IoT-Based Smart Outlet for an Autonomous Electrical Safety Management Service

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***Abstract*— At present, individual households within a multi-family residential are at vulnerable to electrical accidents. As if during a blind spot, they can't be covered under electrical safety management. This paper presents issues about an autonomous electrical safety management service which uses smart outlets to make sure electrical safety for individual households. Risk factors surrounding electrical incidents occurring during a mashup tech-based environment were analyzed and a sensible outlet equipped with a prediction technique was developed. Additionally to the present, an autonomous electrical safety management service scenario was developed to handle mechanical failures in autonomous electrical safety devices which run on IoT-based smart outlets. By utilizing such an autonomous electrical safety management service model, technology for electrical safety security was developed for individual households or each residential unit in multi-dwelling unit. The correlation among voltage, current, and 0 phase current was analyzed to spot the danger factors of electrical accidents and to predict accidents. In order to detect arc faults, a replacement prediction technique was developed. The technique the techniques applied to research nonlinear models like an arc fault show the diversity within the application areas of traditional fast Fourier transform (FFT) algorithms. Furthermore, by using such a way for electrical accident prediction, an autonomous electrical safety management model was developed. Thus, a measure to make sure micro-grid electrical safety was presented. There's the hope that this development of the management technique for individual households in reference to the fourth industrial revolution would contribute to electrical safety.**

Keywords—Electrical safety, autonomous management service, IoT adaptor, smart outlet, mashup, effective leakage current, over current, arc fault.

I. INTRODUCTION

General houses among residential types like townhouses, apartment, etc. are classified for general electrical installation and frequently receive an electrical safety check from experts pursuant to Article 66 of the Electrical Utility Act and Article 35 of its Enforcement Decree. Multi-family residential which are classified for general electrical installation also are subject to regular inspections for every residential unit. But some multi-family residential exist that look an equivalent as others, but are classified for self-electrical installation rather than general ones, and that they are not subject to such safety management services from the govt (1).

Currently, the world leakage breaker and molded case breaker are being used for electrical safety. Still, however, electrical incidents still reveal the limit of existing protective systems. for instance , year 2016 saw 9 deaths and 74 injuries from 916 accidents caused by electricity(2). In response, IoT-based preventive measures for electrical accidents were developed, accelerated by the fourth industrial revolution and the advancement of ICT technologies, but their use is solely confined to monitoring power usage, electrical status information, and load usage (3).

Existing electrical safety management is usually focused on the detection of voltage, current, leakage current, and arc, individually. And as each management factor approaches to its protective devices individually instead of comprehensively, the effective prevention against electrical incidents proves to be fairly difficult. To resolve this issue, an IoT-based smart outlet was developed which enables the risk factors of electrical incidents to be detected, and for the utilization of the smart outlet the Autonomous Electrical Safety Management System (AESMS) service was also created for individual households (4-5).

Mashups are a mashup of two or more data sources that have been combined into one. It entails mixing existing single-factor data, such as voltage, current, and leakage current, to create new data. Mashup analysis technique was used to detect irregularities including leakage, overcurrent, and arc faults. An ethernet and wireless communications module was also employed to provide detection and status information to a smart panel board or external terminals. A nano-grid management service model was also developed based on the needs of each residential unit and was utilised to aid in the development of an AESMS service for individual houses. By establishing guidelines for electrical event-specific nano-grid management, an operating system was created.

As a result, the current study discusses the technologies and approaches that may be used to successfully avoid any electrical event that may occur in each residential unit in a multi-dwelling unit that is vulnerable to safety hazards. For each residential unit, IoT-based smart outlet technology was developed, and household-based nano-grid management was thought to be the key to the AESMS service's success.

As a result, this work proposes a methodology for circuit theory instruction that is both practical and applicable. The approaches used to evaluate nonlinear models such as arc faults, in particular, demonstrate the breadth of classical FFT algorithms' application areas. The results provide a useful learning area for degrading models of electrical materials through analytical methodologies that employ established modelling methods to assess the integrity of materials in the examination of electrical risks.

The formatter will need to create these components, incorporating the applicable criteria that follow.

II. Development of an IoT-based smart outlet

A smart outlet was built utilizing an IoT-based autonomous electrical safety device, which is utilized in conjunction with smart panel boards, to analyse the risk aspects of electric circuits already in use by families. Smart panel boards keep track of branch circuit power lines and load status, while smart outlets keep track of load from plug-in outlet to circuit. Any abnormal load status, such as leakage, overcurrent, or arc faults, is detected by the smart outlet. A block diagram of an IoT-based autonomous electrical safety device is shown in Figure 1. It consists of a microcontroller unit (MCU), a status indicator, an on-off relay for autonomous control, a local area network (LAN), and a modem to convey the current state and forecast results for five different types of sensor inputs.

