Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

Unmanned Mobile Monitoring for Nuclear Emergency Response

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1. Introduction

Severe accidents at nuclear power plant have led to significant consequences to the people, the environment or the facility [1]. Therefore, the appropriate response is required for the mitigation of the accidents. In the past, most of responses were performed by human beings, but it was dangerous and risky. In this paper, we proposed unmanned mobile system for the monitoring of nuclear accident in order to response effectively. For the integrity of reactor cooling and containment building, reactor cooling pipe and hydrogen distribution monitoring with unmanned ground vehicle was designed. And, for the safety of workers, radiation distribution monitoring with unmanned aerial vehicle was designed.

2. Concepts and Methods

In this section three methods of the unmanned mobile monitoring methods are described. Firstly, the concept of reinforcing the integrity of RCS and containment building using unmanned mobile monitoring system are described. And radiation monitoring using unmanned aerial vehicle for the safety of human beings is described. Then design concepts of unmanned monitoring system are described.

2.1 Concept of reinforcing the integrity of RCS and containment by using unmanned mobile monitoring

Safety requirements for preventing the leakage of radioactive material from nuclear power plants are reactor power control, continuous cooling of the nuclear fuel and maintaining containment building integrity. For this cause, nuclear power plants are deployed protection and safety system to prevent serious condition with DiD(Defense-in-depth) concept shown as Fig. 1 [2,3]. For accident management, typical example of protection system is a reactor shutdown system and typical examples of safety system are a reactor coolant system and maintaining containment building integrity. We propose methods to reinforce the integrity of RCS and containment building, and reduce the risk of radiation exposure. Firstly, for reinforcing the integrity of RCS, coolant fluid will be measured using high temperature ultrasonic sensor which deployed at mobile platform. Secondly, for reinforcing the integrity of containment building, hydrogen distribution will be measured using Raman Lidar(Light detecting and ranging). Thirdly, for the safety of human beings, radiation monitoring will be measured using radiation sensor deployed at unmanned aerial vehicle.

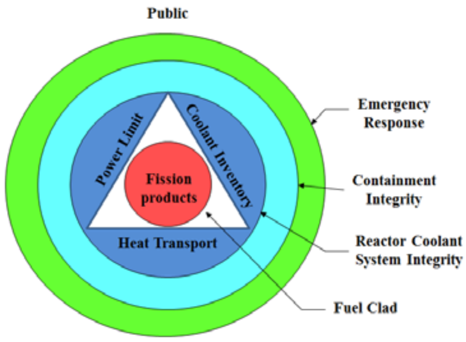

Fig. 1. Defense in depth – barriers and release

2.2 Design of unmanned mobile monitoring

For the integrity of RCS, flows of internal coolant pipe are measured using ultrasonic transducer. Flow rate is calculated by the difference of arrival time of the ultrasonic signal shown as Fig.2. Considering emergency situation, we selected dry ultrasonic method for rapid installation. And, considering high temperature of the environment of pipes, we applied contactless electromagnetic ultrasonic transducer.

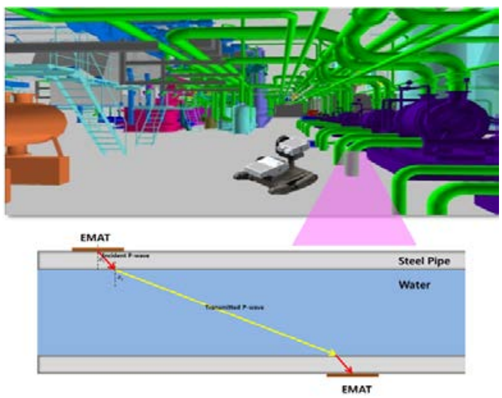

Fig. 2. Concept of coolant flow measuring using EMAT.

The distribution of the hydrogen within the containment determines local and global hydrogen concentrations, which are decisive for the various combustion modes, such as diffusion flames, deflagration and detonation, depending on geometrical effects and concentrations [4]. Hydrogen distribution is monitored by scanning of Raman Lidar module which design concept is illustrated in Fig. 3. We designed optics of laser transmitter and signal receiver, and optical signal acquisition and processing module.

