

## A Study on Cloud-based Safety ESS Watchdog System Using Ultra-Compact Wireless Sensor

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**Article History:**Received:11 november 2020; Accepted: 27 December 2020; Published online: 05 April 2021

**Abstract: Background/Objectives:** Safety matters are being discussed and countermeasures to prevent various breakdowns/accidents are urgently required. Therefore, we propose a safety management solution for ESS fire monitoring.

**Methods/Statistical analysis:** BLE 5.0-based ultra-compact wireless sensor-based edge that can detect off-gas early, as well as measure the temperature, humidity, vibration, and smoke in the golden time of approximately 10 minutes from the occurrence of thermal runaway inside the ESS to a fire. This paper proposes a safety system and an ESS-integrated safety management solution. **Findings:** It is known that the ESS currently in operation is installed without an integrated control method and a systematic protection system between facilities in order to connect new and renewable energy and to quickly supply the site, so there are many problems. For this reason, various accidents such as reactor failure and fire are occurring in the ESS installed at the actual site. Recently, 22 fires occurred in ESS facilities installed nationwide in 2019, and the government has urgently stopped ESS operation and formed a joint public-private investigation committee to clarify the cause. Among the various causes of ESS fires that have been raised, the ESS design should be considered. This paper reported an edge safety-based on BLE 5.0 that is capable of detecting off-gas and detecting temperature, humidity, vibration, and smoke early in the golden time of approximately 10 minutes from the occurrence of thermal runaway inside the ESS to a fire. A system and ESS integrated safety management solution were proposed. In this study, internal monitoring of an ESS was possible by integrating directly with existing and new ESS. The administrator can observe all conditions on the web through the cloud-based ESS integrated safety management system. **Improvements/Applications:** This paper analyzed and developed a cloud-based ESS integrated safety management system. It will be helpful in ESS fire management in the future and will be useful in designing artificial intelligence-based safety management solutions.

**Keywords:** ESS, Fire prevention, Wireless sensor, edge computing, gas sensor.

### 1. Introduction

As environmental problems, such as fine dust and global warming, have arisen, and the demand for clean energy has increased. With this, the use of wind and solar power has increased. An increasing number of new and renewable distributed power sources are being installed. Accordingly, the government expanded the use of new and renewable energy sources by introducing 'renewable energy 3020', and ESSs (Energy Storage Systems) to increase the reliability of the system because of the increase in distributed generation sources without system inertia. Applications are also increasing [1-3]. On the other hand, the currently operating ESSs have a range of problems because they are installed without an integrated control method or a systematic protection system between the facilities for new and renewable linkages and rapid on-site supply. Therefore, many accidents, such as reactor failure and fire, have occurred in ESSs installed at actual sites [4-7]. Recently, 22 fires occurred in 2019 in ESS facilities installed nationwide. As a result, the Korean Government urgently stopped the use of ESSs and formed a joint public-private investigation committee to determine the causes of these accidents. Various causes of ESS fires need to be considered when designing ESS safety procedures, and measures to prevent failures/accidents are needed urgently [8-10]. Currently, the development of technology related to preventing fires in ESSs in Korea is mainly in the development stage, with most studies performed by large companies, such as Samsung SDI, LG Chemical, and Hyosung Heavy Industries. The research in this area has focused mainly on preventing battery cell defects in the production process, monitoring PCS, arc occurrence, cell separator, and surge insulation destruction. Technology development is underway. Therefore, this paper reports a BLE 5.0-based ultra-compact wireless sensor-based edge that can detect off-gas early, as well as measure the temperature, humidity, vibration, and smoke in the golden time of approximately 10 minutes from the occurrence of thermal runaway inside the ESS to a fire. This paper proposes a safety system and an ESS-integrated safety management solution[11,12].