A voltage sensor detects blackouts, overcurrent, and undercurrents in power lines; a current sensor detects load current; a ZCT sensor detects zero phase current in single-phase circuit; an RF current sensor detects arc fault pulse; and a temperature sensor detects any failure within the outlet. The data collected from the voltage sensor (V) and current sensor (I) is analysed to detect overvoltage and overcurrent (I). The modulator determines the voltage zero-crossing for voltage sensor input, and the ZCT determines the resistive leakage current based on the phase difference between the leakage current and voltage, as stated by formula (1) (6-7).

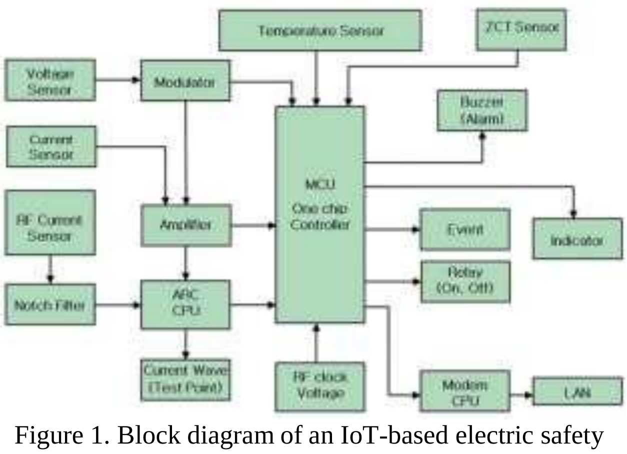


Figure 1. Block diagram of an IoT-based electric safety device.

$$Igr = Igo * \mathbf{cos}\,\theta \qquad \textbf{(1)}$$

The voltage sensor's standard phase and the current waveform from the current sensor are used to detect an arc fault. After analyzing both the FFT on load current and the arc fault pulse collected from the RF current sensor, the ARC CPU detects an arc fault.

Figure 2 shows a flow chart for detecting failure in an autonomous safety equipment. According to the flowchart, voltage, load current, and RF current can be used to determine an arc fault for the five types of sensors shown in Figure 1. In that order, it is meant to detect leakage, overload, and overheating. An LED warning light will illuminate if it isin a condition of failure, and data on the present state will be supplied to each household.

III. Performance variation of smart outlet

Figure 3 shows a newly created smart outlet, which is a self-contained electrical safety device. LEDs represent the present state of the power line as well as load condition such as leakage, overload, overheating, arc fault, and cutoff. For use in real-time Ethernet communications, data transfers of the electrical safety status was chosen for adoption.

