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Robot dispatching Scenario for Accident Condition Monitoring of NPP

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1. Introduction

In March of 2011, unanticipated big size of tsunami attacks Fukushima NPP. Emergency diesel generator located in the underground room was submerged by sea water, which caused station black out. Due to loss of emergency power, reactor core cooling pump couldn't circulate the water and reactor fuel became melt down. Hydrogen gas couldn't be removed due to power loss of active hydrogen remover. This accident results in explosion of containment building.

Tokyo electric power of Japan couldn't dispatch a robot for monitoring of containment inside. USA Packbot robot used for desert war in Iraq was supplied to Fukushima NPP for monitoring of high radiation area. Packbot also couldn't reach deep inside of Fukushima NPP due to short length of power cable. Japanese robot 'Queens' also failed to complete a mission due to communication problem between robot and operator.

I think major reason of these robot failures is absence of robot dispatching scenario. If there was a scenario and a rehearsal for monitoring during or after accident, these unanticipated obstacles could be overcome. Robot dispatching scenario studied for accident of nuclear power plant was described herein.

2. Methods and Results

2.1 Accident steps of nuclear power plant

NPP have normal, abnormal, design base accident and severe accident mode. It is required to follow emergency operation procedure in the case of DBA and severe accident mode. Since safety class equipments of NPP is strictly qualified in accordance with EQ requirement of DBA, no additional monitoring action by dispatching a robot into plant is required during DBA mode.

In the case of severe accident, plant situation getting severe if there is no action for mitigation. It finally results in hydrogen explosion which cause destruction of containment building. Fig. 1 shows propagation step of severe accident[1].

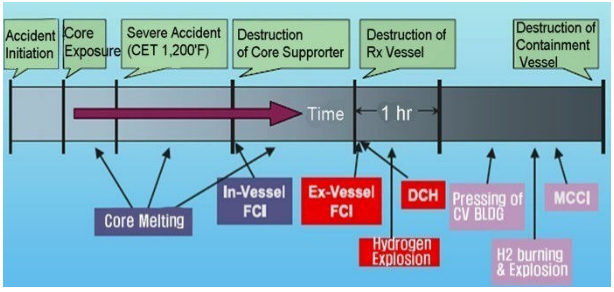

Fig. 1. Propagation step of Severe Accident

2.2 Requirement for accident monitoring

According to the SAMG, function of instrument required during severe accident of NPP is monitoring of core cooling and removal of residual core heat. Equipments used for protection and mitigation of severe accident need not to follow requirements of 10CFR50.49(EQ), 10CFR50 App. A(redundancy and diversity) and App. B(QA). Consideration of equipment survivability based on reasonable assurance should be given to the equipments necessary for protection and mitigation of severe accident.

Instruments required for monitoring of severe accident can be selected as CET(Core Exit Thermocouple), HJTC(Heated Junction Thermocouple), RCS/PZR pressure detector, flow meter of safety injection, auxiliary feed water and containment building spray, level indicator of IRWST(in-containment refueling water storage tank), hydrogen detector, pressure & temperature detector of containment building[2].

2.3 Experience of robot monitoring in NPP

There was no experience of accident monitoring by robot system in domestic NPP. USA had an experience of robot monitoring during the TMI-2 NPP accident. Ukraine has used remote wireless robot for radiation monitoring of Chernoville NPP after the nuclear accident. Japan dispatched two types of robot for the monitoring of Fukushima accident. Fig. 2 is Packbot which had been used for war of Iraq war. Main task of this robot was monitoring of Fukushima plant inside by camera and radiation measurement device. Fig. 3 is T-halk flying robot which had been used for army. T-halk was used for monitoring of containment inside of Fukushima NPP. It was known that all of these robots were not successful for monitoring of Fukushima NPP because a scenario was not sufficient to support accessing of plant inside. No working robot for valve close or cutting of the wreck was considered.

Fig. 2 Packbot robot Fig. 3 T-hak flying robot

2.4 Scenario of robot in NPP

2.4.1 Flying monitoring robot

If station camera doesn't work properly because of an unanticipated accident and valve actuator is out of order, operator has to walk inside of containment building to solve the problem. Human may not be allowed to access the containment building due to high temperature and high radiation. In this case, robot will be useful instead of human.

In nuclear plant accident, fast action to mitigate the accident is very important. Walking robot can't complete the monitoring mission quickly due to several obstacles in the walking path of NPP. Flying robot can be a good solution for quick monitoring of containment inside.

Fig. 4 shows sample path of flying robot in containment building of APR1400 NPP. About 120m flying is required to reach PZR room from personnel hatch. If flying robot is capable of 2m/sec moving, 60 second will be taken to reach the PZR relief valve. 3~5 minutes flying will be enough if we consider 60 second monitoring and 60 second return flying.

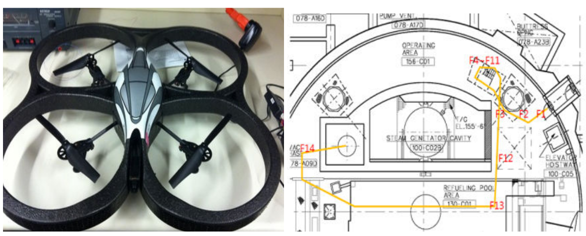

Fig. 4. Flying robot and accessing path of NPP inside

2.4.2 Working robot

When we are aware of accident condition through flying robot camera, some action will be taken to mitigate the accident. If valve actuator is out of order due to accident impact, working robot which can turn the handle of valve for emergency close will be helpful. Fig. 5 shows concept of NPP working robot which is under development through DARPA robot challenge project.

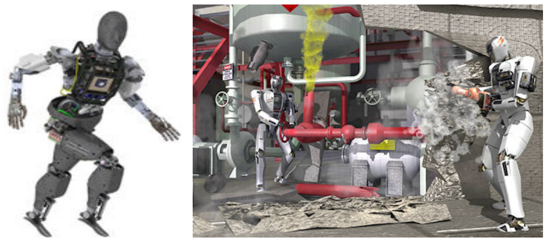

Fig. 4. Artist's concepts of DARPA robot challenge

2.5 Obstacles of robot application in NPP

2.5.1 Radiation

IC used for robot system can be guaranteed under gamma radiation of 1E+03 rad. Shielding of IC from gamma radiation by thick lead is not proper because it makes robot heavier and bigger. Short time work in high radiation area and shift work by another robot can increase a survivability of robot IC in high radiation area.

2.5.2 Communication

Wireless communication is preferred solution for robot. Since radio wave interferes with cables of neutron detector and radiation monitor, it is not allowed to use when the fuel is loaded in the reactor core. Development of thin and soft cable with rolling reel can give good advantage of long time operation of robot.

3. Conclusions

Study on scenario of robot dispatching is performed. Flying robot is regarded as good choice for accident monitoring. Walking robot with arm equipped is good for emergency valve close. Short time work and shift work by several robots can be a solution for high radiation area. Thin and soft cable with rolling reel can be a good solution for long time work and good communication.

REFERENCES

[1] NETEC, Protection design for severe accident in domestic NPP, The 9th nuclear safety information conference, 2004.
[2] Westinghouse electric company, AP1000Equipment Survivability Assessment, APP-GW-VP-025, Revision 0, May 2007