EPRI Report: Guidance in the Use of Robotics and Automation for Decommissioning Nuclear Power Plants - 17440

Richard McGrath *, Richard Reid*, Phung Tran*
*Electric Power Research Institute, 3420 Hillview Ave., Palo Alto, California. USA.
rmcgrath@epri.com, rreid@epri.com, ptran@epri.com

ABSTRACT

In the coming ten years, approximately 100 commercial nuclear power plants will be shut down worldwide, adding to the fifty nuclear power plants already shut down that have not yet entered into decommissioning. Just under a half of the overall cost of decommissioning a nuclear power plant is utility staffing costs (costing approximately 20 million USD per year of the decommissioning project), with waste and dismantlement costs making up the remainder. Decommissioning across the globe is being executed largely by manual labor. Some overview organizations such as OECD have concluded that the nuclear industry has not fully exploited or implemented current technological capabilities, and relies on outdated technology to perform decommissioning tasks.

The use of more efficient and effective decommissioning technologies and processes could reduce the decommissioning project schedule and therefore the $20M/year staffing costs incurred throughout the decommissioning project life. Such systems may also offer a substantial benefit with respect to worker safety and exposure reduction. However, tasks for which use of such systems is beneficial must be carefully considered. The systems themselves need to be robust and generally trouble free to operate in the demanding environment of commercial power plant decommissioning.

EPRI is preparing a report, *Guidance in the Use of Robotics and Automation for Decommissioning Nuclear Power Plants*, which documents approaches that can perform decommissioning work in a safe and ALARA manner while reducing the overall cost to decommission a nuclear power plant.

INTRODUCTION

The approach to nuclear power plant decommissioning is currently highly labor intensive. The increased use of robotics and automation could be beneficial to reduce radiation exposure, schedule and therefore the substantial costs of decommissioning which will be incurred in decommissioning nuclear reactors worldwide.

A facility to be decommissioned often already contains remote equipment that can be used in the decommissioning effort. Remotely operated cranes, fuel handling machines and other equipment can be used during this phase as they were used during operation. Such possibilities should be extensively studied before implementing new equipment, as using existing equipment will reduce the overall cost of the decommissioning project. Most facilities also have a materials handling system in situ, and if it is still functional at the time of decommissioning, operating costs and potential procurement delays can be reduced if this equipment can be effectively used. Existing operating systems that can aid handling operations include automatic guided vehicles, palletizing robots, cranes, hoists, elevators and conveyors. Robotics solutions being used for operations may also be able to be used during decommissioning, and the investment in robotics or automation of processes may be able to be spread over the costs of multiple operations or decommissioning projects.

BACKGROUND

Project Approach Used by EPRI

EPRI evaluated the following two kinds of technologies in terms of their potential to make power plant decommissioning projects more efficient and less costly:

1. Robotics – robotics is defined as technologies where human intervention and control is required to conduct the task, but the task itself is conducted remote from the individual. Typically, such tasks are conducted to reduce work safety and radiation exposure risks. The task itself is not usually repeatable or programmable and requires human navigation.
2. Automation – an automated task is one which is programmable. Typically, this is because the task is easy to do and may be highly repeatable. In this case, the task is programmed by an operator and then left to operate without ongoing intervention. Manual over-ride may remain possible.

Challenges faced in the use of robotics and automation were reviewed as a part of this project. A review of currently available technologies in both robotics and automation was then conducted, including commercial and government nuclear operations and decommissioning applications within the US and internationally. This included component removal and segregation, component inspections, conduct of radiological surveys, monitoring and sampling, mechanical and chemical decontamination, application of strippable coatings/fixatives and work control.

The major tasks of decommissioning a commercial nuclear power plant were then examined and assessed using a matrix developed to identify those tasks that would benefit from the use of robotics or automation. The available solutions that have been and could be applied in nuclear decommissioning projects, whether already tried in nuclear decommissioning, tried in other applications or under development were then matched against the decommissioning tasks that had been identified to benefit from the use of robotics or automation.