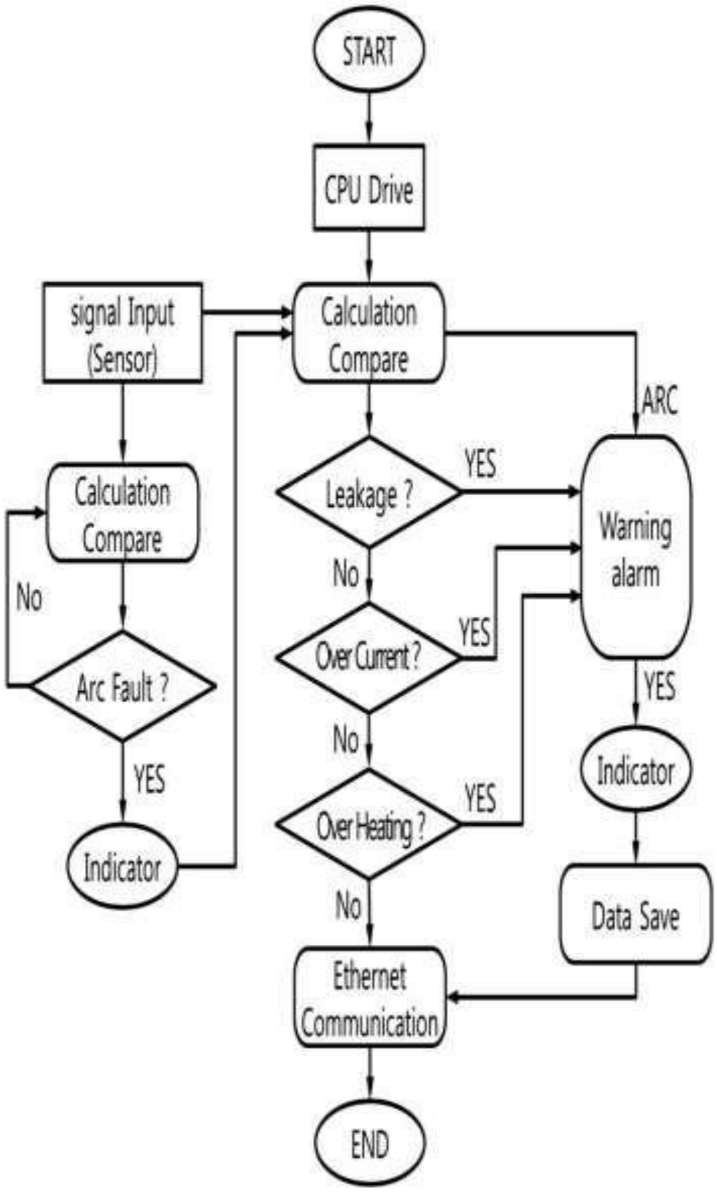


Figure 2. Flow chart for failure detection of IoT-based autonomous safety device.

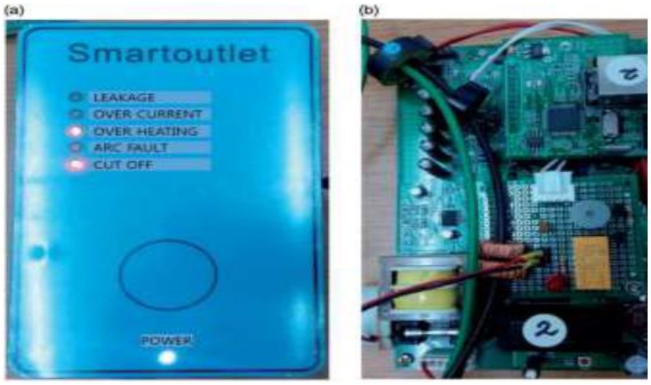


Figure 3. Development of a smart outlet (IoT-based autonomous safety device). (a) Appearance; (b) inner circuit board.

Figure 4 shows the performance test results for the arc fault detecting development presented in Figure 3(a). The smart outlet recognised the arc fault and switched off the load power, according to the test, which used a UL1699-based test facility. A leakage detection is shown in Figure 3(b). The detecting leakage current was limited to 15 mA during the test.

The test generated a 15.2mA flow and identified the device for which the phenomena was noticed, as well as cutting off the load power. An overload detection is shown in Figure 3(c). The cutoff load current was limited to 7.5A. The gadget recognised an irregularity and switched off the load power during the test, which allowed 7.7A to flow. An overheating detection is shown in Figure 3(d).The highest temperature was set to be 18 degrees Celsius. At 20 degrees Celsius, overheating was detected, and the load power was turned off.

IV DEVELOPMENT OF AUTONOMOUS ELECTRICAL SAFETY MANAGEMENT SERVICE

Individual residents or users living in the residential will benefit from the autonomous electrical safety management service, and the service manager will refer to the residential management office's safety manager. And the control tower is the government (or public organisation) that offers the public service. Figure 5 depicts how to use an autonomous electrical safety management service model, while Figure 6 depicts the functional levels in each step of the model. A smart outlet and a smart panel board are installed in each multi-family residential unit.

Step 1: The smart outlet sends multiple data on load status to the panel board such as the load type connected and incident status.

