INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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EVOLUTION OF ROBOTICS IN NUCLEAR REACTOR AND NUCLEAR WASTE HANDLING

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Accepted Date: 15/03/2016; Published Date: 01/05/2016

Abstract: Robotics can be said to be technology that deals with robots which are automated machines that can replace human personnel in risky and hazardous environments or processes to perform tasks with accuracy and that too at high speeds. One such risky but skilful operation of robotics is required in the nuclear power plants and reactors specifically as these areas are hazardous for human beings to work and also sometimes when the work places are out of human reach. Nuclear robotics in reactor and waste handling is an implementation of robotics which is dedicated to handling, monitoring, surveillance and cleaning of nuclear power plant and its associated processes through tele robotics as well as automated systems and programming. This paper aims at surveying the various forms of robots used in nuclear power plants especially in nuclear reactors and nuclear waste handling and tracing their evolution in this field.

Key Words: Evolution Of Robotics, Nuclear Robotics, Nuclear Reactors, Nuclear Waste Handling.

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Access Online On:

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How to Cite This Article:

Tejashree Bendale, IJPRET, 2016; Volume 4 (9): 136-143

PAPER-QR CODE

INTRODUCTION

The problem of increasing demand for power and that too through environmental friendly generation has become a major issue before researchers throughout the world. One of the solutions suggested for this problem is the use of nuclear reactors for power generation. The nuclear power plant is the place where power is generated using energy released from the nuclear fission reactions. It consists of various processes such as fabrication of the fuel rods, power generation in the reactor and the nuclear waste handling which includes the spent fuel rods storage and disposal tasks. It also includes power distribution as one of its functions.

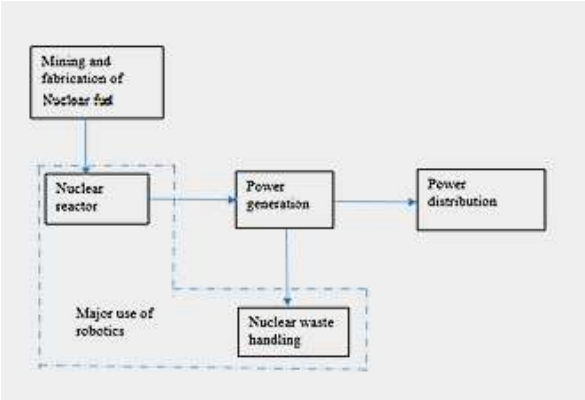

Figure 1- Block diagram of Nuclear Power Plant

The nuclear fission being a very high energy reaction, it is really dangerous and risky for humans to work in. The introduction of robotics in this field is really important because along with the risk of radiation exposure there are also accidents which took place due to small human errors. The Three Mile Island accident is one of such instances. This can be avoided further by inclusion of robotics. Also certain places in the power plant especially the reactor are out of human reach, so those tasks can also be accomplished using robots. Amongst the functions mentioned above, robotics is mainly used in various processes of the nuclear reactor and nuclear waste handling.

II.EVOLUTION OF NUCLEAR ROBOTICS

Robotics deals with the design, construction, operation, and application of machines to perform certain tasks. According to some researchers, the Robots can be said to be an example of industrial automation systems. This is beneficial because it saves labor, energy and materials although providing good efficiency, accuracy, precision and that too at a high speed.

The focus of work done on robots in nuclear industry include developing mobile robots (aerial, submersible and ground-based) able to monitor and explore radioactive areas, designing the

low-level control systems for the mobile robots, such that they can react to changes in environment or vehicle dynamics

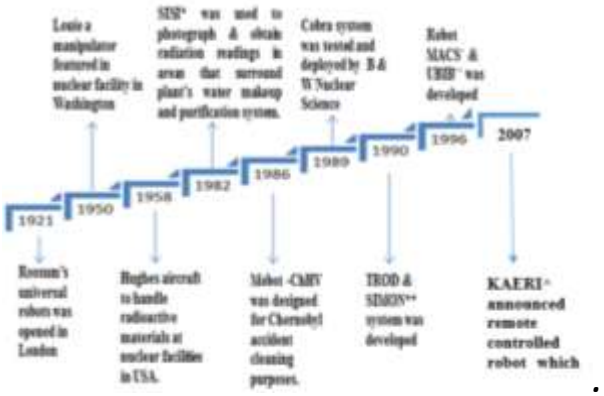

Figure 2-Nuclear robotics evolution up to 2007

SISI*-System In Service Inspection

UBIB (Upper Bundle in Bundle)-cleaning and inspection purposes.

KAERI^ -Korean Atomic Energy Research Institute

This includes many disparate technologies including distributed estimation, control, optimization, the integration of intelligence in to the systems and optimization techniques for path planning.

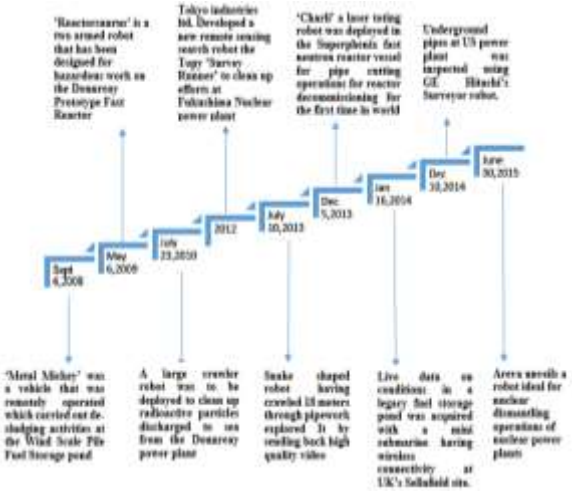

Figure 3- Nuclear robotics evolution up to 2015 [3]