### 2. Main subject

#### 2.1. Artificial Intelligence-based Safety ESS Watchdog System

Figure 1(a) presents the conceptual diagram of the Safety ESS Watchdog System. The BLE 5.0-based

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gateway for data collection was applied to this system, and multiple communication interfaces were implemented to support interworking with various facilities and external platforms. In addition, the PKI algorithm security chipset board for edge-device security authentication and server-interworking communication security function implementation, as well as a high-speed edge rules engine service for real-time ESS operation status monitoring and control, were applied. Figure 1(b) shows the Edge Rules data model. The Edge Rules Engine Service has an automatic operation scheduler function, event alarm logging/management function, real-time data visualization, emergency stop function, and real-time stream data analysis function. In addition, to analyze the correlation of the sensor data, a deep learning-based ESS fire prediction and detection algorithm was applied to analyze the correlation of five sensor data and real-time RNN Recurrent Neural Network. The LSTM algorithm was also applied to perform model training and correct the learning errors of the RNN technique, as shown in Figure 1(c).

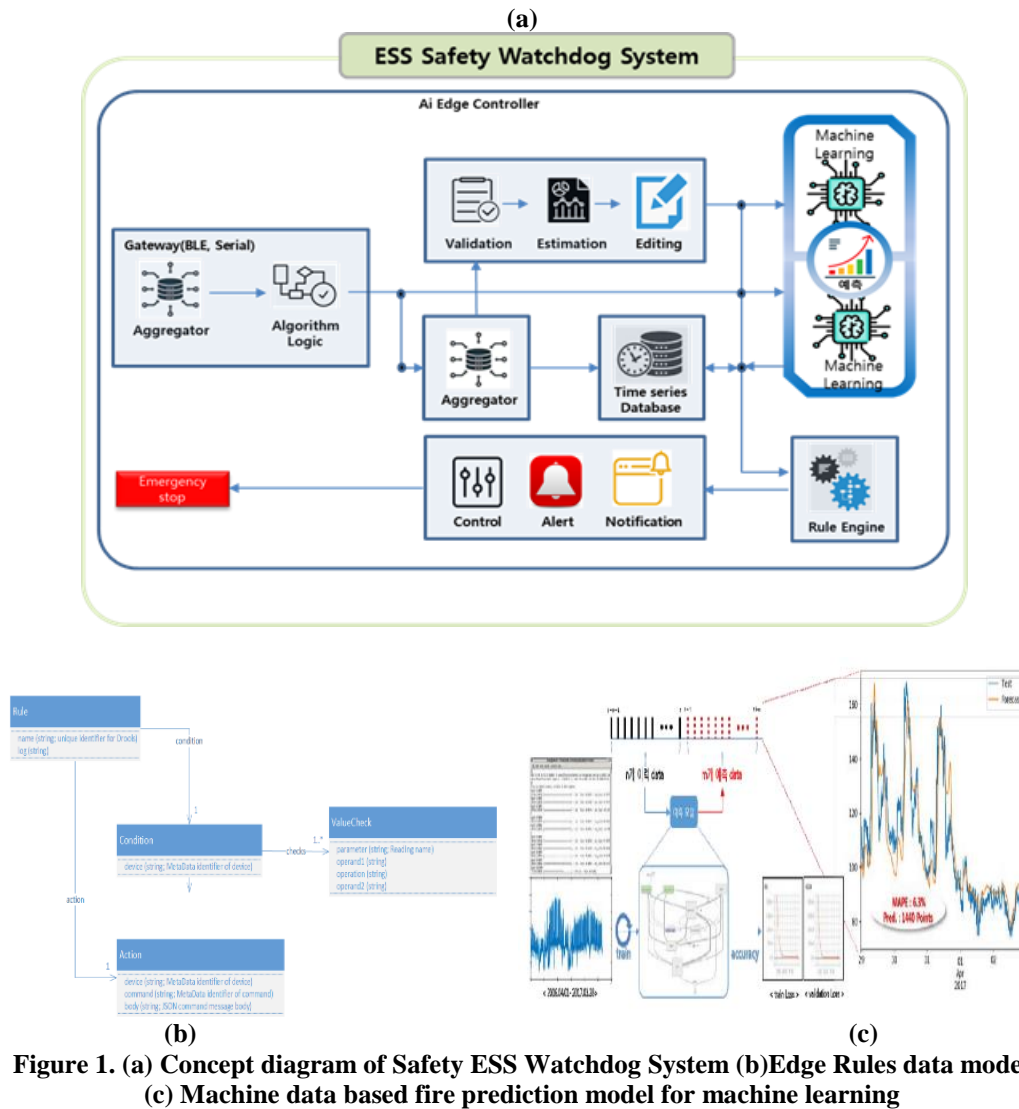


Figure 1. (a) Concept diagram of Safety ESS Watchdog System (b)Edge Rules data model (c) Machine data based fire prediction model for machine learning

