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Considerations for the application of IoT technology to nuclear power plants

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1. Introduction

Wireless technology is emerging as a way to monitor devices in nuclear power plants. Compared to wired technology, wireless technology is very excellent in terms of economic feasibility of installation cost and maintenance cost. Wireless technology can be composed of a wireless sensor network composed of wireless sensors and a wireless communication infrastructure to efficiently transmit signals from the wireless sensor network to the power plant's wired network.

In order to apply wireless technology to nuclear power plants, wireless sensor network communication protocols are required to harmonize with wireless communication infrastructure, and wireless smart sensor technology is also important.

2. Current Status of Wireless Technology in Nuclear Power Plant

The electric field strength generated by wireless devices is a kind of noise and can cause malfunction of nuclear power plant instruments, so NRC strictly regulates this. The part where wireless devices can generate electric field strength that can affect surrounding instruments is a wireless antenna.

Through NRC R.G.(Nuclear Regulatory Commission Regulatory Guide) 1.180 and EPRI(Electric Power Research Institute) TR-102323, wireless measuring instruments applied to nuclear power plants require a electric field strength of less than 27 dBm (4 V/m), and wireless communication antennas are the biggest cause of electric field strength in wireless devices[1][2]. IEC(international Electro-technical Commission) TR 6335-2021 proposed the application of industrial wireless standard technology to SMR development to improve economic feasibility. In the US EPRI, 2.4 GHz and 700 MHz wireless communication infrastructure was built at Crystal River and Zion nuclear power plants through the development of the Distributed Antenna System (DAS), and in Korea, through an experiment using Hanbit Unit 6, a DAS-type wireless communication infrastructure is being built at Saeul Unit 3&4 and Shin Kori Unit 5&6, which are currently under construction, and Saeul Unit 1&2 which are already in operation.

In particular, Hanbit Unit 6 monitors the vibration of the rotors in the turbine building by applying WirelessHart technology, and it monitors vibration once a day due to the absence of low-power smart sensing technology to reduce battery current consumption

The IAEA (International Atomic Energy Agency) actively recommends the application of wireless technology not only to existing nuclear power plants but also to next-generation nuclear power plants to improve the economic feasibility of nuclear power plants in line with the trend of declining power generation costs of new and renewable energy other than nuclear power at NPIC 2023. However, it emphasizes that the application of technology must be made within the regulations of the NRC[3].

The wireless sensor network for wireless monitoring should be established as a wireless sensor network that meets the electric field strength regulations provided by the NRC. For the immediate detection of abnormalities in the device, it is required to perform monitoring in the shortest period, and it is required to integrate low-power wireless sensing technology and low-power wireless communication technology that can be operated for a planned maintenance cycle (18-24 months) of a nuclear power plant. In addition, the application of multi-band heterogeneous network technology is proposed as a way to efficiently collect various types of signals in the wireless sensor network and alleviate the problem of radio interference[4].

The application of wireless technology in nuclear power plants is developing in the direction of monitoring devices in a wide area while meeting the NRC's electric field strength regulations. In order to solve the problem of the electric field strength occurring in the antennas of wireless devices, wireless communication technology with a low electric field strength that includes the IoT industry's standards is applied, and multiple antennas that can cover small areas are distributedly installed and operated instead of centralized signal collection antennas.

3. Considerations

A wireless sensor network for radio monitoring shall meet the NRC's electric field strength regulations. The following Figure 1 is the recommended emission standard for electric field strength defined in EPRI TR-

102323 according to NRC R.G. 1.180[1][2]. As shown in Figure 1, the installed measuring instrument must withstand the electric field strength of 10V/m and adhere to the EIRP (effective isotropic radiated power) limit within 4V/m[2].

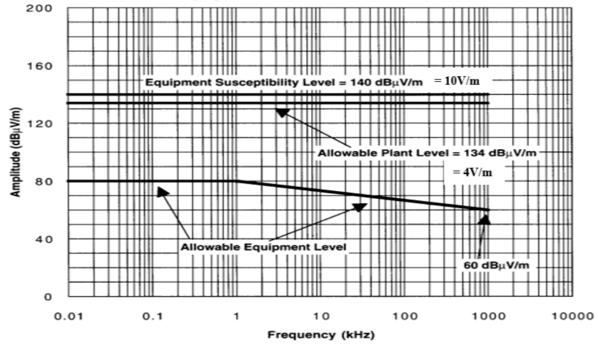

Fig. 1. Permissible radiation electric field strength

The correlation between radiation field strength and distance is as follows.

(1) $d = (30\ P_tG_t)^{0.5} / E$

{ P_t = EMI/RFI emitter radiation output (Watts)
G_t = EMI/RFI emitter radiation output gain
E = allowable emission electric field strength (V/m) at EMI/RFI emitter installation point }

In the above equation (1), when G_t is 1 and d is 1m, the P_t (EMI/RFI radiation output) is 533mW, which is expressed as 27.3dBm. Therefore, wireless measuring instruments with an EIRP of 27dBm or less can be used. The EIRP of wireless devices is determined by wireless communication methods, and WirelessHart and WiFi Hallow in the IoT industry meet this condition. Table I shows the standards and EIRP of WirelessHart and WiFi Halow.

Table I: IEEE Standard and EIRP of Wireless Hart and WiFi Halow

Communication	IEEE Standard	EIRP
WirelessHart	IEEE 802.15.4	10 dbm
WiFi-Halow	IEEE 802.11.a	18 dbm

WirelessHart uses an ISM band of 2.4 GHz as an IEEE 802.15.4 series low-power wireless communication protocol. By adopting a time division multiple access (TDMA) method using slot channel hopping using a time slot of 10 ms, time-deterministic communication is possible and up to 80 radio sensing modules can be connected. WiFi Halow is an IEEE 802.11a family that uses an ISM band of 917.5 MHz to 923.5 MHz in Korea. About 8,000 radio sensing modules can be connected using a code division multiple access (CDMA) method as a low-power wireless communication protocol that combines the advantages of WiFi and LoRA.

Considering the data size and wireless transmission distance collected by the wireless sensing module, the combination of WiFi Halow and Wireless Hart can reduce radio interference, increase data transmission efficiency and current consumption reduction efficiency of wireless devices, and configure a multiband heterogeneous wireless sensor network. Table II is a comparative analysis table of the scalability, radio interference, data rate, pay load, and communication distance of these two wireless communication protocols.

Table II: Wireless Hart and WiFi Halow comparison

	WirelessHART	WiFi Halow
Purpose	Process Industry	IoT
Key Features	High reliability, real-time support	Long range, power saving
Scalability	Good	Very Good
Interference	Large	Small
Data Rate	~250kbps	150kbps~
Payload	Max 127bytes	Same to 802.11's MSDU (maximum payload size – 2034 bytes)
Transmission Distance	225 meter	> 1 km

4. Conclusion

Currently, the introduction of wireless technology for a higher level of monitoring and economic improvement is becoming active in nuclear power plants, and research on applying wireless communication infrastructure called DAS and wireless technology in the IoT industry is active. For effective application of wireless technology, it is necessary to consider reducing the interference of data size, wireless communication distance, and applied radio waves collected through wireless monitoring. Currently, issues related to wireless communication are emerging, but low-power wireless smart sensor technology that performs wireless sensing is also essential.

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