III. ROBOTICS IN NUCLEAR REACTOR

Robotics in nuclear reactor can be used in a wide number of applications like mobile robots for routine monitoring and surveillance for which robots such as SIMON (Semi-Intelligent Mobile Observing Navigator) [6] was developed in 1990 followed by MACS (Mobile Automated

Characterization System) [6] designed in 1996.Also for inspection and cleaning of a steam generators ,its pipes and welds,

Figure 4-Snake shaped robot[3]

various robots came into picture like the robotic snakes and worms that were designed for reaching inaccessible areas of the CANDU reactors in the year 2009 succeeded by the small ball shaped robots designed for inspection and check if there were any signs of corrosion in July,2011. [3]

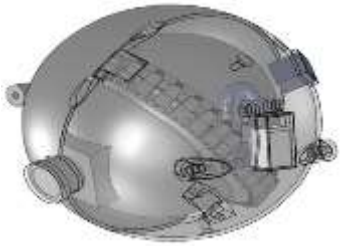

Figure 5-A cut away of spherical eye ball robot[3]

'Charli' a laser toting robot was deployed in the Superphenix fast neutron reactor vessel for pipe cutting operations for reactor decommissioning for the first time in world in Dec, 2013. [3]

Figure 6 -Charli will be used for pipe-cutting work at Superphenix [3]

Areva unveiled a robot ideal for nuclear dismantling on June 30,2015[3] There are also refueling reactor operations which take place using robots like the Kaerot M-3 robot which is a fully mobile, remote-controlled robot that can change the fuel of a PHWR in a fifth of the time taken by conventional fuel loading machines [3].

IV.ROBOTICS IN NUCLEAR WASTE HANDLING

The waste residue of products and by products of the reactions in the reactor, the fuel rods and the remnants of the old machines or other materials inside the reactor in combination can be called as nuclear waste which is hazardous and has to be handled carefully. A fast and versatile tool for situation assessment is needed without putting personnel at risk. In such situations certain general-purpose robots for these jobs are incorporated like the Remotec ANDROS or Rovtech Scarab. [6] For a long time, the manipulation of hazardous material has been executed by a master/slave system. The operator manipulates a master arm that is mechanically connected to a slave robot in a hot cell. The robot reproduces every movement of the operator. For radioactive environments, the requirements for tele operated robots are a good sealing of the parts to avoid contamination, the installation of a force feedback system, an acceptable level of radiation hardness, a good payload/mass ratio, a high reliability and modularity for easier maintenance and an easy integration into embedded equipment. The installation of a radiation-hardened force feedback system is very important when upgrading a commercial manipulator to its 29 nuclear equivalent. [6]

V. ROBOTICS IN POST NUCLEAR ACCIDENT OPERATIONS

The Chernobyl accident on April 26th 1986 has stressed the need for robots for intervention purposes in cases of nuclear accidents. The first robots that were sent to Chernobyl failed because of a lack of radiation hardness or because their tethers became stuck in the rubble. The Russians were the first to design a robot especially for the site of the Chernobyl accident. The Mobot-ChHV was on site as soon as August 1986 and successfully cleaned the roof [7]. On 19th August 2010, a significant subcontract was awarded to US based PaR systems to supply main cranes system which is to be used in NSC constructed over Chernobyl power plant's work unit 4.

Another such disaster took place in The Three Mile Island where there was a partial meltdown of the core. In 1980, 'Workhorse'- a robot was built to remove debris from reactor followed by Rover which came in 1984 for the reactor clean-up process [3]

Figure 7– Rover[5]

After which came a variation of the Rover known as CoreSampler [3] that was designed to use its automated drills to remove circular pieces from the reactor walls, which would allow scientists to discover how far and how much radiation had soaked into the walls.

The Fukushima Daiichi accident took place on March 11, 2011 where all the three cores melted in the first three days. Various robots were designed and deployed for the survey and clean up purposes. The robots include scorpion robots, snake shaped robots for survey, the Topy's 'Survey Runner', Raccoon-a vacuum cleaner robot [3] and many more.

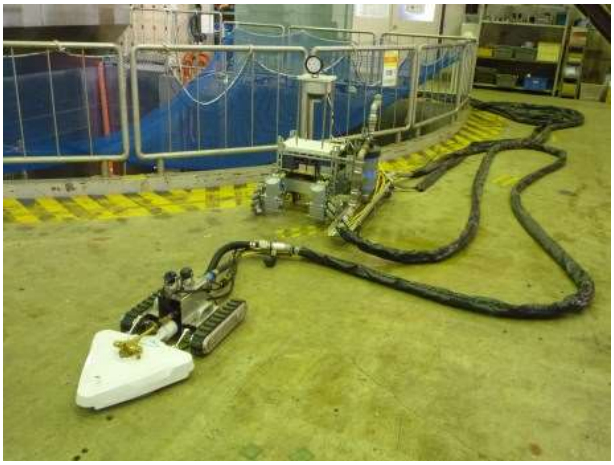

Figure 8-Raccoon[3]

CONCLUSION

Dating back several decades, there is a long history of robotics in nuclear plants. Advances in robotics technology has helped enhance plant performance by improving safety and efficiency. When in future the radiation dosage for the workers in nuclear power plants that is allowable will reduce, more and more use of robotics will come into picture.

By the year 2050 or so, intelligent robots would have evolved to such an extent that they would take their further evolution into their own hands. The scenario beyond this crossover stage has been the subject of considerable debate.

Stephen Hawking has commented that the present century will be the century of complexity. Complexity and evolution have a strong link. Evolution of really smart artificial structures will emerge with a great pace once our understanding of the complexity of nature will start increasing. With the increase in demand for power and hence use and development of more power plants, application of robotics in this field cannot be turned a deaf ear to at all.

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