The resulting EPRI report provides information and guidance on robotics and automation applications, whether previously used or not, for the decommissioning of nuclear power plants and is a useful reference for anyone approaching this type of work.

The EPRI report provides guidance in the following areas:

1. General issues associated with the use of robotics and automation along with an overview of the types of solutions that are currently available.
2. A review of the major decommissioning tasks involved in the decommissioning a nuclear power plant and an assessment of each of the tasks as to its suitability for the use of robotics and/or automation.
3. Available solutions that could be applied to each of the identified decommissioning tasks are discussed. Solutions that have been used in other industries or are under development are also provided.

DISCUSSION

Findings and Guidance Contained in the EPRI Report on Robotics and Automation

One-off customized robotic development and deployment has been more typical in the worldwide nuclear industry as a whole, and these systems can cost millions and take months, if not years, for research and development, mockups and trial runs, operator training and deployment. Robotic system failures due to high radiation effects pose an obstacle that may impact further deployment and longevity of these systems. This has been found within the U.S. Department of Energy high-level tank and other waste cleanup efforts, U.S. commercial nuclear reactor inspections, and in the response to nuclear accidents where such capabilities are required.

Experience has shown that in highly hazardous and radioactive environments, robotic systems need to be designed to handle rugged environmental or radiation environments. In a number of cases, remote devices or tool end-effectors have broken down resulting in tool replacement costs, labor, and collective dose expenditures associated with maintenance to repair the equipment. For nuclear facility management dealing with tight schedules and high expenses during decommissioning operations, it may be difficult to justify expenditures on these new technologies versus standard techniques. Some decommissioning contractors have experienced problems with complex customized robotic systems and remain skeptical about their use.

Customized solutions for very specific problems and physical and environmental conditions, even if effective, are also not very transferrable to other buildings or other sites with different conditions. If the industry continues to reinvent current technologies for limited specialized tasks at isolated decommissioning sitess and insists on demonstrating a higher level of performance than that which can be achieved using conventional manual methods, it will fall further behind in exploiting ongoing developments in automated and robotic technologies that are occurring outside the industry. Unfortunately, this is exacerbated by the fact that decommissioning projects often start and stop for various reasons during their lifecycle. This may change as more decommissioning projects are undertaken, especially at the utility fleet level.

In general, remote handling equipment should be kept simple or be proven under a variety of similar circumstances to ensure the success of the equipment's intervention, to prevent loss of time and effort, and to minimize exposure to hazardous environments caused by retrieving a failed piece of remotely operated equipment. Whenever possible, simplified, off-the-shelf technologies should be considered for both robotics and automation, and adapted, as this presents potential significant time and cost savings in development. Such systems can also be more reliable, having been proven in other applications and can be modified for use in a radioactive environment as required.

If systems can be outfitted or readily adapted for numerous functions and standardized, it is anticipated that costs can be reduced, and their use can be expanded outside of their original focus. Some robotic systems that have been deployed and tested extensively for other purposes or industries (e.g. defense, emergency recovery, underwater inspections, etc.) show reliability and potential cost-effective transfer to nuclear operations and decommissioning. An example was the use of iRobots in other applications with subsequent deployment during the Fukushima reactor building post-accident inspections as well as use at U.S. nuclear plants for remote inspections and waste operations. Likewise, the transfer of technology from the automobile and munitions industry to use in decontamination is proving very effective in Magnox plants in the United Kingdom.

The use of off the shelf automated systems for the conduct of repetitive tasks where it has been deployed (for example, automated decontamination, welding, etc.) has also been effective and this may be an area where cost savings could be found.

Robots and automated systems could also be designed by one manufacturer and used within more than one utility or one sector (e.g. operations versus decommissioning, commercial versus government, one country versus multiple countries). This customized approach would support increased widespread use throughout the industry.