## 2.2. Cloud-based ESS integrated safety management system

In the ESS integrated safety management system, various ESS-type setting functions and data maps were implemented for the integrated management of ESSs, and a device-object structure and ESS-type support communication interface were used for integrated management of multiple ESSs at a distance. Figure 2(a) presents the Cloud-based ESS integrated safety management system conceptual diagram. Therefore, ESS-integrated management is possible in real-time, and ESS integrated monitoring, individual monitoring, and emergency control functions are provided. If an emergency event occurs, an alarm is announced on the user's web; Figure 2(b) presents the Safety ESS integrated safety management system data flow chart.

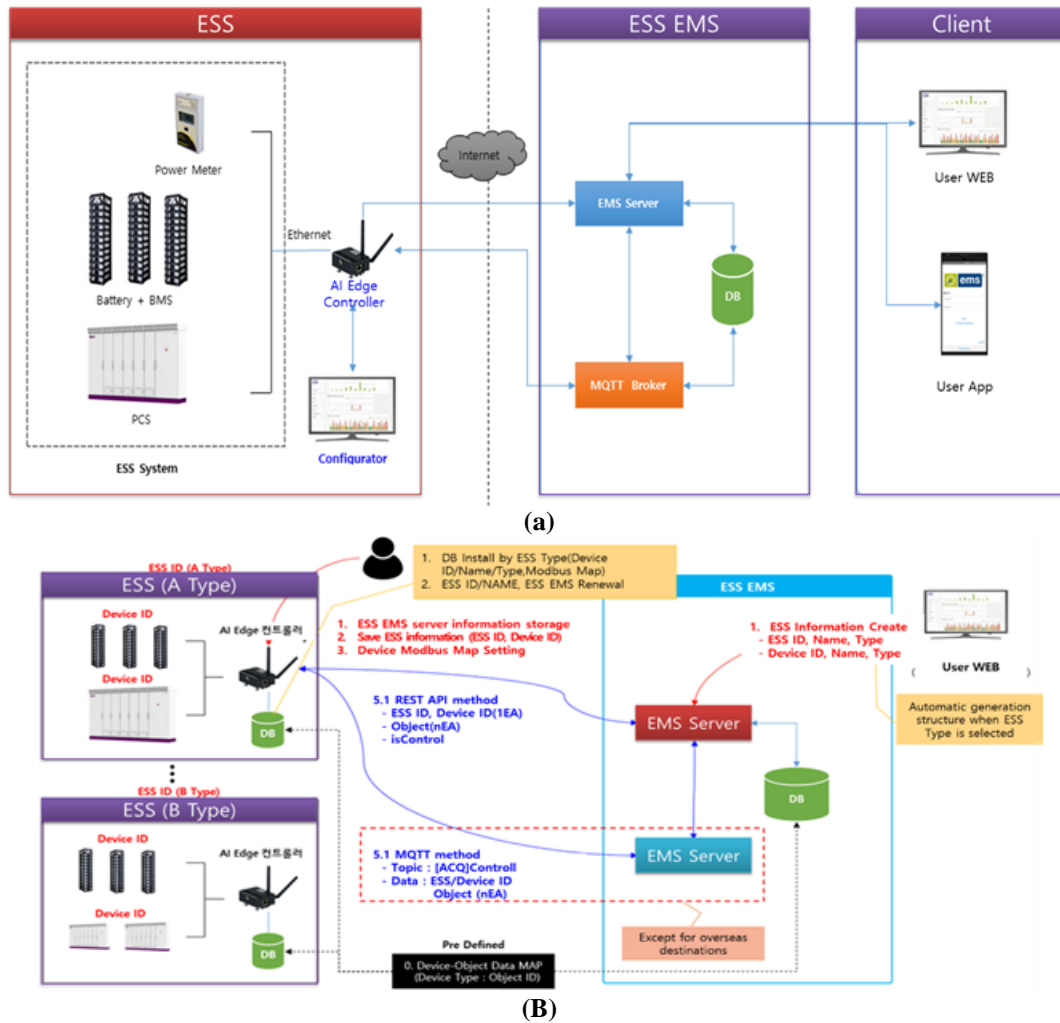


Figure 2. (a) Cloud-based ESS integrated safety management system conceptual diagram  
(b) Safety ESS integrated safety management system data flow chart

