

Perception Layer: Includes sensors, actuators, and meters that collect physical parameters—voltage, current, power, temperature, and equipment status.

Network Layer: Transmits data using wired or wireless communication technologies such as Wi-Fi, LoRaWAN, ZigBee, 4G/5G, or PLC (Power Line Communication).

Application Layer: Processes and visualizes the data on cloud or edge computing platforms, enabling analytics, alerts, and control actions.

IoT transforms static energy infrastructure into dynamic, responsive, and self-learning systems. By integrating AI and machine learning algorithms, these platforms can forecast energy demand, detect anomalies, and autonomously optimize resource allocation.

The implementation of IoT in energy monitoring systems involves the integration of multiple hardware and software components into a unified, scalable platform. This process includes device deployment, communication setup, data management, and analytics integration.

IoT-enabled energy monitoring begins with installing sensors and smart meters across key points of the energy infrastructure—generation units, substations, and consumer facilities. These devices measure electrical parameters such as voltage, current, frequency, and energy consumption.

Modern sensors are equipped with wireless connectivity and low-power microcontrollers that allow continuous operation and minimal maintenance. The collected data provide insights into energy losses, load fluctuations, and equipment performance (Zhang & Wang, 2021).

Reliable communication is critical for IoT systems. Depending on the application environment, various communication protocols are used:

ZigBee and LoRaWAN for low-power, wide-area monitoring;

Wi-Fi or Ethernet for industrial and building energy systems;

5G or LTE for high-speed, large-scale energy infrastructure;

MQTT and CoAP as lightweight data exchange protocols.

A well-designed communication network ensures minimal latency, high data reliability, and scalability for future expansion.

Collected data are transmitted to cloud servers or edge computing nodes, where processing and analytics occur.

Cloud platforms (e.g., AWS IoT, Azure IoT Hub, or Google Cloud IoT) provide powerful data storage, visualization dashboards, and predictive analytics capabilities.

In contrast, edge computing allows local processing near the data source, reducing latency and enhancing real-time control - a crucial feature for time-sensitive energy applications such as grid stability management (Kumar et al., 2022).

IoT software platforms integrate energy data into unified dashboards. Through AI-driven analytics, the system identifies consumption patterns, predicts equipment failures, and recommends optimization strategies. These platforms also support automated alerts and remote control actions, enabling operators to take immediate corrective measures.

Popular open-source and industrial software used for IoT energy monitoring include:

ThingsBoard (open-source IoT visualization),

Siemens MindSphere (industrial IoT platform),

IBM Watson IoT, and

OpenEnergyMonitor for small-scale renewable systems.

The integration of IoT platforms brings multiple benefits to the energy industry:

IoT systems enable continuous tracking of energy flows and equipment status, improving transparency and reliability. Real-time data allow instant responses to power fluctuations or system faults.

By analyzing vibration, temperature, and electrical signatures, IoT sensors can identify early signs of equipment wear. Predictive maintenance minimizes downtime and extends the lifetime of power assets (Chen et al., 2021).

Data-driven analytics reveal inefficiencies in production and consumption, allowing precise energy-saving strategies. For example, AI-based load management can automatically reduce peak consumption periods.

IoT platforms facilitate the integration of distributed renewable sources-solar panels, wind turbines, and battery systems-into the grid, balancing supply and demand through automated control (IEA, 2023).

Enhanced efficiency and predictive capabilities lead to lower operational costs and reduced carbon emissions. The ability to monitor energy use at every level contributes to achieving sustainability goals.

While IoT provides transformative benefits, its implementation in the energy sector is not without challenges.

The growing interconnection of devices increases the vulnerability of energy networks to cyberattacks. Unsecured IoT devices can be exploited to disrupt grid operations or steal sensitive data (Gupta et al., 2022). Ensuring encryption, authentication, and intrusion detection is essential.

IoT systems generate vast amounts of data that must be processed, stored, and analyzed. Inadequate data management strategies can lead to network congestion and system inefficiency.

Different vendors use diverse protocols and standards, complicating system integration. Developing interoperable architectures and open communication standards remains a major challenge.

Implementing IoT platforms requires significant investment in sensors, communication networks, and software systems. For developing countries, these costs can limit large-scale adoption.

Effective use of IoT technologies demands expertise in data science, network engineering, and energy systems. Capacity-building programs and collaboration between academia and industry are crucial.

The future of IoT in the energy sector lies in deeper integration with Artificial Intelligence (AI), Blockchain, and Edge Computing technologies. AI will enhance predictive analytics and autonomous control; Blockchain will secure data exchange in decentralized grids; and Edge Computing will improve response times and reduce network dependency (UN, 2024).

Emerging technologies such as 5G-enabled IoT, digital twins, and energy virtualization platforms will create smarter, more flexible, and resilient energy systems.

Furthermore, the trend toward green IoT-developing energy-efficient communication and low-power devices-will ensure environmental sustainability in digital energy transformation.

Conclusion

The implementation of IoT platforms in energy monitoring systems marks a crucial step toward the digital and sustainable evolution of the global energy industry. By linking physical infrastructure with intelligent digital platforms, IoT enables real-time control, predictive maintenance, and optimized energy management. Despite challenges related to cybersecurity, cost, and interoperability, the benefits of IoT-efficiency, reliability, and sustainability-are undeniable. As innovation accelerates, IoT will remain a key driver of smart energy systems and the foundation of the future low-carbon economy.

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ARTIFICIAL INTELLIGENCE APPLICATIONS IN ENERGY MANAGEMENT

Abstract. *The rapid evolution of digital technologies has transformed the global energy sector, paving the way for intelligent, data-driven decision-making. Artificial Intelligence (AI) plays a central role in modernizing energy systems, enhancing efficiency, reliability, and sustainability across power generation, transmission, and consumption.*

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