There is, however, a commercial market for robotics and automation and various engineering companies, specialty decommissioning firms and university research centers are working on robotics and remote systems for use in various industries (e.g. mining, marine), including nuclear facilities. This shift towards commercialization has tended to result in some constraints in release of information due to proprietary and competitiveness reasons. Therefore, data regarding cost, failure breakdown rates, and other important information may not be fully shared among vendors and institutions, making it more difficult for end-user decision-makers to perform initial cost-benefit analyses to determine whether to pursue robotic applications. Sharing of information between end users would be beneficial in bridging this gap. Further collaboration between companies and suppliers and between organizations and countries would also be a helpful platform to support the industry going forward.

Tokyo Electric Power Company (TEPCO) is trying to come to grips with the somewhat negative view of robotic capabilities that pervades the industry in order to expedite the application of robotics to the pressing issues facing the severely damaged decommissioning of the Fukushima units. TEPCO is developing a “technical catalogue” for R&D technologies based on the plant manufacturers’ database for Japanese nuclear facilities. They are also seeking to include other applicable remote decontamination technologies and decontamination and dismantlement (D&D) services in the catalogue through voluntary submission of applications. The catalogue should provide a comprehensive snapshot of the decontamination and robotics capabilities available in the industry and could be a useful step forward to sharing of information.

Desirable Attributes for Robotic/Automated Technologies

The EPRI project has determined the following as desirable attributes in the development of robotic/automated technologies:

- System and peripherals must also be operator-friendly. Ideally, the system must be designed to allow personnel currently available for the D&D project to become trained as operators within a reasonable time frame. Controls should be well laid out, with ergonomics suitable for numerous personnel with differing levels of experience, and normal operations should be logical and easy to execute. The trend to the use of gaming system interfaces should also be explored.

- The system must be flexible and easily adapted to changing conditions, tooling requirements and operational needs. The equipment must be able to perform all tasks within its capabilities safely, effectively and efficiently with little downtime and no failures that would jeopardize personnel safety or place the system or task in a non-recoverable position.
- Preventive maintenance must be minimal with only moderate to long term frequencies (minimum 3 to 6 months) under normal or expected operating conditions. When the need arises, the maintenance should be simple and straightforward with a duration of less than one work shift. Replacement parts and common wear items should be available at a reasonable cost.
- Reliability is of paramount importance. Downtime and system or component failures translate into additional costs, possible personnel exposure, and if unexpected, possible safety impact.
- The systems, if possible, should be able to perform remote tasks nearly as rapidly as conventional practices would allow OR have the ability to perform tasks that would otherwise be difficult, impossible or impractical to perform.

Existing Robotics and Automated Systems

In 2004, EPRI evaluated available robotic systems for application in power reactor decommissioning applications in EPRI Report, *Application of Non-Nuclear Robotics to Nuclear Industry Decommissioning* (Reference 1). Since that time, some of these systems identified in the 2004 report, as well as many other robotic systems, were applied in nuclear plant operations and decommissioning applications, with varying levels of success. Also since 2004, substantial advancements were made in robotics. Numerous robotic systems were employed throughout the US and internationally in both the private and public sectors since 2004 to address work involving radiation controls, including in the military and in response to terrorism. The use of robotics also accelerated due to the Fukushima accident and the accident also led to the acceleration of plans to decommission nuclear reactors worldwide. OECD have published two documents concerning robotics (References 3 and 4).

Figure 1 is a listing of the robotic/automation technologies described in the more recent EPRI report on this subject.

CONCLUSIONS

An updated review of robotics and automation use in the nuclear industry in commercial nuclear power plants, in decommissioning operations and in emergency clean ups has been conducted as part of an EPRI project. Robotic systems have been successfully applied in areas such as component segmentation and structural demolition; site surveys; demolition debris handling; and radioactive waste retrieval, handling, conditioning and packaging. Another area that may result in cost savings in decommissioning is the use of automation for the performance of decommissioning tasks, whether or not in a radioactive environment. The use of automated systems in non-radiation or radiation environments have been less well documented in the literature. While a few examples are provided, such as the automation of the use of coatings, inspections of underground pipework, and automation of sample collection, there is much room for development in this area. These types of systems were identified in four categories – those used for cutting, for handling, for inspection, for measurement and automation.