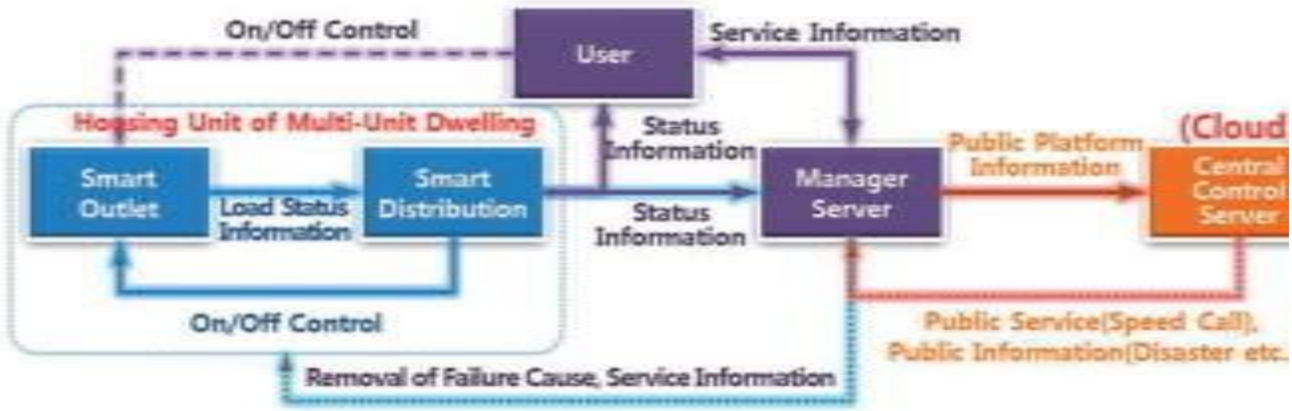
Step 2: The smart panel board collects information on smart outlet load status inside residential units. It also gathers and analyzes the current state of power lines of branch circuits. Based on such results, it provides data on the status of each residential unit to both the control server and users. The smart panel board, in addition, controls the branch circuit breaker when an electrical incident is expected and turns the smart outlet on or off by analyzing information on a branch circuit's power lines. The information about the status that smart panel board sends will be delivered differently to users and managers depending on data type and this will be processed to lead to safe electrical use.

Step 3: The manager server is controlled by the residential management office where the state of each residential unit's electrical safety is monitored. If any electrical event occurs, the office takes immediate action to fix the problem and provides service information to users. It also transmits the multi-dwelling unit's current state in terms of electrical safety to the central control server via a public platform and receives public service and accident-related information from the control server for ultimate use in the management of each multi-family residential unit.

Step 4: The central control server is run by the government or a public institution which can provide public information about accidents and the relevant service. The central control system helps collect and manage via public platform data from multifamily residential management servers and secures user safety when an incident occurs. The autonomous electrical safety management system is operated based on the IoT electrical safety device collecting and analyzing of the data that the device brings to respond proactively to electrical incidents and ultimately ensure a safe environment to use electricity in multi-dwelling units. The autonomous electrical safety service model for a multi-dwelling unit is designed to spontaneously respond to data from smart outlets or a smart panel board by collecting and analyzing such data. It shares the results from the current stat-based prediction and information about each residential unit with users and the manager server. Then, the necessary steps will be provided to fix failures, if any.

Figure 4. Detection characteristics of smart outlet by electrical accident types. (a) Test of arc fault; (b) Test of leakage; (c) Test of over current; (d) Test of over-heating.

Figure 5. Design of autonomous electrical safety management service model.



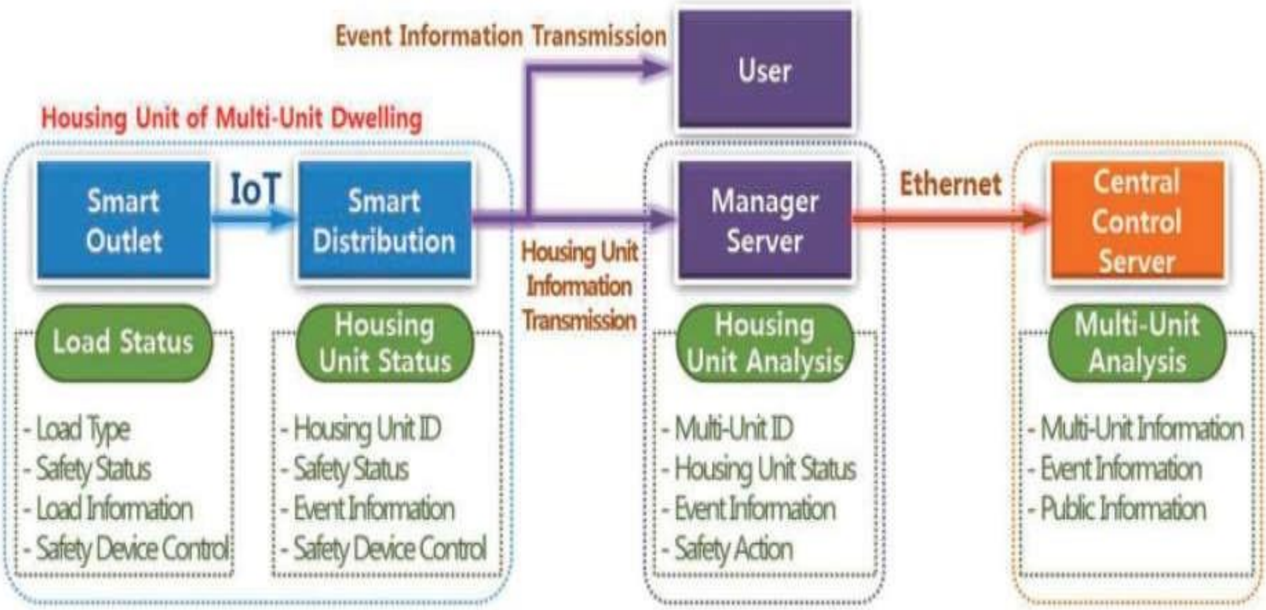


Figure 6. Define of functional levels in steps for autonomous electrical safety management.

