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R&D Strategy on Remote Response Technology for Emergency Situations of Nuclear Facilities in KAERI

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1. Introduction

Generally speaking, robotic technologies are anticipated to be very useful for hazardous works in nuclear facilities because robotic systems are relatively immune to radiation exposure. But the application of robotic systems for such environments has not been increasing during past 20 years.

Applying highly reliable and conservative "defense in depth" concepts in the design and construction of NPPs, there is very little probability of accidents occurring or radioactive materials being released into the environments. As a precaution, however NPPs are prepared with emergency response procedures and routinely conduct exercises for post-accident circumstances based on these procedures.

The last year's accident at the Fukushima Daiichi nuclear power plant promotes the needs for remote response technologies based on mobile robotic system to recognize the internal status and mitigate the unanticipated events of nuclear power plants in emergency situations.

For initial observation of reactor buildings two robots named "PackBot" were used because the internal conditions were unknown so as to allow human workers for entrance into the reactor building. But there were severe limitations for the robots to perform the given tasks from various obstacles and poor visibility inside though they provided crucial information such as views of internal structures, dose level and temperature that supported the decision for human worker's entrance.

The application of robots for emergency response tasks for post-accidents in nuclear facilities is not a new concept. Robots were sent to recover the damaged reactor at Chernobyl where human workers could have received a lifetime dose of radiation in minutes. Based on NRC's TMI-2 Cleanup Program, several robots were built in the 1980s to help gather information and remove debris from a reactor at the Three Mile Island nuclear power plant that partially melted down in 1979. A robot was used for several years equipped with various tools allowing it to scour surfaces, scoop samples and vacuum sludge. To perform cleanup tasks, they built Workhorse that featured system redundancy and had a boom extendable to reach high places, but it was never used because it had too many complexities and to clean and fix.

While remote robotics technology has proven to remove the human from the radioactive environment, it is also difficult to make it useful because it may requires skill about remote control and obtaining remote situation awareness regardless of the actual task. The efficiency of the human-robot interaction is very important to obtain the overall goal for the emergency response in timely manner. It would be a bottle-neck to apply the robotic technology for carrying the emergency response in NPP. Simple remote operation schemes are not adequate, more intelligent autonomous operation schemes are required to enhance the effectiveness of robots for the emergency response.

KAERI has been developing various robotic systems for nuclear power plants over than 20 years after the Chernobyl accident. But the majority of the developed robotic systems is for the inspection and maintenance of nuclear power plants during their outage periods.

Based on the lessons learned from the Fukushima accident, KAERI has planned R&D projects for developing remote response technologies really applicable in emergency situations of nuclear facilities.

This paper presents the R&D strategy to achieve real usability and the purpose and research activity plans of on-going three projects derived from the strategy.

2. R&D strategy for remote response technology

In the initial stage of robot dispatch, Japan had no preparedness for using robots in real situations immediately after nuclear accidents. They developed large number of robotic systems for nuclear facilities after JCO criticality accident had occurred in 1999.

However, none of robotic system was placed at nuclear power plants as a nuclear emergency equipment and used when nuclear disaster prevention and mitigation training. Thus any robotic system developed should be prepared for deploying in any time immediately.

Another lesson learned from the fukushima accident is that the state of the art of remotely-operated robotic technology is not sufficient for performing urgent tasks for nuclear accident mitigation. The performance of remotely-operated robotic system needs to be better than that of human workers in order for the robotic system to take the place of human workers. Considering the limitation of mobility and handling, such robotic system can only be used as a last resort and it may be the time when there remains only a little task to do.

It means that robotic technology with comparable or better performance on mobility and handling of objects should be developed. Because such performance couldn't be reached at short-term development, the

development should be planned and started just from now on as a mid and long-term research project.

As a countermeasure for accidents that may occur sooner or later, current robotic technology should also be systemized to have nuclear emergency preparedness and tested for the performance and reliability under the similar environments of emergency situations.

Thus KAERI has planned and started three R&D projects for remote response technology for nuclear emergency situations as follows:

(1) A short-term R&D project for developing two types of monitoring robot system for PWR and PHWR nuclear power plants,
(2) a mid-term R&D project for developing robotic technology with higher performance on mobility and handling than human workers,
(3) a long-term project for organizing and keeping a technical support task-force having proven robotic systems developed by the above mentioned R&D projects.

3 The Purposes and Research Activity Plans

The title of the first project is "Development of monitoring robot systems for working environments of high radiation in nuclear power plants" funded by the ministry of knowledge and economy. This short-term project has been planned for 3 years to integrate available technologies for radiation hardened camera and controllers, coolant leakage and radiation detection sensors, acoustic and vibration sensors, and mobile robot to enhance monitoring capabilities in nuclear facilities. Two types of robotic systems will be provided for PWR and PHWR nuclear power plants respectively as shown in Fig.1.

The robotic technologies include autonomous navigation and 3-dimensional mapping, remote door opening, etc. The performance and reliability of those integrated systems will be tested in mock-up environments.

Fig. 1 Monitoring robots for nuclear power plants

The second project is to develop challenging technologies to enable better performance on mobility and remote handling relative to human workers. This project is funded by the ministry of education and science and scheduled for 5 years. This project specially focus on 3-dimensional measurements of internal structures of invisible through conventional vision systems, motion driving technologies for prompt access and handling of object remotely, and evaluation technologies for performance and reliability of remote response systems.

The purpose of third project is organizing and keeping a technical support team for rapid response to unanticipated abnormal situations in nuclear power plants. This team maintains and improves existing remotely operated equipments developed previously and new technologies and equipments developed through the R&D projects mentioned above.

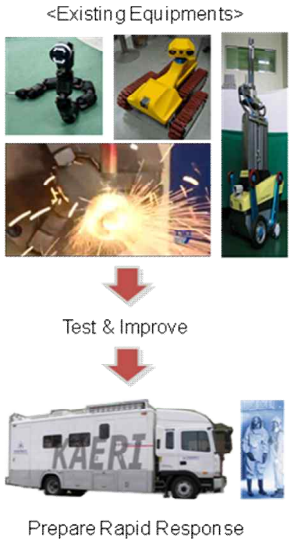

Fig. 2 Organization of technical support team for rapid response to unanticipated situations of nuclear power plant

4. Conclusions

This paper presented the R&D strategy of KAERI to achieve real usability of remote response technologies for emergency situations of nuclear power plants and introduced the purpose and research activity plans of on-going three projects derived from the strategy.

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