Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2009

Feasibility of Wireless Sensor Applications for Nuclear I&C Systems

Kyemin Oh, Gyunyoung Heo*
Kyung Hee University, Yongin-si, Gyeonggi-do, 446-701, Korea
**Corresponding author: gheo@khu.ac.kr*

1. Introduction

Digital technologies which are widely used in common industries cannot be applied to nuclear power plants (NPPs) promptly because of the principle of the proven technology, which is one of the top priorities for nuclear safety. A majority of instrumentation and control (I&C) systems in NPPs is still based on analog technologies. It should be noted that operation and maintenance (O&M) of I&C systems is getting more difficult and expensive because workers are exposed to radioactivity when they are testing or servicing, and analog parts are no longer available. However, the shifting to digital systems seems quite retarded because of such conservativeness of nuclear industry. [1] Among I&C related problems, the degradation of cables occurring in long-term operation NPPs should be noticed. While cables are important to performance and safety of a plant, the cost for O&M should be hugely paid out. As a solution of this problem, the introduction of digital technologies seems crucial.

This paper suggested wireless sensor applications for cable aging management. With the domestic and international examples, this paper reviewed and summarized the requirements considered in case that wireless applications are applied to nuclear fields.

2. Methods and Results

2.1 Problems of Wired Instrumentation

Cables are vital components of I&C systems. All safety-related components including I&C cables, therefore, needs to be qualified to perform their functions both under normal operating conditions and under a design basis accidents (DBAs) and post-DBA conditions.

Generally, the qualification of safety-related I&C cables is based on IEC-780. This aims at demonstrating cable's ability to survive during a DBA after exposure under normal conditions for the life time of NPPs by providing the detail procedures which is based on accelerated ageing test methods. The evaluation of cables using these methods is important for verifying that cables are being used within the constraints of their environmental qualification and thus providing greater assurance of the long-term functionality of cables, particularly, inside containment.

However, in case of an extended long-term operation, all components should work without any defects during the extended period. In this connection, it is useful to mention that there are currently no practical in situ electrical tests that can verify functionality of installed aged cables under DBA and post-DBA conditions. Therefore, the management of the ageing of cables requires the evaluation of the material condition of cable insulation, which was the focus of the CRP on ageing management of I&C cables. [2]

The most desirable way of this problem is to replace cables with new one, but the point is cost. Considering radiation exposure to worker, it is not quite an easy problem.

2.2 Wireless Sensor Applications

Even though they are a demonstrative level, there are many instances to use wireless I&C systems. The followings are domestic and foreign examples of those techniques.

○ Charging Pump Gearbox Monitoring

EPRI has developed and installed a charging pump gearbox smart sensor. The objective of this work is to improve availability while reducing maintenance costs and downtime. The developed wireless smart sensor acquiring and processing data from two vibration channels estimates current health and predicts remaining useful life. The output from the smart sensor provide information about the condition of the gearbox and its ability to perform its function for a given mission duration, such as the remainder of the fuel cycle. Through the frequency and protocol test, the standard frequency of wireless LAN which used in transmission of data of I&C system was determined to IEEE 802.11b considering compatibility with other instruments and security. [3]

○ Power Plant and Safety Control System

Korea Midland Power Company (KOMIPO) has built 'u-IT Plant Management System' using RFID (Radio-Frequency Identification) / USN (Ubiquitous Sensor Network). It is expected for the u-IT Plant Management System to extremely increase convenience and exactness. First of all, drawing or document searching for O&M became easier. Due to faithful maintenance takes, troubles could be reduced.