Based on the results of the smart outlet and smart panel board assessments, Table 1 indicates the administrative norms for electrical accident events. Leakage current, overcurrent, arc fault, overvoltage, and blackout are all monitored and categorized into three levels: caution, warning, and danger. Table 1 lists the thresholds for each event.

The user will be notified if the detection results from the smart outlet and panel board fall below the threshold of caution. Both the user and the management office will be notified in the event of a warning level detection. If a danger level is detected, an event will be transmitted to the user, management office, and central control server, as well as electrical safety experts. Experts assess the level of safety and correct any issues to avoid electrical mishaps. The complete procedure is carried out on its own.

V. CONCLUSION

The current study describes how an autonomous electrical safety management service can ensure electrical safety for each household in a multidwelling unit. To respond spontaneously and proactively to events, a service model was designed in which smart outlets and a smart panel board detect and assess the risk elements of electrical safety events according to the actions outlined in the autonomous electrical safety management device. An IoT-based smart outlet was designed to detect any electrical accident risk factors such as leakage, overcurrent, and arc. The mashup technology was used on voltage, zero phase current, load current, and RF currents for smart outlets. The size and fluctuation of waveforms, as well as FFT, could be examined in a thorough manner using mashup technology, and detecting performance enhanced as a result. Experiments on the smart outlet's detection performance for each electrical safety risk element were conducted.

Monitoring factor	Event	Threshold	Action procedures
Leakage current	Caution	More than (Igr) 4.0 mA More than (Igo) 16.0 mA	In case the event persists for three da or longer • On-the-spot inspections after contacting the user
	Warning	More than (Igr) 8.0 mA More than (Igo) 20.0 mA	Immediately upon occurrence • On-the-spot inspection after contacting the user
	Dangerous	30.0 mA or more	On-the-spot inspection immediately upon occurrence (Circuit breaker check)
Over current	Caution	90% at the rated current 2 min or more	If increased 200% compared to the maximum level in the previous month • On-the-spot inspection after contacting the user
	Warning	100% at the rated current 2 min or more	In case of continued events for three days or longer • Notification to user
	Dangerous	120% at the rated current 2 min. or more	In case of continued events for 30 m or longer • On-the-spot inspection after contacting the user
Arc fault	Caution	Arc warning	In case of continued events for three days or longer • On-the-spot inspection after contacting the user
	Dangerous	Arc cutoff	Immediately upon occurrence • On-the-spot inspection after contacting the user
Over voltage	Warning	More than 242 V	Call to the management office for che • On-the-spot inspection and/or test if necessary
Blackout	Warning	190 V or less	Call to the management office for che • On-the-spot inspection and/or testi if necessary

Equipment where the autonomous electrical safety management service is applied can identify the location of failure for the load and electrical circuit and perform cause analysis. By analyzing data on the failure, predictions can be made on electrical equipment failure. Also, if the role of manager is required as was the case with the electrical circuit, the causes of failure can be resolved without any action by the user. The user benefits from being able to immediately resolve the cause of failure through an analysis of the location of failure that occurs in the electrical circuit or load. Likewise, by providing a service that uses status information that is transmitted to the user and manager through the autonomous electrical safety management service, safety and convenience are enhanced, which in turn can prevent small failures from becoming major accidents.

This paper presented functions and responsive actions needed at each phase of the smart outlet, smart panel board, manager server, and central control server in the development of an autonomous electrical safety management service. The standard value (threshold) for the service model operation was demonstrated and an autonomous system responding to an event occurrence was introduced. Further, a more in-depth empirical study will be conducted focused on resolving issues in the detection and/or operation of the autonomous electrical safety management service model using an electrical safety device presented by this paper. Through further empirical research, there is a desire to enhance user convenience and complete the responsive process of managers and the safety management body, leading to the development of a more accessible and convenient operating system benefiting more users. It is anticipated that electrical safety for individual households in multi-family residentials, who are not protected by the legal safety management, will greatly improve once the autonomous management service is applied in reality.

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