Development of Remote-controlled Smart Outlets using IoT Technology

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1. Introduction

In recent times, the government has been at the forefront of initiatives encouraging energy-saving practices. These efforts are rooted in the disruptions experienced during previous oil crises, which shifted the national focus to more efficient energy use. Current long-term projections for energy supply and demand suggest that a reduction of about 50.3 million kilolitres is achievable. The data shown in Figure 1, which illustrates the final energy demand within the energy mix, emphasizes the importance of efficient and waste-free electricity management to reduce power consumption. A key energy-saving strategy has been the implementation of smart meters. These devices track and display electricity usage within households, enabling users to visualize their consumption. The deployment of smart meters has empowered consumers to actively participate in energy conservation.

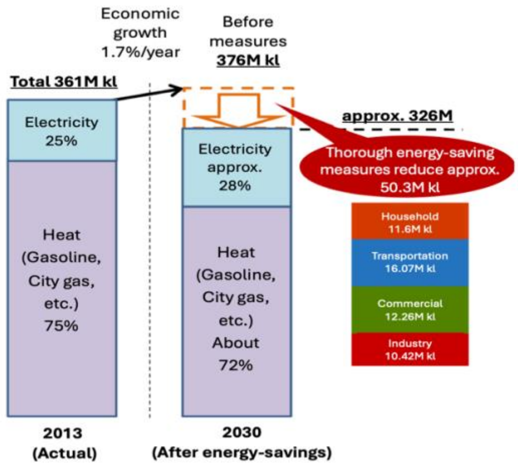

Figure 1. Final energy demand in the energy mix[1]

2. Objective

This study aims to create a device known as a smart outlet. The smart outlet, equipped with sensors, measures electricity usage, temperature, and humidity, using IoT technology to display the data on users' devices and enable remote control. By implementing this, users can monitor power consumption in real time at the installation site, promoting energy-saving and helping to decrease overall electricity usage.

3. Contents of Research

3.1 Classification of the smart outlet

Earlier research has led to the development of 100 V embedded smart outlets for use by general consumers in Japan and 200 V smart outlets designed for standard EV charging. This study extends these efforts by refining the technology, performing operational tests, and conducting pilot installations to move toward commercialization. Furthermore, a 200 V embedded smart outlet is being developed to curb energy waste from hotel guests who leave their air conditioners running.

3.2 Smart outlet systems

This research involves the development of a 100 V smart outlet equipped with a power meter (HLW8012) and a temperature/humidity sensor (DHT22) for data collection. The system's core component, an ESP32, transmits the gathered data to Amazon Web Services. Figure 2 illustrates the system operation layout. Furthermore, the remote-control features of the 100 V version were adapted to create the 200 V smart outlet with remote operation capabilities.

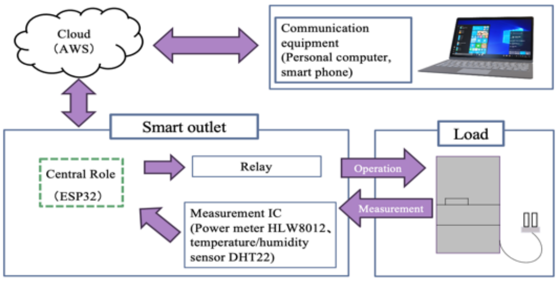

Figure 2. System operation diagram

3.3 Recessed smart outlet hardware for 100 V

The 100 V smart outlet's hardware has a two-layer board design, shown in Figure 3. The first layer ① features an AM2302 temperature and humidity sensor and an ESP32 microcontroller, while the second layer ② has an HLW8012 power meter that measures current, voltage, and power, transmitting data as pulse signals to the ESP32. The ESP32 gathers data, uploading it to AWS via Wi-Fi. Although the hardware was previously developed, this study validated its remote operation with software and an iOS app. Successful measurements and AWS data transmission were confirmed, though data accuracy concerns require further verification.

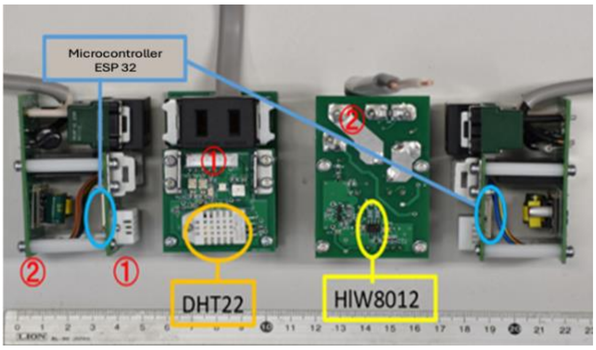

Figure 3. Hardware diagram from four directions

3.4 Smart outlet hardware for EVs

Past studies developed a 200 V, 30 A smart outlet for EV charging by modifying a 100 V model to include remote-control and charging control features. The design includes a 100 V smart outlet ①, an EV charging controller EKEPC2, ② and a 200 V, 30 A electromagnetic contactor ③. Shown in Figure 4. Currently, the 100 V unit serves as the control system. However, it lacks sensor insulation, which hinders safety certification. This study primarily focuses on testing the EV smart outlet in 'destination charging' locations, such as hotels in Nagano Prefecture. An improved version with upgraded components is also being developed to meet increasing demand.

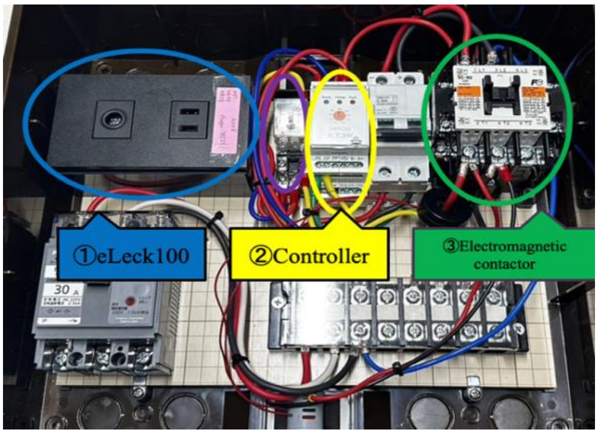

Figure 4. Hardware diagram of the developed smart outlet for 200[V]

3.5 Smart outlet hardware for 200 V

The 200 V smart outlet hardware in this study is in the process of being designed. It must fit into the size constraints of a standard double-panel box, shown in Figure 5, making a more compact design necessary compared to the existing EV smart outlet. Previous findings showed that the HLW8012 power meter, used in the 100 V smart outlet, can only measure up to 20 A, which is inadequate for 30 A needs. It was also noted that the measurement unit lacked proper insulation. To prioritize safety for commercial use, a new power meter capable of measuring up to 30 A with insulation was selected and tested individually. While the sensor's output response to input current changes was somewhat unstable, it was sufficient to proceed with prototyping the 200 V smart outlet for further refinement.

Figure 5. Panel box in which the PCB is to be fitted

4. Conclusion and Future Works

The 100 V smart outlet hardware has been completed, and ongoing tests in different environments, including varied frequencies, are addressing potential issues. Due to the current lack of insulation in the 100 V model, future development is expected to focus on insulated EV and 200 V models that have the necessary space for proper insulation. Moving forward, there is a need to enhance the stability and reliability of all smart outlets, including the 100 V version, while also considering component changes for cost reduction and performance improvements. Additionally, since the goal for the EV smart outlet is to introduce a user-charging system, it is crucial to enable the ESP32 to read signals from the EV charging controller via RS-485 communication to manage and detect charging completion, full charge, interruptions, or power outages.

References

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