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Considerations for the application of IoT technology to nuclear power plants

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1. Introduction

IoT technology is developing very fast based on the development of electronic device technology, communication technology, and computing technology. In particular, after the advent of AlphaGo, the AI technology field began to be applied in almost all fields with the improvement of computing power.

Nuclear power plants are plants that value safety the most and operate under the influence of strong safety-related regulations. It is clear that various regulations on nuclear power plants play a role in protecting the essential safety functions of nuclear power plants, but it is also true that it makes it difficult to apply advanced technologies like the IoT industry. As the number of years of operation of nuclear power plants increases, accidents caused by the aging of BOPs are more frequent than the primary system[1]. A total of 72 domestic nuclear power plant failures have occurred over the past five years since 2016, of which 29 have occurred in the secondary system, accounting for 40.3% of the total failures during the period.

Table. 1. Status of failure accidents by nuclear power plant safety operation information system

Period 2016 to 2021							
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**Total**
primary system	**12 (52.2%)**	**3 (42.9%)**	**5 (35.7%)**	**4 (44.4%)**	**7 (70.0%)**	**1 (11.1%)**	**32 (44.4%)**
Secondary. system	**7 (30.4%)**	**1 (14.3%)**	**7 (50.5%)**	**3 (33.3%)**	**3 (30.0%)**	**8 (88.9%)**	**29 (40.3%)**
Other	**4 (52.2%)**	**3 (52.2%)**	**2 (52.2%)**	**2 (52.2%)**	**0**	**0**	**11 (15.3%)**
the sum	**23**	**7**	**14**	**9**	**10**	**9**	**72**

Therefore, technologies are required to detect and prevent failure accidents on the aging BOP side early, and it is time to try to apply advanced technologies in the IoT industry to nuclear power plants under strict regulations.

2. Cable problem

The IEC classifies nuclear equipment into three classes (Category A-B-C). Category A is a safety grade device, Category B is a non-safety grade device related to safety grade, Category C is a non-safety grade device, and I&C is treated as an area of Category C. Due to the aging of I&Cs due to the increase in the number of operating years of nuclear power plants, the need to replace them continues to increase.

Additional monitoring sensors need to be introduced to increase the safety of nuclear power plants, but they are not smooth due to various problems. The installation and operation of new cables according to the additional application of many wired sensors is virtually impossible because it causes the situation as shown in Figure 1.

Figure 1. Nuclear power plant cable installation status

The price of cables used for communication and power supply in nuclear power plants is above $1,000/ft. The maintenance cost of cables amounting to hundreds of kilometers due to wired sensors installed or required to be installed in nuclear power plants also has a serious impact on economic feasibility. Considering that the unit price of renewable energy generation continues to decrease, the economic feasibility of nuclear power plants is also very important in enhancing competitiveness.

Wireless technology can be proposed as an alternative to solving this problem, and wireless technology is already being developed in the IoT industry in a commercially available form. In order to apply wireless technology, regulations according to the application of wireless technology must be satisfied, and a technology that processes a lot of sensor data is required.

3. Wireless Technology and Artificial Intelligence Technology

NRC defined regulations on EMC impact required for the application of wireless technology through R.G. 1.180, and EPRI presented a guide to EMC that meets the regulations of R.G. 1.180 experimentally through TR-102323. However, the IEC standard restricts the application of wireless technology to Category C and prohibits Category A and B.

At the Arkansas One nuclear power plant, a cooling fan failure inside the containment building caused a huge economic loss by shutting down the reactor as the internal temperature rose. Since then, two wireless vibration sensors have been installed on the cooling fan in the horizontal direction of the rotation axis to establish and operate a technology that transmits spectra and waveforms every five minutes using WiFi communication [2]. A simple technical measure could have prevented the shutdown of the reactor, but it can be defined as an accident caused by the neglect of monitoring of the cooling fan.

IEEE and IEC are revising standards for wireless technology for application to nuclear power plants, and IAEA wants these standards to achieve Harmonization, but suggests that new wireless technologies that meet these standards can be applied within the regulatory framework.

The IAEA wants innovative technologies such as smart sensors and wireless communication technologies to be applied within regulations, and the SRM field is already actively utilizing the technologies of the IoT industry. The industry has already commercialized low-power wireless communication technologies such as IEEE 802.15 (WirelessHart) and IEEE 802.11 (WiFi-halow), and KHNP is applying WirelessHart wireless communication to monitor wireless vibration for rotators installed in the turbine building of Hanbit Unit 6. According to EPRI TR-102323, the EIRP (Effective Isotropic Radiated Power) of wireless devices must perform documented engineering evaluations on devices with 27 dBm or more, and wireless devices that meet EIRP standards can be implemented with Wireless Heart and WiFi-halow technologies. In order to reduce current consumption of the wireless communication unit, a technology utilizing a sleep mode may be applied, and a function of synchronizing a wake-up of a wireless device may be used.

In the case of artificial intelligence technology, it is not certain about the acceptance of technology from the perspective of nuclear power plant regulation that follows the deterministic methodology. However, considering that research is underway to use risk-informed regulation in the regulatory decision-making process along with the existing concept of deep defense, engineering judgment, and driving experience, artificial intelligence technology is expected to be applied as an auxiliary means of decision-making. Wireless sensors have the advantage of being able to be installed in large quantities, which results in a large amount of surveillance data collection, so the demand for the use of artificial intelligence technology for diagnosis is bound to increase.

4. Power supply for wireless devices

Wireless devices use batteries as power sources. Due to the characteristics of wireless devices that are installed in large quantities, frequent battery replacement seriously undermines the operation and economic feasibility of wireless devices.

In the case of currently commercialized wireless sensing devices, signal collection cycles are often set in hours or days to reduce current consumption, and simple signal collection and wireless transmission of collected raw signals are provided.

It is efficient to apply a technology that transmits meaningful small-sized data instead of large raw signals through signal collection and signal processing, and for this, HW implementation technology for low-power sensing and signal processing is required.

5. Conclusion

In the field of nuclear energy, including SRM, there is a trend to actively utilize technology in the IoT industry. The IAEA recognizes the need to apply artificial intelligence technology to regulations and diagnoses necessary to apply innovative technologies such as smart sensors and wireless communication technologies to nuclear power plants.

These advanced technologies in the IoT industry can be applied to a level that thoroughly satisfies regulations. Currently, the need to introduce these technologies is emphasized, but in order to be applied to the actual nuclear industry, regulations and standards need to be developed in a direction that can be embraced.

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