2.3 Industrial Wireless Sensor Technologies

There are many commercialized wireless network techniques such as LAN, UWB, Bluetooth, ZigBee, etc. Table 1 compares wireless network techniques. The techniques are approximately divided into WLAN (Wireless Local Area Network) and WPAN (Wireless Personal Area Network). WLAN ranges from 2.5GHz to 5GHz. WLAN is an infra-structure method which necessitates access points. WPAN can be divided into

<Table. 1 Summary of Wireless Network Technologies>

Method	Frequency	Speed	Distance	Service
Wireless LAN IEEE 802.11.a～n	2.4/5GHz	54/600Mbps	50～100m	Wireless Internet
UWB IEEE 802.15.3a	3.1～10.6GHz	200/480Mbps	10m	HD A/V transmission
Low Speed UWB IEEE 802.15.4a	3.1～10.6GHz	1Mbps	50m	Consumer electronics control Location-aware
Bluetooth IEEE 802.15.1	2.4GHz	1Mbps	10m	Wireless headsets
ZigBee IEEE 802.15.4	868/915MHz 2.4GHz	20/80Kbps 250Kbps	30m 100m	Consumer electronics control, Remote monitoring

low speed and high speed. The latter belongs to UWB and the former belongs to ZigBee, Bluetooth, low speed UWB, etc.

WPAN is the component which directly communicates among personal communication tools without access points. This method is called ad-hoc network.

2.4 Applications in NPPs

One of the main barriers preventing widespread implementation of wireless technologies in nuclear area is the industrial perception that wireless transmission may cause interference with the existing sensitive plant equipment. Differently from those misconceptions, the characteristics of modern wireless devices (lower power and higher frequency) significantly decrease the chances of interference with mechanical or electrical equipment. A valuable tool to assess the possible impact of EMI (Electro-Magnetic Interference) / RFI (Radio Frequency Interference) is to measure the frequencies of the plant's electromagnetic environment. The measurements are performed using the applicable guidance in NRC Regulatory Guide 1.180 and EPRI TR-102323. [4]

Following contents are the essential points to be considered when we install wireless devices

○ Antenna Type: The selection of antenna gain, direction, orientation, and type affects the performance of wireless transmission and reception.

○ Carrier Frequency: Frequency of the waveform used to modulate the message signal for transmission.

○ Coexistence: Ability for a device to perform its intended function without affecting or being affected by other devices.

○ Coverage Area: The geographic area in which the signal strength is sufficient to allow for a wireless signal to be correctly received and decoded.

○ EMI/RFI: The effect of radiated emissions of the plant equipment and wireless system on each other's performance.

○ Network Topology: Defines how wireless devices are linked to each other and the routing of data traffic.

○ Reliability: Ability of a system to perform a required function under stated conditions for a specified period of time.

○ Security: The protection of system resources from accidental or malicious access, use, modification, destruction, or disclosure.

○ Signal Propagation: Deals with how a signal travels through the air and the physical characteristics of the environment which could affect transmission such as reflection, diffraction, and scattering. [5]

3. Conclusions

In this paper, we reviewed the advantages and disadvantages of wireless sensors and networks, and their feasibility for nuclear applications. The wireless sensor techniques even in foreign countries has not yet introduced actively to nuclear fields. However, as a solution of achieving cable ageing management, the application of wireless sensors and networks seems inevitable. Accordingly, we recommend continue interests from research institutes and utilities on this technology.

Reference

[1] J.T. Kim, "Condition Monitoring Through Advanced Sensor and Computational Technology", KAERI/RR-2563, 2004

[2] IAEA, "Assessment and management of ageing of major nuclear power plant components important to safety", IAEA-TECDOC-1188 Volume 1, December 2000

[3] B.J. Kaldenbach, M.R. Moore, P.D. Ewing, W.W. Manges, C.L. Dillard, K. Korsah, R.A. Kisner, "Assessment of Wireless Technologies and Their Application at Nuclear Facilities, NUREG/CR-6882 ORNL/TM-2004/317, July 2006

[4] H.M. Hashemian, C.J. Kiger, G.W. Morton, and B.D. Shumaker, "Wireless Sensor Applications in Nuclear Power Plants", NPIC&HMIT 2009, Knoxville, Tennessee, April 5-9, 2009

[5] H.M. Hashemian, C.J. Kiger, G.W. Morton,B.D. Shumaker, "Wireless Sensors for Equipment and Process Condition Monitoring in Nuclear Power Plants", Analysis and Measurement Services Corporation AMS Technology Center, August 13 2008