### 2.3. BLE 5.0 based compact wireless sensor module

To pre-detect fire-causing factors, five types of sensors were applied: temperature, humidity, smoke, vibration, and off-gas sensors. This ultra-compact wireless sensor was equipped with an attached sensor case using neodymium magnets and non-combustible materials so it can be installed easily in a battery rack (RACK) and perform communication and sensing functions for a certain period (five minutes or more) during a fire. In addition, a low-power wireless communication method was applied to secure a long battery replacement cycle. Figure 3(a) shows the shape of the five sensors. Figure 3(b) and Table 1 show the sensor installation method, type, location, and number according to the monitoring equipment. In addition, fire-level diagnosis and fire prevention/response according to the action plan were prepared, as shown in Table 2. Figure 4 Example of off-gas sensor product shape and ESS RACK installation method. Figure 5 shows the BLE sensor mechanism, composition and parts arrangement.



Figure 3. (a) Prototype of ultra-small wireless sensor module (b) Sensor installation location according to monitoring equipment

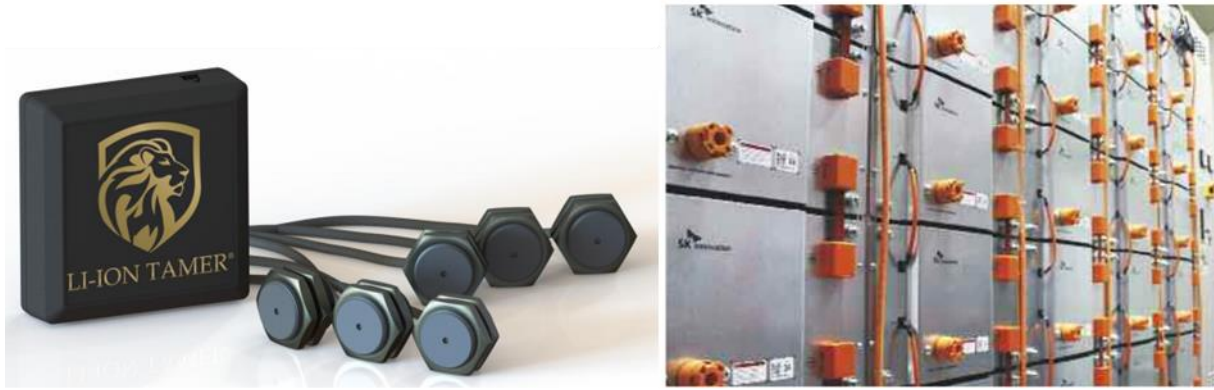


Figure 4. Example of off-gas sensor product shape and ESS RACK installation method

