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Highly Reliable Power and Communication System for Essential Instruments under a Severe Accident of NPPs

S. J. Yoo*, B. H. Choi, S. Y. Jung, and Chun T. Rim
Dept. of Nuclear and Quantum Eng., KAIST, Daejeon 305-701, Korea
**Corresponding author: yoosj@kaist.ac.kr*

1. Introduction

After the Fukushima nuclear accident, survivability of essential instruments has been emphasized for immediate and accurate response. The essential instruments can measure environment conditions such as temperature, pressure, radioactivity and corium behavior inside nuclear power plants (NPPs) under a severe accident. Access to the inside of NPPs is restricted to human beings because of hazardous environment such as high radioactivity, high temperature and high pressure. Thus, monitoring the inside of NPPs is necessary for avoiding damage from the severe accident. Even though there were a number of instruments in Fukushima Daiichi NPP, they failed to obtain exact monitoring information. According to the details of the Fukushima nuclear accident, following problems can be counted as strong candidates of this instruments failure. Firstly, the life time of emergency batteries after the station blackout (SBO) was insufficient to operate targeted instruments. Secondly, the absence of proper protection in the containment building for extremely harsh environment after severe accident caused malfunctions. Lastly, since the power or communication cable was cut off, the instruments in the containment building could not transmit information to the outside, or their power source could be lost because most of the equipment in NPPs is wired-system based.

(a) (b)

Fig. 1 Fukushima Daiichi Nuclear Disaster
(a) Unit 1 5th Floor, (b) Unit 4 Overview [1]

In this paper, three survivable strategies to overcome the problems listed above are proposed for the essential instruments under the severe accident of NPPs.

First, wire/wireless multi power systems are adopted to the essential instruments for continuous power supply.

Second, wire/wireless communication systems are proposed for reliable transmission of measuring information among instruments and operators.

Third, a physical protection system such as a harness and a heat isolation box is introduced to ensure operable conditions for the proposed systems.

2. Review of Conventional Power and Communication System

According to findings by various international research organizations, the instruments connected to conventional power and communication system in current NPPs are vulnerable to physical shock followed by the severe accident. Moreover, the development of an alternative power system is inevitable for preparing further long term SBO such as the Fukushima nuclear accident [2].

3. Proposed Highly Reliable Power and Communication System

3.1 Design Principle

The priority of proposed system is to ensure normal operation of the essential instruments. As shown in Fig. 2, the proposed system consists of wire/wireless multi power, communication systems and physical protection system. The design principles of the proposed power and communication system aim to reinforce the conventional system reviewed in section 2 as follows:

1) Power and communication for the essential instruments should always be operated under any environment including the SBO condition.
2) The instruments themselves and the cables should survive under extremely harsh conditions such as high radioactivity, high temperature, high pressure, high humidity and hydrogen/steam explosion.

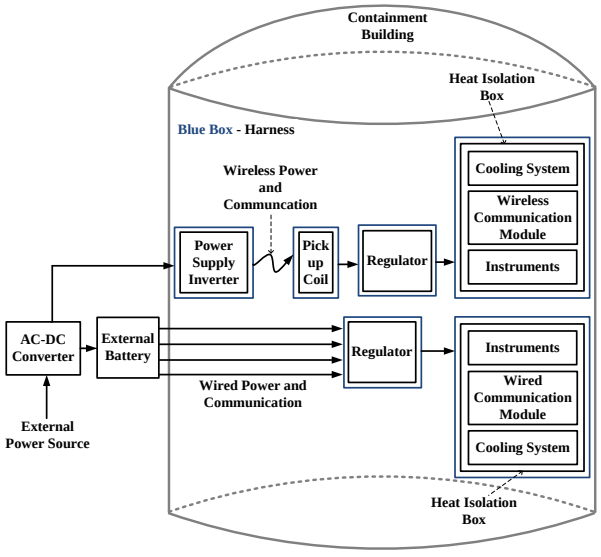

Fig. 2 Configuration of Proposed System

3.2 Design of Wire/Wireless Multi Power and Communication Systems

The proposed multi power and communication system include a multi wired system and an emergency wireless system. The multi wired system consists of a number of cables, which are designed to replace one another in case one fails. When there is no replaceable cable due to the physical damage, the emergency wireless system is adopted and it transfers power and data between instruments and operators. Because this wireless system is activated in emergency cases only, its installation is relatively free from EMI/RFI (Electro Magnetic Interference / Radio Frequency Interference) regulation of NPPs. Fig. 3 shows the available area for wireless system whose location is not restricted for high radioactivity on electric devices.

Based on the experience on long distance wireless power transmission at KAIST [3], an inductive type of wireless power system prototype was built and wireless transfer of several watts was verified. For the wireless communication methods, the radio frequency (RF) and magnetic field communication are nominated. Particularly, the magnetic field communication can synthesize wireless power system as Fig. 5 shows [4]. It is also well known that the magnetic field is superior to RF at the aspect of attenuation [5].

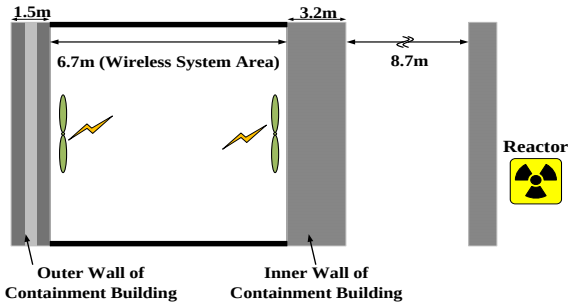

Fig. 3 Applicable Wireless System to NPPs

Fig. 4 Experiment of 7 m Wireless Power Transfer

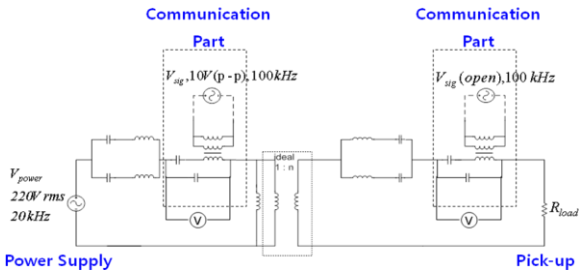

Fig. 5 Example of Magnetic Field Communication Circuit

3.3 Physical Protection System: Harness and Heat Isolation Box

Due to the harsh environment in the severe accident, the physical protection system such as the harness and the heat isolation box are required to offer operable conditions for the essential instruments and cables. The harness and the heat isolation box are basically made of metal to survive from high temperature and a shock from scattered mass. An example of metal laminated harness for a wireless system is designed as shown in Fig. 6.

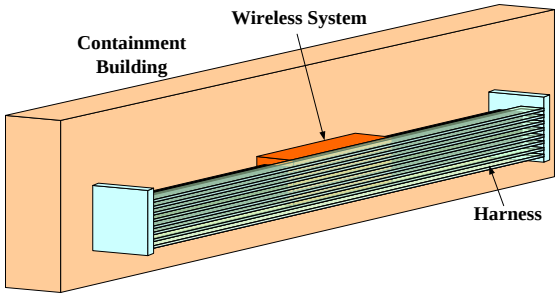

Fig. 6 Example of the Harness

4. Conclusions

In this paper, a highly reliable strategy, which consists of wire/wireless multi power and communication systems and physical protection system is proposed to ensure the survival of the essential instruments under harsh external conditions. The wire/wireless multi power and communication systems are designed to transfer power and data in spite of the failure of conventional wired systems. The physical protection system provides operable environments to the instruments. Therefore, the proposed system can be considered as a candidate of practical and urgent remedy for NPPs under the severe accident.

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