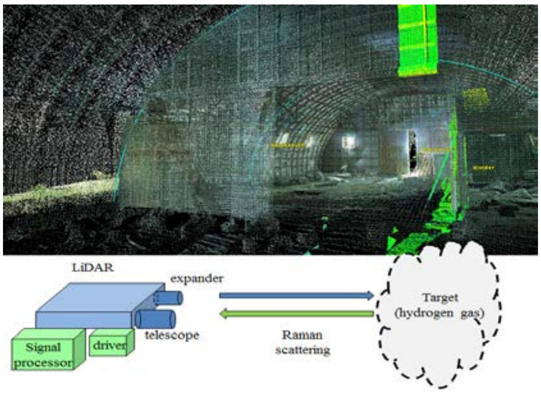

Fig. 3. Concept of hydrogen distribution measuring using Raman LiDAR.

The distribution of the environmental conditions such as radiation, temperature and humidity are needed to assess the mitigation strategy. An unmanned aerial vehicle equipped with environmental sensors navigate inside or outside of the containment building and collect point cloud information. Fig. 4 shows a design example of aerial monitoring vehicle equipped with small radiation sensor. We designed radiation measuring module which are deployed to unmanned aerial vehicle. The designed module has small size, light weight(200g), and wide measuring ranges(10 uSv/h ~ 100 Sv/h).

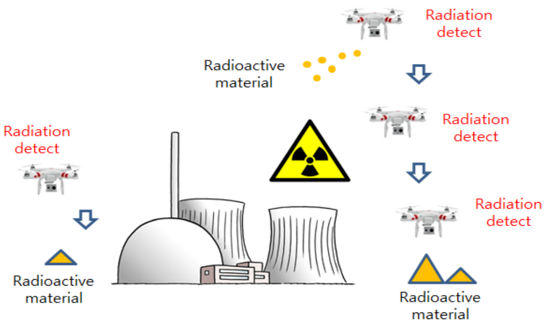

Fig. 4. Concept of radiation monitoring using unmanned aerial vehicle.

2.3 Design of unmanned mobile vehicle

In the situation of nuclear accident, the access of human workers into the containment building is very dangerous because of hazardous environment such as high radiation and temperature. So the unmanned mobile systems are put into the hazardous area to perform their task, but human workers operate the robot system and monitor at safety zone.

Unmanned mobile vehicle is designed to deploy the monitoring modules which are described above section. The width of vehicle is less than 80cm to pass through the passage and payload is more than 30kg. The moving parts of the vehicle are chosen by crawler type for irregular surface of ground.

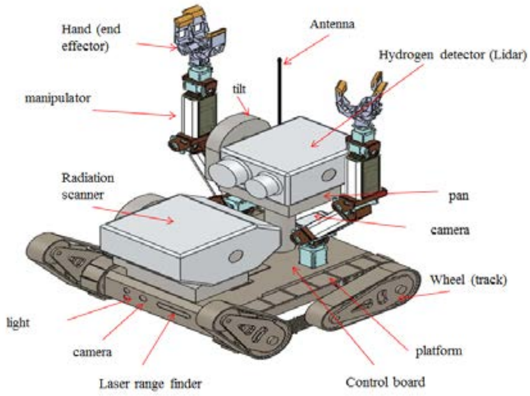

Fig. 5. Design of unmanned mobile vehicle

3. Conclusions

Unmanned mobile monitoring system was proposed to respond nuclear accidents effectively. Concept of reinforcing the integrity of RCS and containment building, and radiation distribution monitoring were described. RCS flow measuring, hydrogen distribution measuring and radiation monitoring deployed at unmanned vehicle were proposed. These systems could be a method for the preparedness of effective response of nuclear accidents.

Acknowledgments

This paper was supported by the Ministry of Science, ICT and Future planning.

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