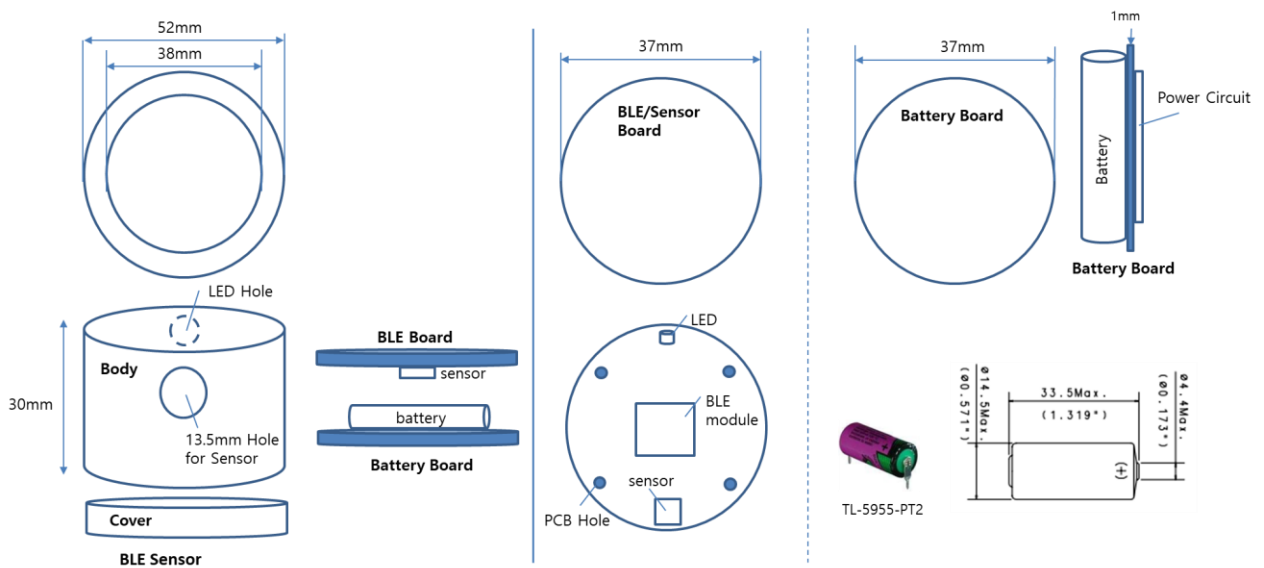


Figure 5. BLE sensor mechanism, composition and parts arrangement

Table 1: Sensor type/location/count/purpose according to monitoring equipment

object	Sensor	Installation location	Count	Purpose of monitoring
Battery rack	Vibration sensor	Rack outer top	1/Rack	Battery rack vibration abnormality detection
	temperature Sensor	Inside rack	1/Rack	Detect abnormal temperature inside the battery rack
	Offgas Sensor	Inside rack	1/Rack	Offgas detection
	Smoke sensor	Inside rack	1/Rack	Smoke detection inside the battery rack
Battery room	temperature Sensor	Battery room Entrance/Center	2/Room	Battery Room Condensation Diagnosis Battery Room Air Conditioning Monitoring
	Humidity sensor	Battery room Entrance/Center	2/Room	Battery Room Condensation Diagnosis Battery Room Air Conditioning Monitoring

Table 2: Fire-level diagnosis, fire prevention/response according to action plan

division	fire			
	Step 1	Step 2	Step 3	Step 4
Occurrence	Thermal Abuse	Off-gas generation	Smoke generation	Fire

	Electrical Abuse			
	Mechanical Abuse			
Diagnostic method	BMS Temperature/humidity/ Vibration sensor	Off-gas sensor	Smoke detection sensor	Flame sensor
Measures	Alarm occurrence Manager Notice	Local alarm alarm Emergency stop Electrical system disconnection Manager Notice	Site alarm alarm Emergency stop System blocking Firefighting started Manager Notice	Site alarm alarm Emergency stop System blocking Firefighting started Manager Notice

### 3. Conclusion

This paper reported an edge safety-based on BLE 5.0 that is capable of detecting off-gas and detecting temperature, humidity, vibration, and smoke early in the golden time of approximately 10 minutes from the occurrence of thermal runaway inside the ESS to a fire. A system and ESS integrated safety management solution were proposed. In this study, internal monitoring of an ESS was possible by integrating directly with existing and new ESS. The administrator can observe all conditions on the web through the cloud-based ESS integrated safety management system. Nevertheless, more research will be needed to improve the ESS fire prevention system in the future.

### 4. Acknowledgment

This study is the result of research conducted by Jeollanam-do Province and Green Energy Research Institute as “Jeonnam Energy New Industry Commercialization Project (R&D, R2-2019-04-01)”.

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