A method for wireless technology application in nuclear power plant

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1. Introduction

The need to apply wireless technology to domestic commercial nuclear power plants (NPPs) is growing. For operating NPPs, the need to introduce an additional monitoring system is raised with aging of NPPs, but problems with cable installation, management and maintenance costs arise. Since there are regulatory issues and difficulties in establishing a wireless communication network to operating NPPs, it is possible to establish a local wireless communication network and introduce wired and wireless technology to connect them. In the case of new NPPs and SMRs, it is possible to solve regulatory problems while establishing a wireless communication network from the design stage. In the United States, wireless technology is already applied to some NPPs, but in Korea, the application of wireless technology is yet to realize as it has not been able to actively cope with the EMC regulation problem [1].

Wireless technology should be implemented in an integrated form of wireless sensing, wireless communication, and artificial intelligence technology for diagnosis. Wireless sensing requires low-power technology to alleviate the battery replacement problem. Here, a method for applying wireless technology to NPPs is described.

2. Electromagnetic Compatibility (EMC)

Figure 1 shows the field strength criteria presented in EPRI TR 102323.

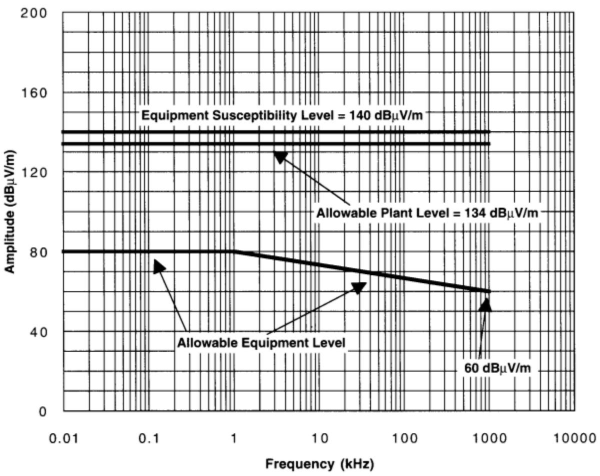

Figure 1. Electric Field Strength

A difference of 8 dB must be maintained between the safety and protection relevant instrumentation and control system. For the radiation field operating area of 10V/m (140dBμV/m), the radiation field emitted from the wireless devices within the restricted area should be limited to 4 V/m (132 dBμV/m). The minimum separation distance for the wireless devices from the instrumentation and control system is defined as follows [1].

$d = (30\ PG)^{0.5} / E$
P = EMI/RFI emitter radiated power (Watts)
G = Radiated power gain of EMI/RFI emitter (unintentional emitter 1 or less, intentional emitter (dipole antenna: 1.5, monopole antenna: 3, horn antenna: 6))
E = Radiated field strength at the point of EMI/RFI emitter installation (V/m)

The characteristics of the WLAN and Radio methods are defined as shown (Table 1).

Table. 1. Feature of WLAN and Radio

List	WLAN		Radio
Frequency	2.4 GHz	5.0 GHz	896/450 MHz
ISM Band			902~928 MHz
Max. radiated power	1W (USA) 100 mW (Europe) 10 mW/MHz (Japan)		4~5W
Communication system	Wi-Fi		Wi-Fi UHF/VHF communication
Standard	IEEE 802.11		
Data transmission rate	2 Mbps		
RFI	Close use for sensitive device		Keep distance

Korea Hydro & Nuclear Power Co., LTD (KHNP) is in its preparation to apply WirelessHART and WiFi method to wireless sensing module, and to wireless communication, respectively. Several repeaters are connected to the PS-LTE network. The characteristics of short-distance wireless communication are shown in Table 2.

Table. 2. Short-range Wireless Communication

	WPAN			WLAN
	Bluetooth	ZigBee	Wi- HART	Wi-Fi

IEEEStd.	802.15.1	802.15.4	802.15.4	802.11b
Max. Speed	1 Mbps	20~25 kbps		54/300 Mbps
Transfer Dst.	tens of meters	10~75m		20~100m
Freq.	2.4GHz	2.4GHz		2.4/5 GHz
Power		< 50mW		< 40mW

Table 2. Short-range Wireless Communication

The EIRP (Effective Isotropic Radiates Power) condition for the radiation field strength presented in EPRI TR-102323 is less than 27 dBm. The EIRP of WirelessHART is 10 dBm, and when an isotropic antenna is applied, the electric field strength at a distance of 1 m is 0.547 V/m.
Therefore, wireless communications based on WirelessHART can be applied with respect to the EMC regulations for NPPs.

3. Low-power Wireless Sensing

One of the issues for wireless sensing technology is battery replacement. It is not practical to apply a large number of wireless sensing modules, if the battery replacement cycle is short. Therefore, a technology capable of low-power sensing is required.

Fig. 2 shows a concept of time-domain and frequency-domain monitoring in wireless sensing. Time-domain is for continuous monitoring at all times, whereas frequency-domain is for periodical monitoring for detecting leakage signals. In time-domain monitoring, the acoustic ultrasonic signal is filtered in terms of specific frequency so the leakage is monitored continuously. In frequency-domain monitoring, the frequencies below 5 kHz are collected, processed and transmitted at specific intervals.

To lower the power required for sensing, PCB (printed circuit board) was designed and manufactured. The sensing module for frequency-domain monitoring for the leakage, the interval was 130 seconds with an average current consumption of 343 μA. The low-power sensing module is protected by a case, so no issues against electric field strength is expected.

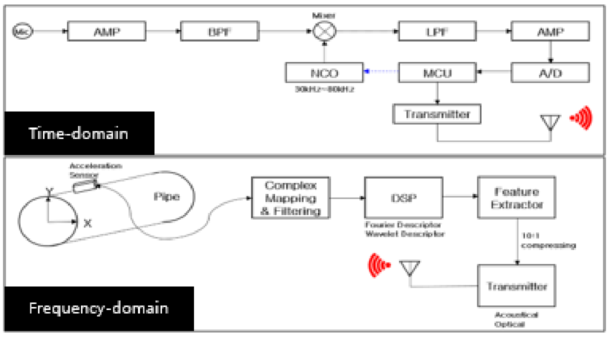

Figure 2. Low-power Sensing Modules.

4. Conclusion

To apply wireless technology in NPPs, EMC regulations must be taken into account. EMC issues can be resolved in a way to use technologies used in the IoT industry, such as WirelessHART and WiFi, for wireless communication, and implementing low-power technology for wireless sensing modules.

REFERENCES

[1] NRC Regulatory Guide RG-1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems", U.S. Nuclear Regulatory Commission, 2003.
[2] EPRI TR-102323-R1, "Guidelines for Wireless Technology in Power Plants", Electric Power Research Institute, 1997

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