Lead Organization	Applications
CUTTING EQUIPMENT	
AREVA	Laser cutting of piping by robot in France
Chiba Institute of Tech.	Tracked robots at Fukushima
Kurion	Mechanical systems for cutting at U.S. DOE sites and Fukushima
Magnox	Decontamination and volume reduction of highly contaminated skips
NuVision Engineering	Hydraulic robotic arms and equipment for pipe cutting, at DOE sites
OC Robotics	Snake arm robotics for segmentation at Swedish and Canadian NPPs
HANDLING EQUIPMENT	
BROKK	Remote-operated equipment for dismantlement, segmentation and waste handling. Used at DOE sites, U.S. and UK commercial NPPs
Chiba Institute of Tech.	Tracked robots at Fukushima
G.E. Hitachi	Robot for movement of rubble at Fukushima
iRobot	Robotic material handling at U.S. nuclear plants and Fukushima

Lead Organization	Applications
KHG	Remote and robotic equipment, German research and power reactors
Kinetrics	Robots for removal of high activity debris at a Canadian nuclear plant
Kurion	Mechanical systems for lifting operations at DOE sites and Fukushima
Nova Machine Products	Automated HydraNut tensioning and detensioning used at U.S. RPVs
NuVision Engineering	Hydraulic robotic arms and equipment waste material handling and decontamination at U.S. DOE sites
PaR Systems	Robotic and main crane equipment for material handling at DOE sites
QinetiQ	Robots for material handling at Fukushima
Rolls-Royce	Cleaning of small diameter piping
Savannah River Remediation, LLC	Various robots for tank cleaning at U.S. DOE site (Savannah River Site)
UK Atomic Energy Authority (UKAEA), Ltd	Nuclear operations; development of remote handling equipment for ITER fusion reactor in France

Fig. 3 Listing of Remote Cutting and Handling Technologies Evaluated by EPRI

The EPRI report that has resulted from this project shows that numerous robotic/automated systems have been employed throughout the US and internationally in both the private and public sectors to address work involving radiation controls as well as the automation of various tasks, typically but not always in high radiation environments. The use of robotics has also accelerated due to the Fukushima accident, which in itself accelerated the use of robotics, and also led to the acceleration of plans to decommission nuclear reactors worldwide.

It is anticipated that this EPRI project will facilitate the process of information sharing by reviewing robotics and automated capabilities that have been used successfully on decommissioning projects. Ideally, reliable methods would be used from project to project, spreading the cost of new developments and advances over multiple decommissioning projects. The process would move technologies from small scale development to standardization which can be continuously employed to improve the efficiency of decommissioning worldwide.

REFERENCES

1. EPRI Report # 1009571, *Application of Non-Nuclear Robotics to Nuclear Industry Decommissioning*, Palo Alto, CA: 2004.
2. EPRI Report # 3002007087, *14th EPRI International Nuclear Power Plant Decommissioning Workshop*, EPRI, Palo Alto, CA: 2016.
3. *R&D and Innovation Needs for Decommissioning Nuclear Facilities*, Organization for Economic Development (OECD)/Nuclear Energy Agency (NEA), NEA No. 7191, 2014.
4. *Remote Handling Techniques in Decommissioning,* NEA/RWM/R (2011)2, 20 September 2011
5. EPRI Report # 3002005411, *Summary of Department of Energy Decommissioning Technology Demonstrations,* Palo Alto, CA: 2015.
6. EPRI Report # 3002005410, "Characterization and Management of Cutting Debris During Plant Dismantlement", Palo Alto, CA: 2015.